AUTOMATICS

Simplifying pneumatics

Control pneumatics

CP4956

MATRIX

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Contents

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Worksheet 1

Electronic control

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.

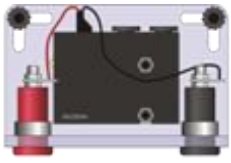
This module uses a MIAC (Matrix Industrial/Automotive Controller) to control pneumatic circuits.

Over to you:

- Build the arrangement shown on the next page, used to demonstrate how MIAC 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 MIAC V+ and black to MIAC 0V;
        - switch - red socket to power link panel red and black socket to MIAC input 1;
        - light sensor - red socket to power link panel red, black socket to power panel black and yellow socket to MIAC input 2;
        - solenoid valve - positive to MIAC output **C** and negative to power panel black.
- Plug in the power supply (12V), and switch on.
- You should see the words `'Automatics Control Program 1'` on the MIAC screen. If not, use the Up / Down arrows on the MIAC to locate this, and press 'OK'.
- Press the switch, and notice that the MIAC LED, labelled 'I1' lights.
  You should also hear the solenoid operate inside the control valve.
- Now shade the light sensor with your hand. Look at MIAC LED 'I2' as you do so.
  You should hear the solenoid valve operate again.

Automatics components:

power link panel



3/2 solenoid valve

switch

light sensor

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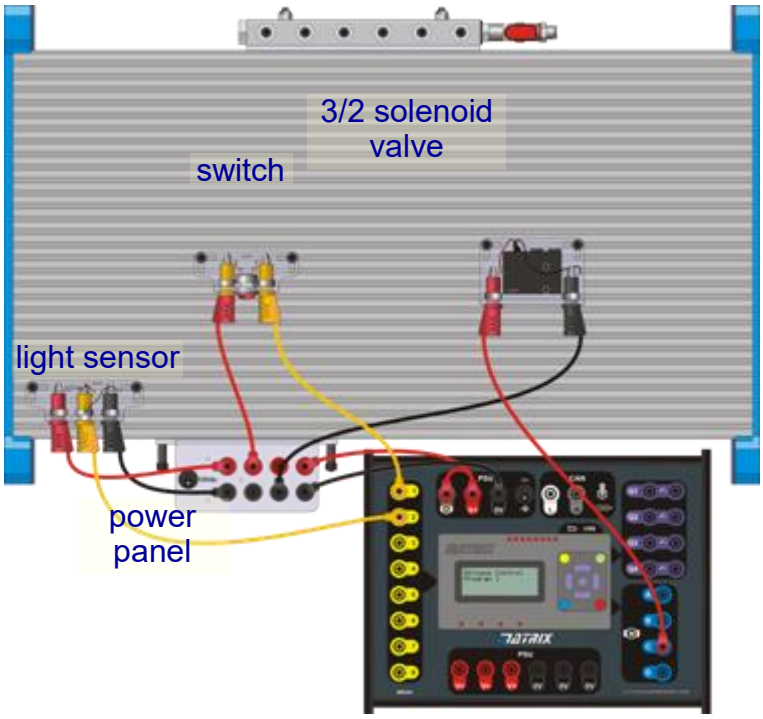
Worksheet 1

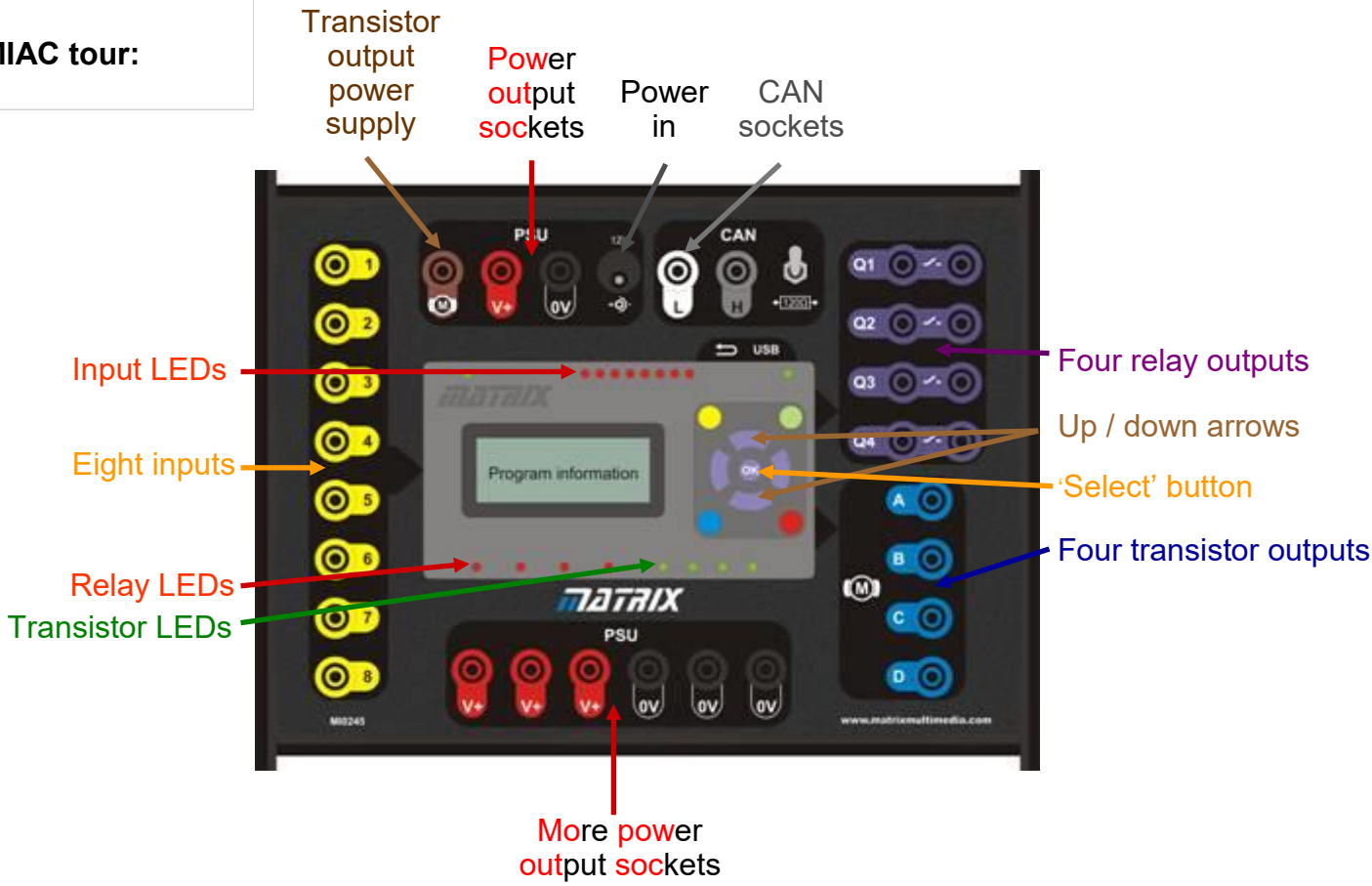
Electronic control

Layout for worksheet 1:



So what:

MIAC tour:



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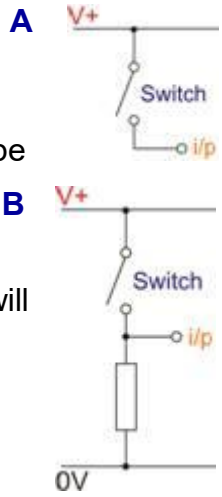
Worksheet 1
Electronic control

So what:

The tour continues:

- The MIAC is a fully specified industrial controller, housed in a rugged, anthracite grey plastic moulding at the centre of the unit, which is fitted with 4mm shrouded sockets, internally connected to all MIAC inputs and outputs (except CAN bus terminations).
- Designed to operate off 12 to 16V DC, it is powered by an 18F4455 microcontroller.
- It has eight analogue / digital inputs, (Software controls whether each behaves as analogue or digital.) The input LEDs show analogue inputs at a brightness that reflects the input signal voltage. They are on or off when the input is configured as digital.
- A 10k pull-down resistor is connected to each input.
  As a result:
  - MIAC 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 MIAC input terminal.



