Unit 16: Automated Computer Systems

Level: **1 and 2**

Unit type: **Optional specialist**

Guided learning hours: **60**

Assessment type: **Internal**

Unit introduction

Automated computer systems feature heavily in our technological lifestyles. We are surrounded by technology systems that monitor and perform activities on our behalf, from central heating controllers regulating our environment to robots exploring the universe.

The development of automated computer systems is becoming essential across the world for manufacturing, security systems and home, industrial and transportation systems. Being able to develop and work with automated systems could lead to a challenging, varied and exciting career in any number of various roles in different companies, for example an electronic engineer and software engineer.

In this unit, you will investigate the characteristics, including benefits and features, of existing automated systems. Using a suitable self-assembly kit, you will design and develop an automated system for a brief. You will develop the system by making progress in small steps and building up programs that can control hardware devices by monitoring sensors and controlling outputs. To do this, you will learn some control programming, hardware assembly and trouble shooting skills.

You will review your final automated system and identify any further improvements.

This unit develops skills from *Unit 2: Technology Systems*, *Unit 8: Mobile Apps Development*, *Unit 11: Computer Networks*, *Unit 12: Software Development* and *Unit 14: Installing and Maintaining Computer Hardware*.

Learning aims

In this unit you will:

A understand the characteristics of automated systems

B design an automated system

C develop and test an automated system

D review the finished automated system.

Learning aims and unit content

What needs to be learnt

Learning aim A: Understand the characteristics of automated systems

Automated systems

Automated systems contain hardware devices that are controlled by software programs that undertake specific activities based on inputs and outputs.

Characteristics of automated systems

- Features
- Benefits
- Reasons for use

Why automated systems are used

Reasons, e.g.:

- operating in hazardous environments, e.g. satellites in space
- completing monotonous tasks, e.g. food-packaging machinery
- completing precision tasks, e.g. manufacturing engineering components
- monitoring and control, e.g. temperature control system.

Benefits, e.g.:

- reduced costs
- improved performance, e.g. efficiency and effectiveness
- customisation, e.g. custom-made engineered parts
- improved repeatability (completing the same activity with a high degree of accuracy)
- improved customer service.

Features of automated systems

Know that automated systems comprise hardware and control software programs.

Systems include:

- hardware devices, including:
    - programmable devices/microcontrollers
    - input devices, e.g. touch and temperature sensors
    - output devices, e.g. LEDs, motors
    - other components, e.g. power source, mechanical structures
- control software programs, e.g. code to make a light or LED flash or to operate a line-following robot.

Use flow charts to represent processes within basic control programs.

What needs to be learnt
Learning aim B: Design an automated system
Designing an automated system Design to include: ● intended purpose and 'client'/user requirements (as defined in a brief) ● at least one programmable device, one input and one output device ● system hardware diagrams showing: o the devices to be used (further guidance in learning aim C) o the input/output data flow between devices o device communication method (either serial or parallel) o any mechanical structures, e.g. chassis and wheels and the assembly method of devices/components ● a control program specification including: o a description of the main program tasks – input and output format o algorithms, e.g. structured English, flow charts, pseudocode ● a list of any predefined code and their sources, e.g. the internet, other media such as CD or DVD ● a brief outline of alternative solutions for the intended automated system, e.g. alternative sensor types and hardware configurations ● a test plan and, if appropriate, test data (to test the system inputs and expected outputs) ● constraints, e.g. device capabilities including connectivity and availability, memory storage or programming language.

What needs to be learnt

Learning aim C: Develop and test an automated system

Develop an automated system

Assemble hardware, including:

- programmable devices/controllers that can read from input devices (e.g. sensors) and control output devices (e.g. actuators, motors) and store and process data (e.g. Lego RCX/NXT, Arduino, PIC)
- input devices, e.g. light-dependent resistors, touch sensors, switches, accelerometers, infrared sensors, potentiometers, sound sensors, touch sensors, temperature sensors
- output devices, e.g. LEDs and LED arrays, lights, motors, servo valves, linear actuators, sound emitters (e.g. piezo speakers, buzzers, amplifiers), relays (e.g. H-bridge ICs for motor control)
- other components:
  - power source, e.g. photovoltaic cells and batteries
  - mechanical structures, e.g. protective/aesthetic shell, chassis (a framework that supports a manmade object), axles, wheels
  - data storage, e.g. solid state storage device.