- A keypad, consisting of nine input buttons are provided for user control.
- A 4 line 16 character LCD display shows system status and user information.
- The MIAC has four high current relay outputs and four transistor driven outputs. The output LEDs light when the corresponding output switches ‘on’.
- The MIAC is programmed directly from the USB port of a computer.
  It is compatible with the Flowcode graphical programming language.
  Users can develop a program using Flowcode, press the reset button on top of the keypad, and the program will automatically download and start.

keypad

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Worksheet 1
Electronic control

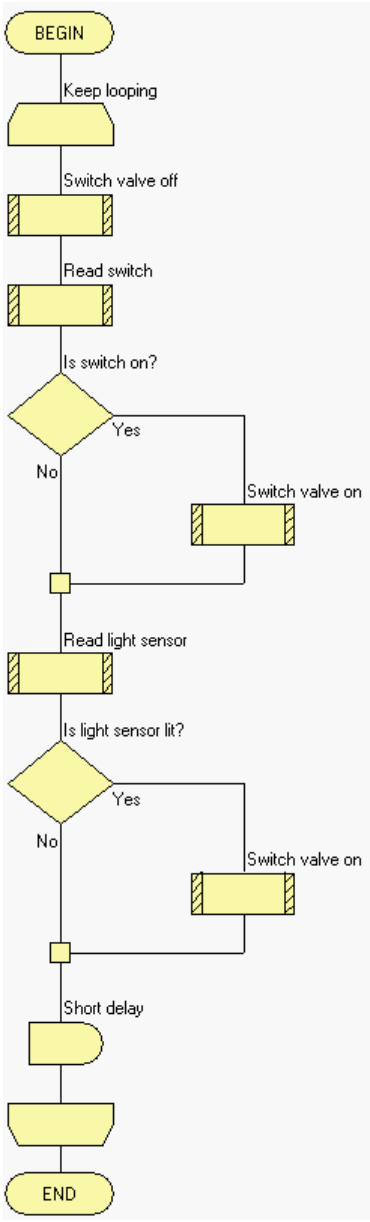
So what:

Overview of Program 1:

The sequence is:

- switch off the control valve;
- check whether the switch is pressed;
- if it is, switch on the control valve;
- then check whether the light sensor is in darkness;
- if it is, switch on the control valve;
- delay for a short interval;
- go back and start the sequence again.

In effect, 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
MIAC input 1 – switch not pressed	
MIAC input 1 – switch pressed	
MIAC input 2 – light sensor in daylight	
MIAC input 2 – light sensor in darkness	
MIAC output C – solenoid not activated	
MIAC output C – solenoid activated	

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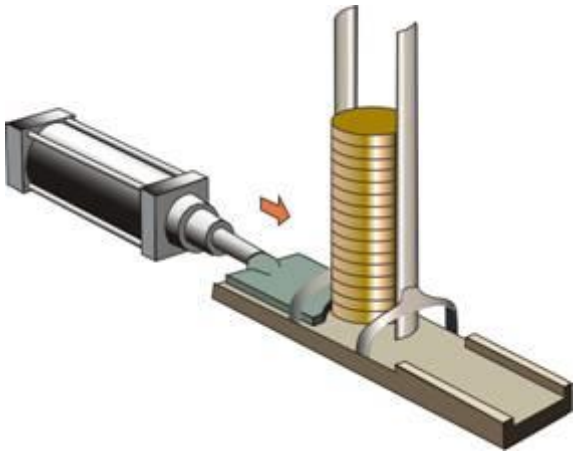
Worksheet 2

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 MIAC V+ and black to MIAC 0V;
        - switch - red socket to power link panel red and black socket to MIAC input 1;
        - solenoid valve - positive to MIAC output **C** and negative to power panel black.
- Plug in the power supply (12V), and switch on.
- Turn on the air supply.
- Use the Up / Down arrows to locate program 2A. You should now see the words `'Automatics Control Program 2A'` on the MIAC screen. Press 'OK'.
- 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.

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Worksheet 2

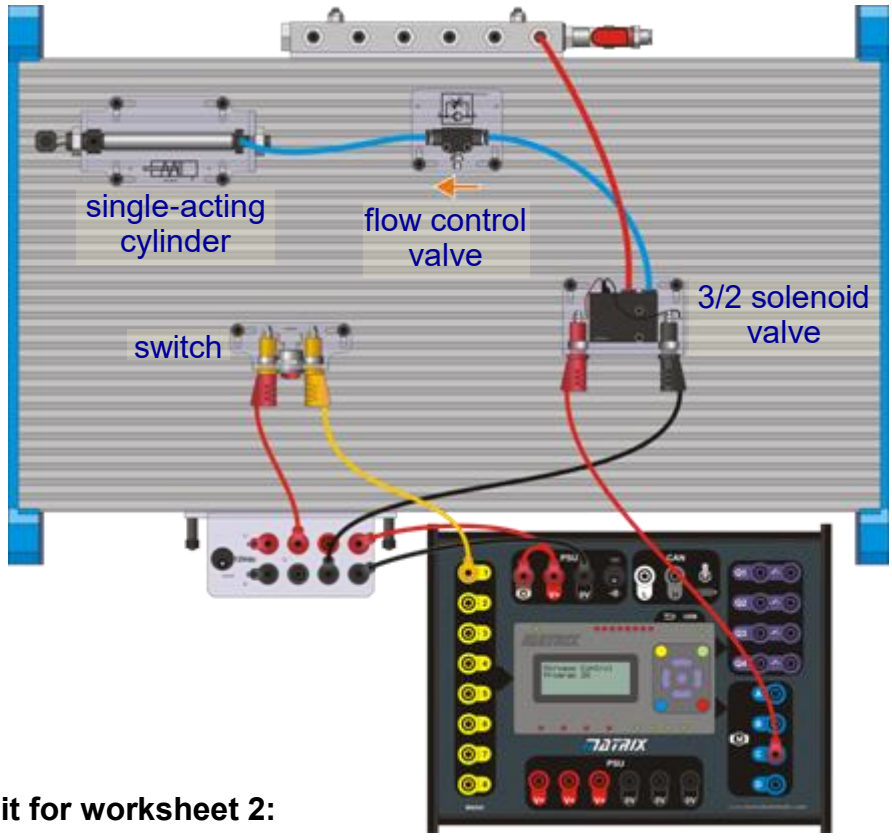
Magazine feed

Safety Rules for Pneumatic Systems

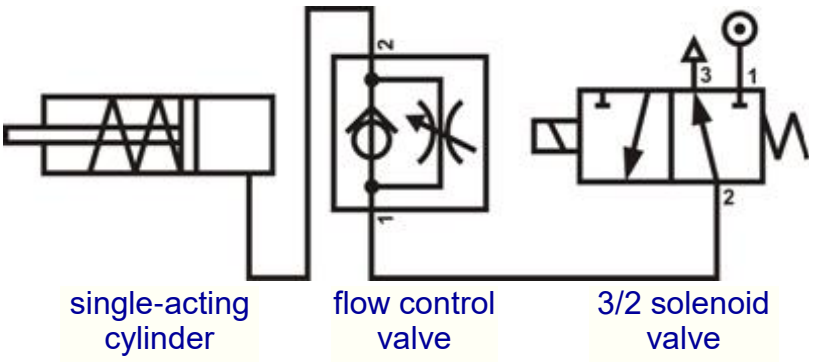
Remember that compressed air and its components are capable of exerting large forces.

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:



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Worksheet 2

Magazine feed

So what:

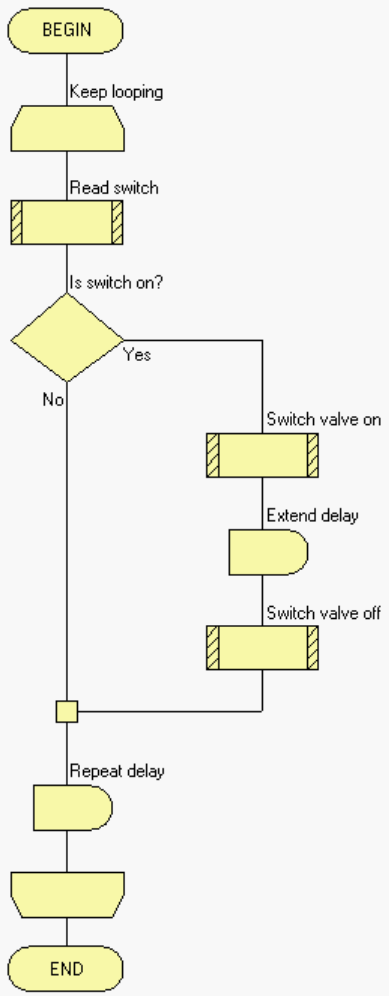
Overview of Program 2A:

The program is similar to that used in worksheet 1, except that the light sensor is not needed.

There are two 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 control valve;
- wait while the valve extends (1 second);
- switch off the control valve;
- wait until the process needs the new blank (3 seconds);
- go back and start the sequence again.



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.

- Use the Up / Down arrows to locate program 2B. When you now see the words `'Automatics Control Program 2B'` on the MIAC screen. Press 'OK'.
- Press and hold down the switch. The cylinder extends and retracts but only ten times. The difference is in the way the loop is configured. Instead of repeating indefinitely, the microprocessor keeps a loop count, and only carries out the looping ten times.

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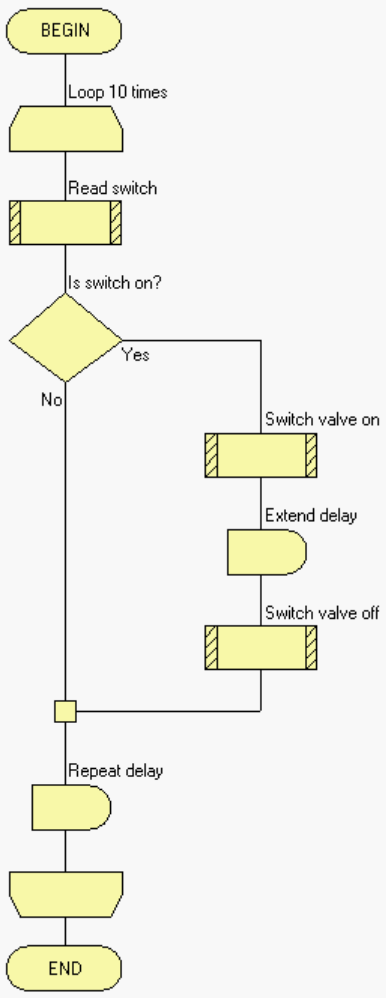
Worksheet 2

Magazine feed

So what:

The modified program:

The only change to the previous program is that the loop is now configured to act only ten times. Previously, it acted continuously.



For your records:

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

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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 MIAC V+ and black to MIAC 0V;
  - switch 1 - red socket to power panel red and black socket to MIAC input 1;
  - switch 2 - red socket to power panel red and black socket to MIAC input 2;
  - solenoid valve 1 - positive to MIAC output **C** and negative to power panel black;
  - solenoid valve 2 - positive to MIAC output **D** and negative to power panel black.
- Plug in the power supply (12V), and switch on.
- Turn on the air supply.
- Use the Up / Down arrows to locate program 3A. You should now see the words `'Automatics Control Program 3A'` on the MIAC screen. Press 'OK'.
- 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.

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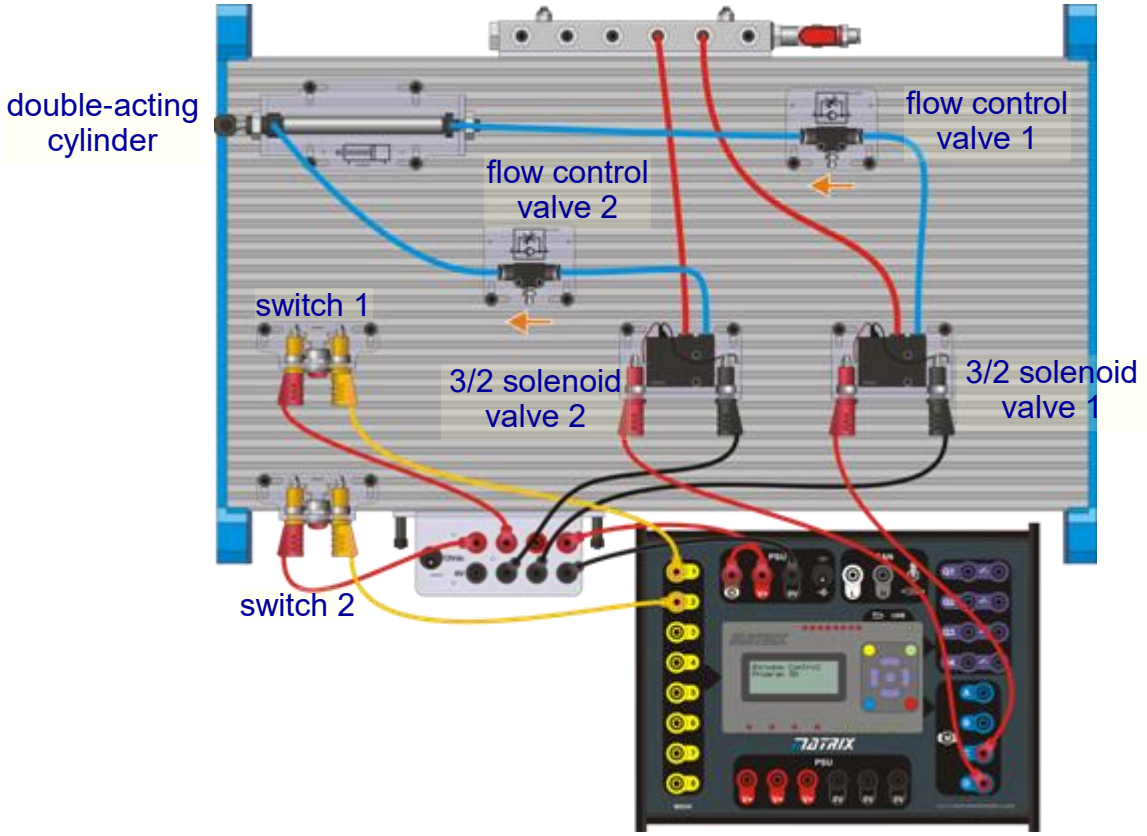
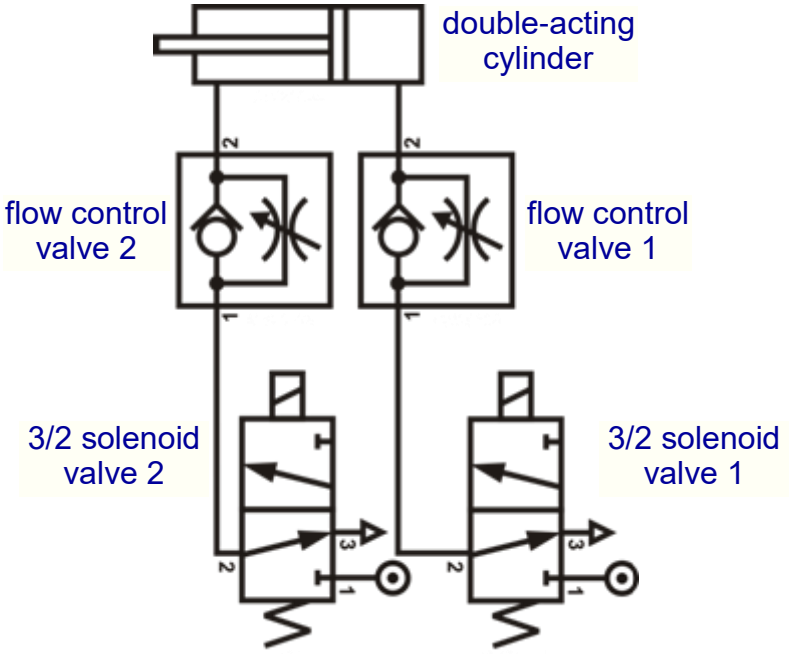
Worksheet 3