Consider Health and safety issues, e.g. hardware, electrical connection risks and guidelines, handling equipment

Develop control software program

Use a development environment to produce original code and edit predefined program or code.

Develop and refine the control program using suitable programming language constructs and techniques.

Annotate the code to demonstrate understanding of the constructs/techniques and processing to allow effective repair/debugging of the program and for maintainability.

Programming constructs and techniques

Program constructs, e.g.:

- comments
- constants (variables with a constant value that cannot change)
- operators (arithmetic [+ – * / %] and logical [< <= > >= AND OR true false])
- reserved words, which have special meaning within the programming language and are used to write instructions in a program, e.g. in NXT ‘motor’ and ‘while’ are reserved words.
- input and output commands
- local and global variables
- assignment
- sequence
- counter controlled and conditional loops (while do, repeat … until, for … next)
- sequential statements, selections (if … then … else)
- data types, e.g. integer and real (numbers), string (text), Boolean

continued

What needs to be learnt
• data structures, e.g. arrays, user-defined variables • data storage, e.g. within hardware devices, on removable media • subroutines/functions/procedures. **Testing and refining the automated system** Test automated system for functionality, e.g. against test plan, and if required, test data. Gather feedback from others, e.g. 'client', users on the automated system. Briefly document any changes to the design, including: • changes to the references of sources for predefined code • annotations on the code • improvements and/or refinements to the automated system.
Learning aim D: Review the finished automated system
Review the finished automated system against: • original requirements and purpose (as defined in the brief) • constraints, e.g. programming language, time, device capabilities such as memory, connectivity, availability • strengths and potential improvements.

Assessment criteria

Level 1	Level 2 Pass	Level 2 Merit	Level 2 Distinction
Learning aim A: Understand the characteristics of automated systems			
1A.1 Identify the features and benefits of two different given automated systems.	2A.P1 Explain the features and benefits of two different given automated systems.	2A.M1 Review what one of the given automated systems does, providing a flow chart to show the processing of the control system.	2A.D1 Discuss the strengths and weaknesses of the automated systems.
Learning aim B: Design an automated system			
1B.2 Identify the purpose and user requirements for an automated system.	2B.P2 Describe the purpose and user requirements for an automated system.	2B.M2 Produce a detailed design for an automated system, including: • alternative solutions • two or more system hardware diagrams • a detailed control program specification.*	2B.D2 Justify final design decisions, explaining how the automated system will fulfil the stated purpose and the user requirements, describing the impact of any constraints on the design.*
1B.3 Produce a design for an automated system, with guidance, including: • an outline system hardware diagram • an outline control program specification • a list of any predefined code.*	2B.P3 Produce a design for an automated system, including: • a system hardware diagram • a control program specification • a list of any predefined code • a test plan.*		

Level 1	**Level 2 Pass**	**Level 2 Merit**	**Level 2 Distinction**
Learning aim C: Develop and test an automated system			
1C.4 Develop an automated system, with guidance, containing: • at least one programmable device, input device and output device • a control program using appropriate constructs/ techniques.* (Please see guidance.)	2C.P4 Develop an automated system containing: • at least one programmable device, input device and output device • a control program using appropriate constructs/techniques, which is appropriately annotated.*	2C.M3 Develop a functional automated system that meets the given brief and contains a default fail-safe state.*	2C.D3 Refine the automated system, using feedback from others, to improve the system's performance.*
1C.5 With guidance: • test the automated system for functionality • repair any hardware and/or program faults.	2C.P5 Test the automated system for functionality using the test plan and against the original requirements. Repair any hardware and/or program faults.	2C.M4 Test the automated system, including additional functionality, against the original requirements, gathering feedback from others. Repair any hardware or program faults.	