Bank vault door controller

Layout for worksheet 3:



Pneumatic circuit for worksheet 3:



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Worksheet 3

Bank vault door controller

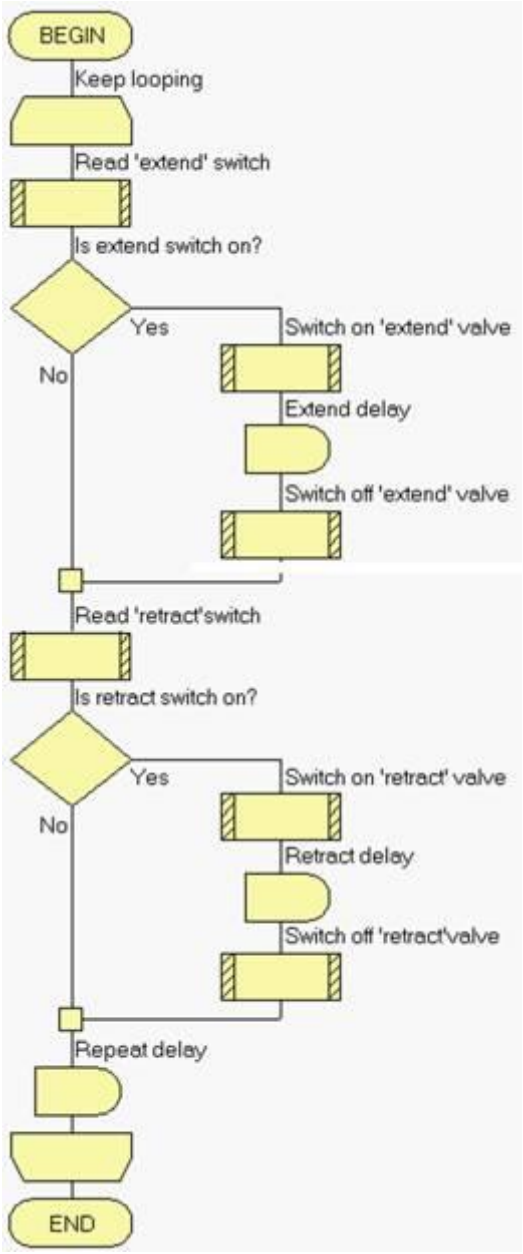
So what:

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;
- wait while the valve extends (0.5 second);
- switch off the ‘extend’ control valve;
- check whether the ‘retract’ switch is closed;
- if it is, switch on the ‘retract’ control valve;
- wait while the valve retracts (0.5 second);
- switch off the ‘retract’ control valve;
- wait to let the system settle (1 second);
- go back and start the sequence again.



A modification:

The bank wants to monitor how many times the bank vault is opened.

The program is modified by incrementing (adding one to) a counter, built into the MIAC, and displaying this count on the LCD display. The result is shown on the next page.

- Use the Up / Down arrows to locate program 3B. When you now see the words `‘Automatics Control Program 3B’` on the MIAC screen. Press ‘OK’.
- Check that the program carries out the functions described above.

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Worksheet 3

Bank vault door controller

So what:

The modified program - program 3B:

There is a complication! The program takes only a few milli-seconds to complete. While one of the switches is pressed, the program may cycle through several times. We do not want to add one to the count every time the program cycles. We want it to increment only when the door is opened, and then closed. This brings in the use of a flag.

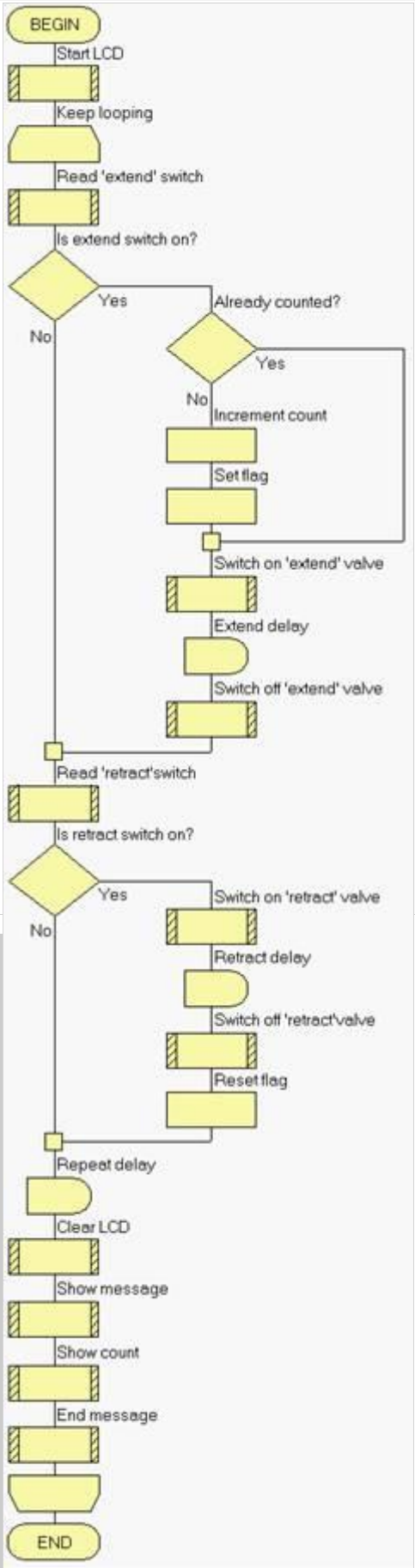
When the door is opened, by pressing the ‘extend’ switch, the flag is not set (‘flag’ = 0), and so the count is incremented. In addition, the flag is set (’flag’ = 1).

When the program simply loops again, while that switch is still pressed, no further increments take place as the flag is still set.

When the ‘retract’ switch is pressed, one effect is to reset the flag, (‘flag’ = 0 again.)

The next time the door is opened, the count is incremented, and the process described above repeats.

The four icons added at the end of the program cause the LCD to display the number of time the door has been opened.



For your records:

- Explain why a double-acting cylinder, rather than a single-acting cylinder is better for this application.
- The introduction hints at security features that could be linked to the electronic door controller.
  These could use the same microprocessor as that used to open and close the door.
  Explain, in less than 100 words in total, the advantages and disadvantages of the following forms of security:
    - PIN;
    - retinal scan.
- Describe two additional safety / security features that could be built into this electronic door controller.

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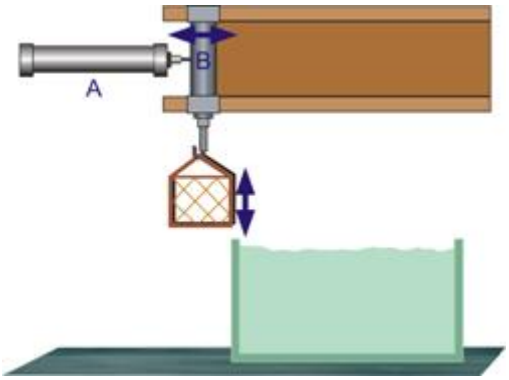
Worksheet 4

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 MIAC V+ and black to MIAC 0V;
  - switch 1 - red socket to power panel red and black socket to MIAC input 1;
  - switch 2 - red socket to power panel red and black socket to MIAC input 2;
  - solenoid valve **a+** - positive to MIAC output **A** and negative to power panel black;
  - solenoid valve **a-** - positive to MIAC output **B** and negative to power panel black.
  - solenoid valve **b+** - positive to MIAC output **C** and negative to power panel black;
  - solenoid valve **b-** - positive to MIAC output **D** and negative to power panel black.
- Plug in the power supply (12V), and switch on. Then turn on the air supply.
- Use the Up / Down arrows to locate program 4A. You should now see the words `'Automatics Control Program 4A'` on the MIAC screen. Press 'OK'.
- 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.

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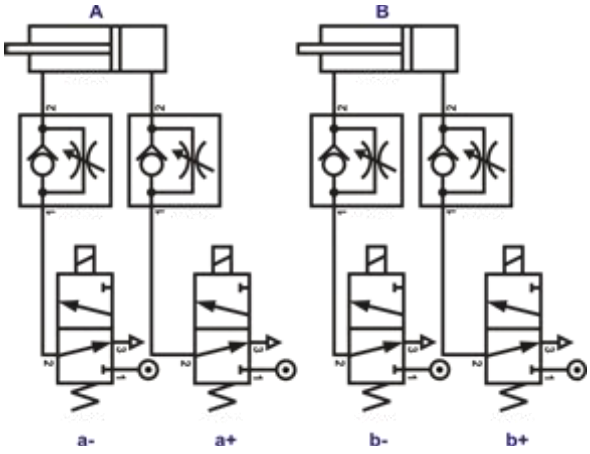
Worksheet 4

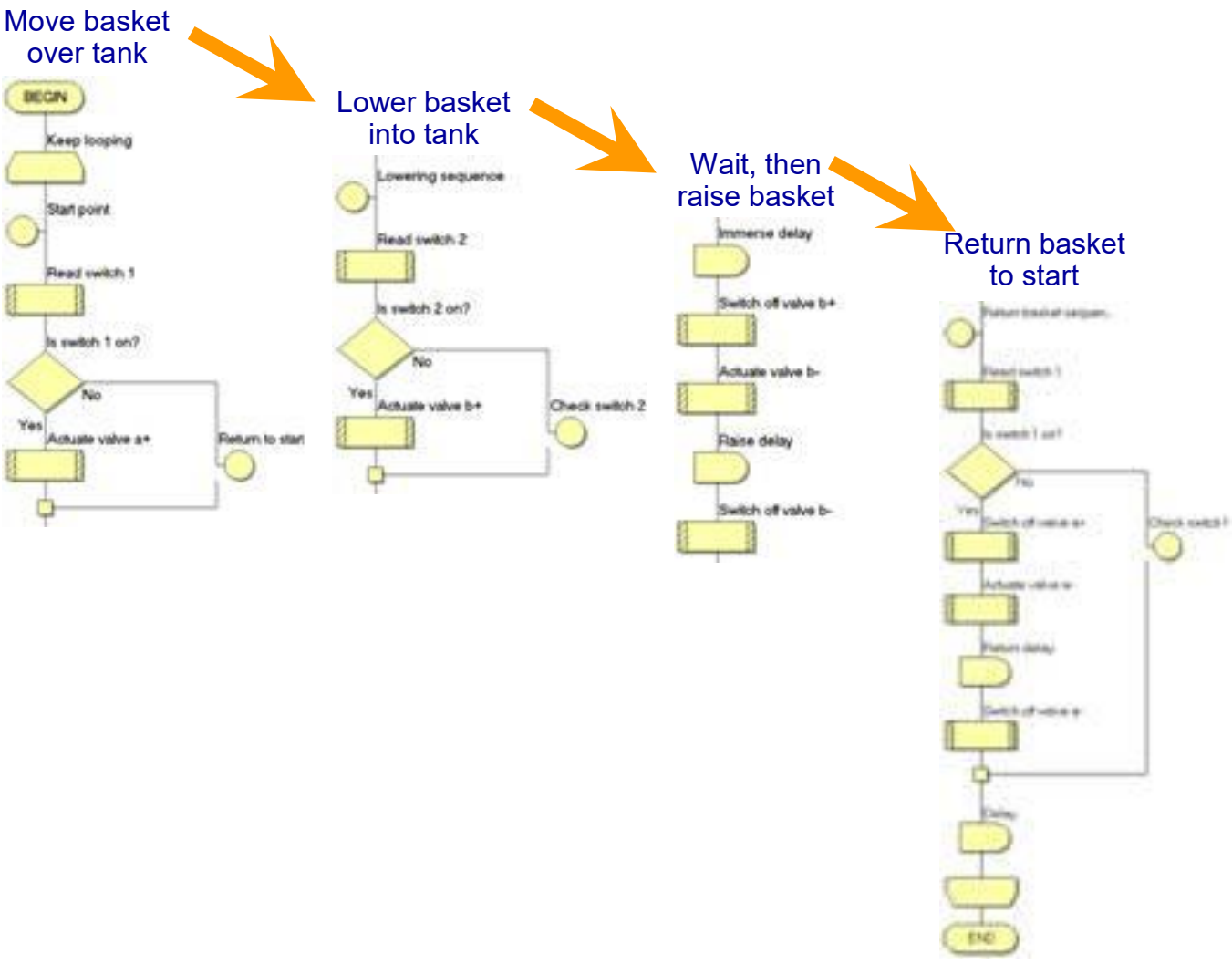
In sequence

Pneumatic circuit for worksheet 4:



So what:

Program 4A:



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Worksheet 4

In sequence

So what:

Overview of Program 4A:

The program is shown in four sections:

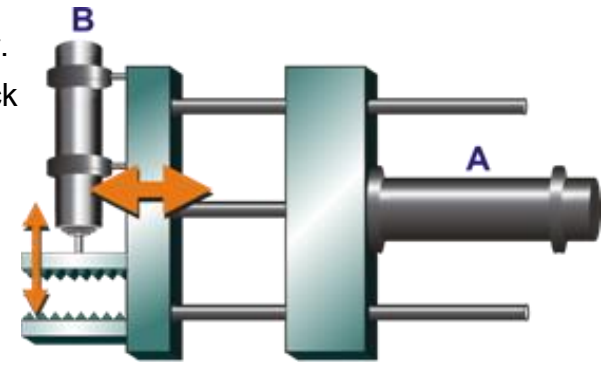
- The first is the start section - the program monitors switch 1. When it is pressed, cylinder **A** extends, moving the basket over the tank.
- The second waits until the start section is complete and then monitors switch 2. When this is pressed, cylinder **B** extends, lowering the basket into the cleaning tank.
- The third section follows automatically. The 'immerse delay' keeps the basket in the cleaning fluid for five seconds. Valve **b+** is then switched off, and valve **b-** is actuated to raise the basket from the tank.
- The fourth section again monitors switch 1. When pressed, valve **a+** is switched off. Then cylinder **A** retracts, returning the basket to its starting position. The 'return delay' actuates valve **a-** for one second.