Level 1	**Level 2 Pass**	**Level 2 Merit**	**Level 2 Distinction**
Learning aim D: Review the finished automated system			
1D.6 Identify how the final system is suitable for the original requirements and purpose.	2D.P6 Explain how the final system meets the original requirements and purpose.	2D.M5 Review the extent to which the system meets the original requirements, considering feedback from others and any constraints.	2D.D4 Evaluate the final system against the initial designs and justify any changes that were made, making recommendations for further improvement.

*Opportunity to assess mathematical skills

Teacher guidance

Resources

As a minimum, each learner will need access to hardware devices found in a suitable self-assembly kit for automated systems, specifically:

- a programmable device/microcontroller, e.g. Arduino, PIC, Lego programmable brick (RCX or NXT) with programming interface and cabling
- a programming environment, e.g. Arduino, PICAXE Programming Editor, PICLogicator, Lego NXT Mindstorms environment, LabVIEW, Flowol 4
- input devices, e.g. sensors for touch, light, sound, humidity, resistance, temperature, infrared, Hall Effect
- output devices, e.g. motors, servos, LEDs, lights, linear actuators
- other components, e.g. mechanical structure, power source, storage media (e.g. SD card).

It is important that hardware devices and components include the accompanying manuals, software installation disks or installation packages (downloaded in advance from the manufacturer’s website).

The practical activities should take place in a workshop with appropriate tools and should take account of health and safety requirements.

Learners should be provided with a brief which allows them to meet the assessment requirements of the unit. Briefs can either be generated by the centre, or by the learner, and then approved by the centre.

Assessment guidance

This unit is assessed internally by the centre and externally verified by Pearson. Please read this guidance in conjunction with *Section 8 Internal assessment*.

Learning aim A

Learners need access to a selection of different automated systems. At least two systems should be investigated: one should be a basic automated (e.g. line-following) vehicle and the other should be a commercial system, e.g. controlling temperature or traffic lights. These can be placed into context by the use of case studies or local examples, and demonstrated in the classroom.

For 2A.P1: learners should explain the characteristics of two given and different automated systems. The description should cover the what the systems do, their benefits and features, for example hardware devices and control programs of the automated system.

For level 1, as a minimum, learners should identify the characteristics of two given and different automated systems. They are likely to be presented as a list without a description of how the system works.

For 2A.M1: learners should review what one of the classroom-demonstrated automated systems does and provide a flow chart to show the processing in the control program.

For 2A.D1: learners should discuss the strengths and weaknesses of one of the classroom-demonstrated automated systems. Learners should consider at least one strength and at least one weakness.

Learning aim B

Learners should understand the functionality of a range of hardware devices and components. They should also be familiar with the control program programming environment and a range of constructs/techniques used within the programming language.

Learners will establish the requirements for developing an automated system given in a brief. The brief should:

- allow learners to explore the possibilities when fulfilling the requirements of the brief
- allow learners to produce an automated system using a suitable kit-based system
- be written with a client in mind with clearly stated resource requirements and objectives.

The brief must include the following requirements (as a minimum):

- a description of the purpose of the automated system, e.g. an automated vehicle designed to carry a 1 kg mass and follow a line, turning right and left as required over a 5 m route
- any special requirements/instructions/configuration
- a timeframe
- a budget (costs)
- the constraints, e.g. system is to operate in an internal, dry environment.

Centres are encouraged to use evidence for the development of the automated system as part of the learner's digital portfolio (*Unit 3: A Digital Portfolio*).

For 2B.P2: learners should describe the user requirements and purpose of the automated system for the design.

For level 1, as a minimum, learners should identify the user requirements and the purpose for the design of the automated system.