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**-.

- Use the Up / Down arrows to locate program 4B. You should now see the words `'Automatics Control Program 4B'` on the MIAC screen. Press 'OK'.
- Press switch 1, and then release it.
- The sequence begins by extending cylinder **A**, and then **B**, and then retracting **A** and then **B**. The program is shown on the next page.

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Worksheet 4

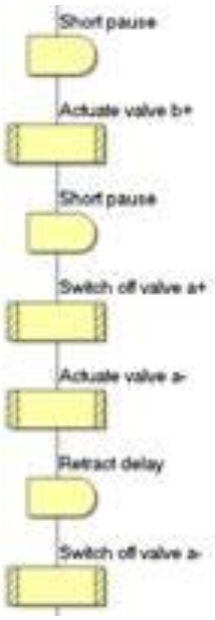
In sequence

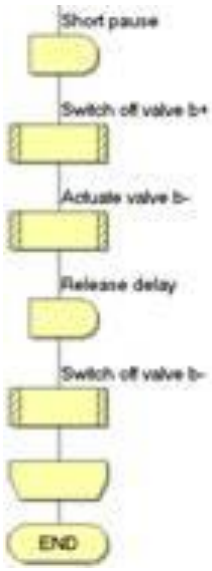
So what:

Overview of Program 4B:

The program is shown in three sections:

Gripper reaches out - → grips - brings back - → and releases.





- The first, the start section, monitors switch 1. When it is pressed, cylinder **A** extends, moving the gripper forwards.
- The second extends cylinder **B** to operate the grip mechanism. After a short pause, cylinder **A** retracts, pulling the object back with it. The 'Retract' delay keeps valve **a-** actuated for one second.
- The third section then retracts cylinder **B**, releasing the grip on the object, by actuating valve **b-** for one second, the 'Release' delay.
- The 'Short pause' blocks allow a one second break between each stage of the sequence.

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.

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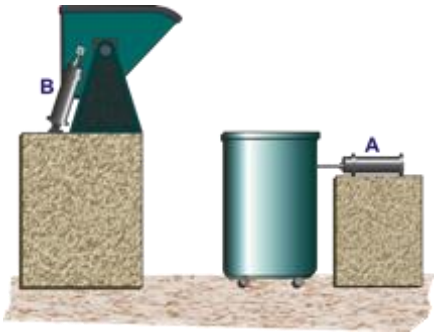
Worksheet 5

Feedback

The programs created so far operate blindly. The MIAC 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 MIAC V+ and black to MIAC 0V;
  - switch 1 - red socket to power panel red and black socket to MIAC input 1;
  - solenoid valve **a+** - positive to MIAC output **A** and negative to power panel black;
  - solenoid valve **a-** - positive to MIAC output **B** and negative to power panel black.
  - solenoid valve **b+** - positive to MIAC output **C** and negative to power panel black;
  - solenoid valve **b-** - positive to MIAC output **D** and negative to power panel black.
- Plug in the power supply (12V), and switch on. Then turn on the air supply.
- Use the Up / Down arrows to locate program 5A so that the words `'Automatics Control Program 5A'` appear on the MIAC screen. Press 'OK'.
- 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.

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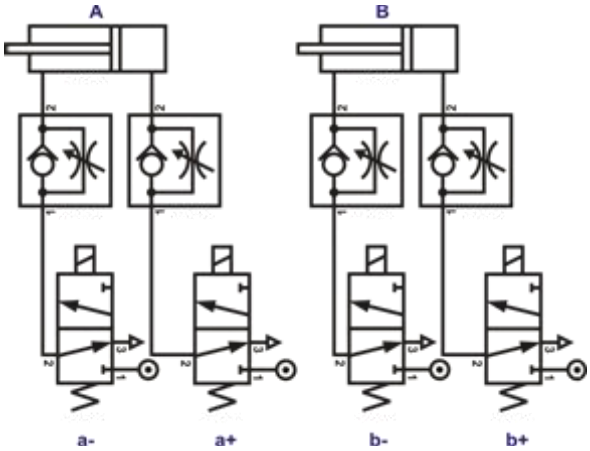
Worksheet 5
Feedback

AUTOMATICS

Pneumatic circuit for worksheet 5:



So what:

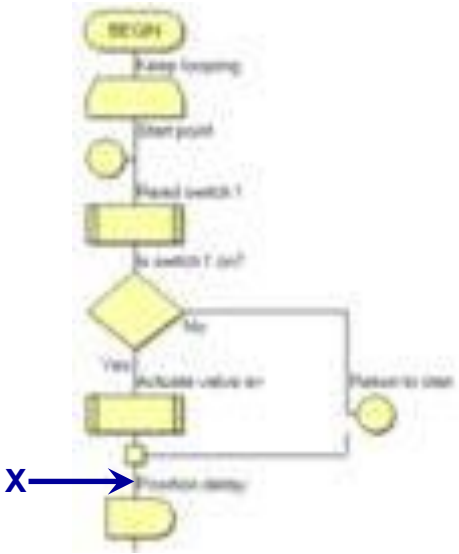
Program 5A:

The program is shown in two sections.

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

(The point labelled **X** is identified for the later discussion about adding feedback. Ignore it for the moment!)

Move container into position → Tip the hopper, wait, and then return both hopper and container.



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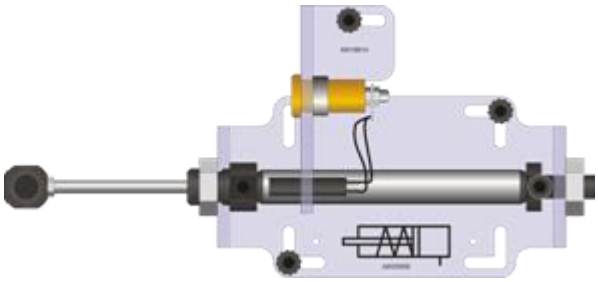
Worksheet 5
Feedback

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 MIAC V+, and the other to MIAC input 2.
- Plug in the power supply (12V), and switch on.
- Use the Up / Down arrows to locate program 5B so that the words `'Automatics Control Program 5B'` appear on the MIAC screen. Press 'OK'.
- 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!

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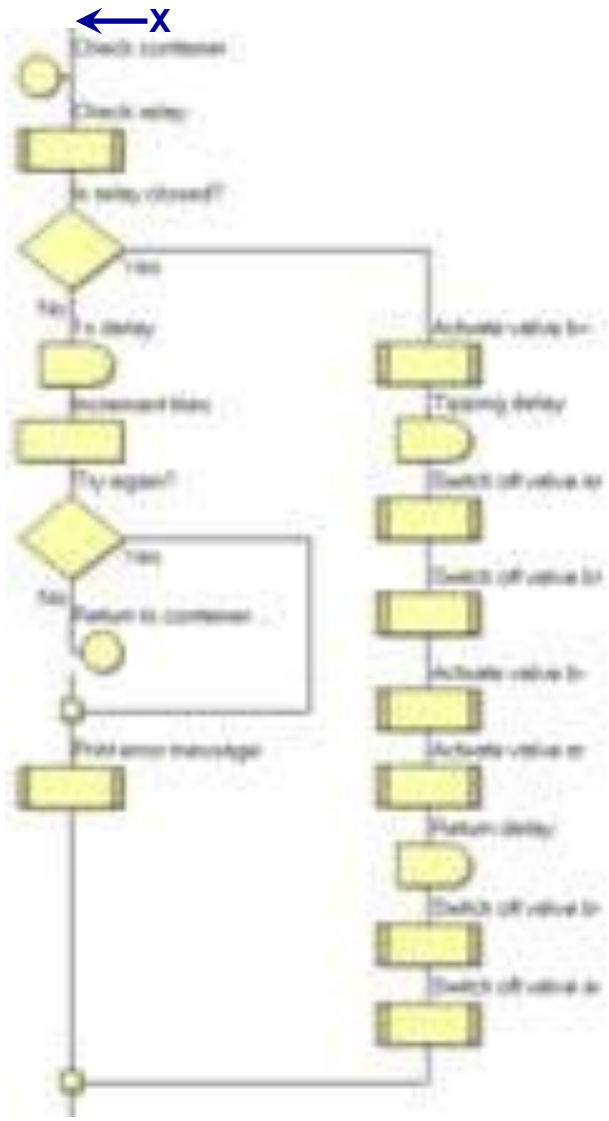
Worksheet 5
Feedback

So what:

Overview of Program 5B:

The program is the same as program 5A, except that:

- it begins with two macros to start and clear the LCD, as in program 3B;
- it has the section shown opposite, added at the point labelled **X**, in the earlier diagram of program 5A. It uses the reed relay output to check that cylinder **A** has extended.
  - if it has, the program proceeds as before, with cylinder **B** extending etc.
  - if it has not, then the program loops back to check the relay five times, including a one second delay within that loop, before posting an error message on the LCD.
- the 'Position delay' is removed because the reed relay actively senses when cylinder **A** is extended.

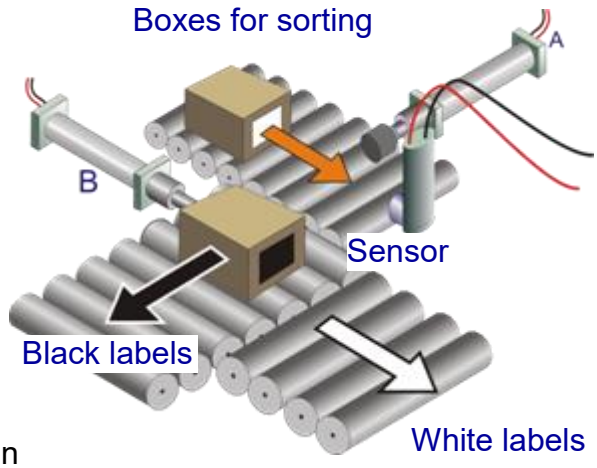


For your records:

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 flowchart for this system, using the ones given in the worksheets so far as a guide.



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Revision questions

AUTOMATICS

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 26.

For questions 1 to 6, choose the correct answer (a, b or c).

1. Electrically operated pneumatic valves are operated by a:

a) solenoid b) lever c) permanent magnet

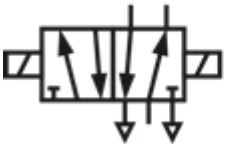
2. Which is the correct description of a 'normally-open' push switch, connected in a circuit?

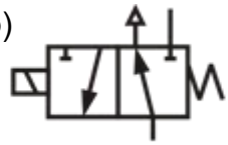
a) It has no cover on it.
b) It has a very low resistance when pressed.
c) it has a high voltage across it when pressed, and a low voltage when not pressed.

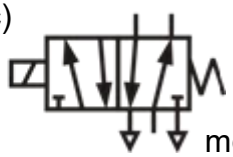
3. What kind of switch is actuated by the magnetic piston ring of a cylinder?

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?

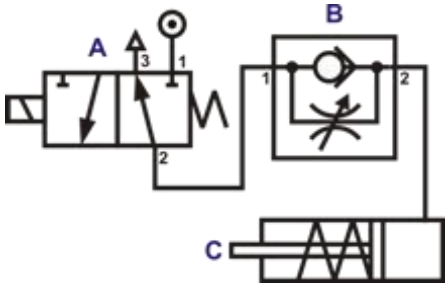
a) 

b) 

c) 

q4

5. Which statement is true for the pneumatic circuit opposite?

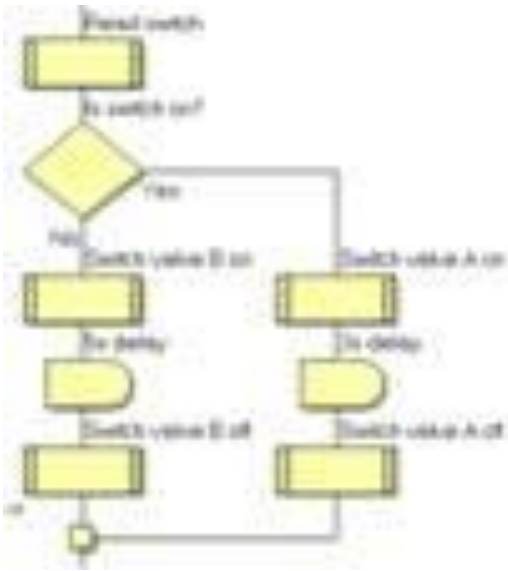


a) Port 3 on valve **A** is an exhaust port.
b) Flow control valve **B** is connected the wrong way round to control the flow of air into cylinder **C**.
c) When valve **A** is actuated, cylinder **C** will retract.

q5

6. Look at the segment of a Flowcode program shown below. Which statement is true?

a) When the switch is pressed, valve **B** is actuated.
b) Before valve **A** actuates, there is a 3 second delay.
c) Before valve **B** de-actuates, there is a 5 second delay.



q6

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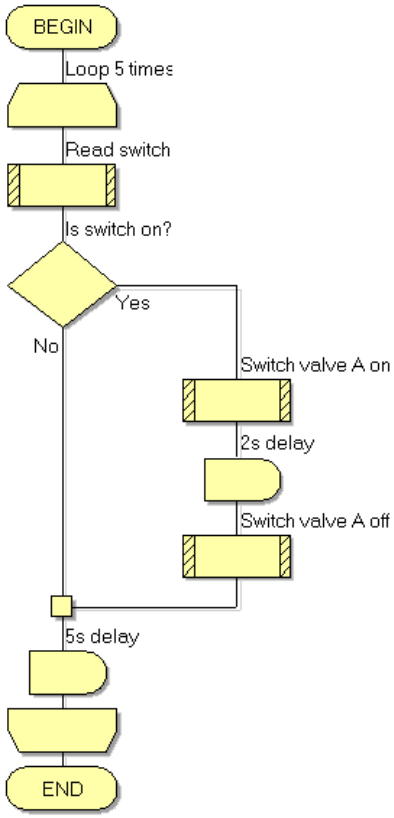
Revision questions

Look at the Flowcode program opposite.