For 2B.P3: learners will produce a design for an automated system built using a self-assembly kit of appropriate hardware devices. As a minimum, the system will contain at least one programmable device, one input device and one output device. Learners' designs should include:

- a description of purpose and the requirements of the client/user
- a system hardware diagram showing the devices to be used and illustrating the mechanical structures, e.g. chassis and wheels and the assembly of devices/components
- a control program specification describing the main program tasks, e.g. data input and output format
- a list of any predefined code
- test plan, outlining a range of tests for logic and functionality.

For level 1, as a minimum, learners should produce an outline design for an automated system containing at least one programmable device, one input device and one output device. The design should include:

- *an outline system hardware diagram showing the devices and components to be used*
- *an outline control program specification containing a description of the main program tasks e.g. data input and output format*
- *a list of any predefined code.*

For 2B.M2: in addition to the requirements for the pass grade, learners should produce:

- at least two system hardware diagrams:
  - o at least one showing the devices to be used, input and output data flow between devices, and the device communication method
  - o at least one illustrating any mechanical structures and the assembly method of devices/components
- a detailed control program specification describing the main program tasks and algorithms, e.g. structured English, flow charts, pseudocode outlining how the control program will work
- a brief outline of any alternative solutions and why they were configured in a certain way.

For 2B.D2: learners are expected to be able to justify their design decisions and how the chosen design fulfils the stated purpose and user requirements for the given brief. They should consider suitability for the end user and the quality and thoroughness of their design work. Learners need to review their design in light of any constraints arising from the hardware (for example operational range of sensors, the availability of devices) and control programming language. Learners should justify why alternative design ideas were rejected.

Learning aim C

This learning aim is all about developing and testing an automated system for a given brief.

For 2C.P4: learners will implement their design. Some learners will find that their designs do not allow them to implement a solution. In this case, learners should amend their automated system and record changes to their design. They should develop their automated system by:

- assembling (while adhering to all health and safety guidelines) a range of hardware devices – as a minimum the system should contain at least:
  - o one programmable device/controller, e.g. Lego RCX/NXT, Arduino, PIC
  - o one input device, e.g. light-dependent resistors, touch sensors, switches
  - o one output device, e.g. LED arrays, motors, relays, servo valves
  - o other components, e.g. power source, mechanical structures
- develop a control program for the automated system by editing predefined code and some original code using appropriate constructs and techniques. The program must include reading from at least one sensor and result in at least one output to a device. Learners should also ensure that they develop solutions using some constructs/techniques from the more complex content in learning aim C (the constructs/techniques for level 1 assessment are shown at the end of this guidance). These include conditional-controlled loops and functions.

  The code should be annotated to demonstrate understanding and to allow effective repair/debugging of the program and maintainability.

For level 1, as a minimum, learners should use their designs to develop an automated system. They will assemble a range of hardware devices (at least one programmable device, one input device and one output device) and develop a control program using level 1 constructs/techniques (identified at the end of this guidance).

For 2C.M3: learners should produce an automated system that satisfies the brief. The system should contain a fail-safe default state, for example, the system shuts down if the system limits are breached. Learners are likely to need to adapt their designs to create a fully-functioning system.

For 2C.P5: learners will test the automated system for functionality against the original requirements and using their test plans. For example, does the system meet its stated purpose; do input devices and output devices respond as expected? The automated system should function; however, it may not fully meet the brief.

As they develop their automated system, learners are likely to experience hardware and control programming technical difficulties. Where this happens, learners should troubleshoot and resolve these difficulties, finding and repairing any faults. To aid this process, learners may want to use a console to monitor the state of the system during operation. It is important that learners make appropriate comments in their code and briefly document any changes made to both the hardware and control program.

Where appropriate, it is acceptable to photograph problems and solutions or to use witness statements as evidence of this process.

For level 1, as a minimum, learners should develop and test the automated system's main functions and repair any hardware and control program faults.

For 2C.M4: learners should test their automated system including any additional functionality and the fail-safe state, using test data as appropriate. The default fail-safe state should operate when certain limits are breached.

They should correct any hardware and control program faults found in the code and produce evidence to show any changes made to the system.