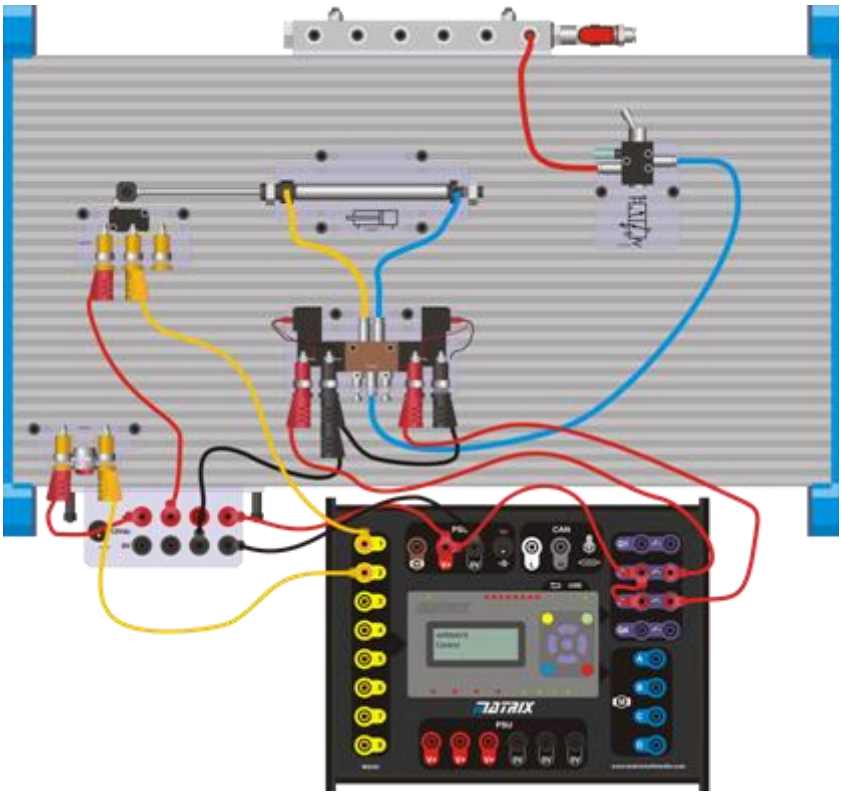
q7

7. Which icon would be modified to make the process repeat ten times?

8. For how many seconds is the cylinder extended?

9. How long does it take to complete one cycle of the program after the switch is pressed?

10. Draw the **pneumatic** circuit diagram for the following system .



q10

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Design Scenarios

AUTOMATICS

Design a program to satisfy the requirements set out in the following letters.
For each, provide a flowchart, 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

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Answers to revision questions

Answers to revision questions (see page 23)

1. a)

2. b)

3. a)

4. c)

5. a)

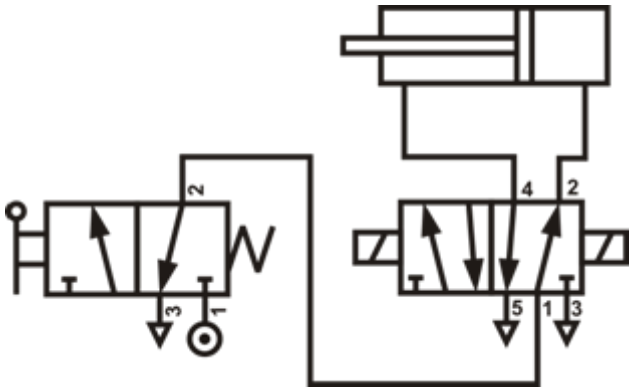
6. c)

7. Loop icon

8. 2s

9. 7s

10.



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Tutor's notes

AUTOMATICS

About this course

Introduction

This workbook reinforces the learning that takes place in the lecture room for courses such as BTEC Nationals in Engineering, Unit 15, "Electro, Pneumatic and Hydraulic Systems and Devices" and BTEC Higher Nationals in Mechanical Engineering, Units 9 and 26: "Applications of Pneumatics and Hydraulics" and "Programmable Logic Controllers".
It provides practical activities and investigations to complement such courses.

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, which, thanks to the symbols printed on each component carrier, look exactly like the pneumatic circuit diagram.

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.

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 'Flowcode' program controlling a pneumatic system;
- modify the number of times a 'Flowcode' program loops through its operating cycle;
- modify a delay within a 'Flowcode' 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;
- display a message on a LCD located on the MIAC programmer;
- use a variable within a 'Flowcode' program to count events;
- describe two electronic security features that could be built into an electronic door control system;
- analyse a 'Flowcode' 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.

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Tutor’s notes

What students will need:

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

Qty	Code	Legacy Code	Description
1	MI0245	MI0245	MIAC controller
2	AU8030	AW-ESWP	Switch, push-to-make
1	AU8025	AW-ERS	Reed Switch and Holder
2	AU3022	AW-V22FC	Valve, flow control
1	AU8010	AW-ELS	Sensor, light
4	AU6010	AW-V32ES	Valve, 3/2, solenoid-spring
1	HP2777	HP2777	Power supply
1	AU8020	AW-EPD	Power panel
6	LK5603	LK5603	Lead, 4mm to 4mm, red
6	LK5604	LK5604	Lead, 4mm to 4mm, black
2	LK5607	LK5607	Lead, 4mm to 4mm, yellow

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

Qty	Code	Legacy Code	Description
1	AU9020	AW20801	Automatics essentials solution
1	AU1050	AW30100	Compressor
1	LK1110	LK1110	Multimeter

Please note: New product codes for Automatics products were created in January 2015. The “legacy codes” in the tables above refer to the part numbers prior to this date and are included as a convenience for customers who bought products before the part number change.

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Tutor's notes

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;
- a section headed 'So What?' which 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.

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Tutor's notes

AUTOMATICS

Worksheet	Notes for the Tutor	Timing
1	This worksheet introduces the student to the MIAC controller, and its role in switching on control valves in response to signals from input devices. It also revisits the fixing method used to attach components to the Automatics platform. In carrying out the assembly, students should consult the MIAC diagram, and the component layout on page 4. The following page lists some of the features of the device. In particular, they should be aware of the LEDs that monitor the MIAC inputs and outputs, as these are a reliable indicator of the progress of the 'Flowcode' program running on the MIAC. Page 6 provides an overview of this program, which students should study carefully to understand the effect of each icon on the hardware.	**20 - 30 minutes**
2	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. 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. On page 8, 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. The next page gives an overview of 'Flowcode' program 2A. This contains an endless loop, to make the sequence repeat indefinitely (as long as the switch is pressed,) a 'component macro' that looks at the state of the switch (and copies it into a variable,) a decision box that uses the value stored in that variable to check whether the switch is pressed or not, two further 'component macros', one to actuate the control valve that extends the cylinder, and the other to actuate the valve that retracts it, and two delays, that cause the controller to make no changes until the delays have expired. Program 2B modifies this behaviour by re-configuring the loop to cycle only ten times. This is shown on page 10.	**30 - 50 minutes**

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Tutor's notes

Worksheet	Notes for the Tutor	Timing
3	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. 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. Page 13 provides an overview of program 3A, which is structurally similar to program 2A, except that, in turn, it monitors switch 1 then switch 2. As written, should switch 2 be pressed when the door is already closed, the valve controlling retraction is actuated, but will do nothing. An alternative would be to use break points, as in program 4A, to make the program wait until switch 1 is pressed before doing anything else. The control system is next modified to display the number of times the door is opened, stored in a variable called 'count' within the program. Using 'Flowcode' the LCD is controlled using 'component macros' - five in all. The first starts the LCD; the second deletes any text present; the third displays the first part of the message; the fourth displays the count, and the fifth completes the message. The modified program, program 3B, is illustrated on p.14. The worksheet ends with a research project in which students investigate a number of electronic security features which could be incorporated into a more elaborate control system.	**40 - 60 minutes**
4	This worksheet shows that the behaviour of a standard set of pneumatic components can be changed radically by changing the control program. 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. 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 analysed on pages 16 and 17. 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 17, which could be part of a robot arm assembly. The elements of the new program, 4B, are the same as in program 4A, but time delays are used to automate the process. Continued on next page...	**40 - 60 minutes**

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Tutor's notes

Worksheet	Notes for the Tutor	Timing
4	continued... 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**-.	
5	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. 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. First of all, the program, 5A, runs without any feedback, to illustrate the problem. It is described on page 20. 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! The modification, quite minor but very powerful, is described on page 22. In a practical situation, some warning device would sound to alert the operator. Here, an error message appears on the screen. 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.	**40 - 60 minutes**

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About this document:
Code: AW4956-80-01
Developed for product code AW4955 – Automatic control add-on kit

Date	Release notes	Release version
January 2013	First version released	AW4956-80-01
January 2015	Part numbers changed	AW4956-80-02

23 08 23 Reformatted to new style

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