Learners should obtain feedback on their automated system from others, for example from someone acting as a user of the system. Their system should fully meet the original requirements of the brief.

For 2C.D3: Teachers should recognise that the process of developing and testing automated systems is iterative and not a sequential process. Consequently, this criterion is assessed during an iterative development process.

Learners should refine the automated system, taking account of feedback from others to improve the system's performance, for example to complete a task more efficiently or more accurately. Examples include controlling temperature within a smaller tolerance or introducing ability to adapt to different external conditions, e.g. an automated vehicle designed to transport a 1 kg mass between two points could adapt to the terrain by changing speed, using less energy and reducing power consumption.

Learning aim D

For 2D.P6: learners should describe how their automated system meets the original requirements and purpose in light of the results of their testing. Learners should be encouraged to celebrate the strengths of their work.

For level 1, as a minimum, learners should identify how their automated system meets the original requirements and purpose.

For 2D.M5: learners should build on the outcomes for the Pass criterion, to consider the outcomes of their testing and describe the extent to which the automated system meets the original requirements of the brief. Learners should gather feedback from others and consider changes they would like to make in the light of this feedback. Learners should consider any constraints that they have had to deal with when modifying the system.

For 2D.D4: learners should evaluate their initial designs and the completed automated system. They should identify any changes made from the design stage and justify them against the requirements and the features of the hardware and control programming language used. Learners should make at least three specific suggestions for improving the completed system, for example, identifying points of potential failure and suggesting how the system could be improved to prevent it. Learners do not have to implement the enhancements.

Control program constructs/ techniques for level 1 assessment

Some learners may fail to achieve a full Pass at level 2, so learners being assessed for the level 1 criteria for learning aims B and C are not required to include all of the different control programming constructs in their work for assessment.

The constructs that learners working at level 1 should be familiar with and include in their assessment evidence are shown below.

Use program constructs and techniques, e.g.:

- program constructs, e.g.:
  - comments
  - constants–variables with a constant value that cannot change
  - operators–arithmetic (+, –)
  - reserved words – that have special meaning within the programming language and are used to write instructions in a program
  - input and output commands
  - local variables - only exist inside the subroutine/function where they are declared and used
  - global variables
  - assignment
  - sequence
  - counter controlled loops
- use a range of data types, e.g. character, string (text), integer and real (numbers)
- use data structures, e.g. user-defined data types and record structures.

Suggested assignments

The table below shows a programme of suggested assignment outlines that cover the pass, merit and distinction criteria. This is guidance and it is recommended that centres either write their own assignments or adapt any assignments we provide to meet local needs and resources.

Please note that for the Automated Systems in Action assignment teachers should allow learners to investigate two different systems. One system should be a working kit-based system that can be demonstrated in the classroom and the other should be a commercial system. For the basic classroom system, the control program should be made available for learners to investigate.

Criteria covered	Assignment title	Scenario	Assessment evidence
1A.1 2A.P1, 2A.M1, 2A.D1	Automated Systems in Action	You work for a company that specialises in developing automated systems. A potential customer wants to know more about the characteristics of automated systems. You have been asked to prepare a presentation on the benefits and features of the following two systems: • a basic line-following automated vehicle that will move through a simple predetermined route and avoid obstacles • a commercial city-centre traffic light control program – the system monitors the flow of traffic based on inputs from inductance sensors in the road and alters the timing of the lights during each 24 hour period depending on the volume of traffic. So that the customer understands how the control program works, you have also been asked to provide a flow chart showing the algorithms used to control the basic automated vehicle.	• Presentation or report • Flow chart.

Criteria covered	Assignment title	Scenario	Assessment evidence
1B.2, 1B.3 2B.P2, 2B.P3, 2B.M2, 2B.D2	Design for an Automated Vehicle	The customer liked the presentation and would now like to see a design for a prototype automated vehicle which can be used to demonstrate the principles of a commercial system. The prototype vehicle should be capable of delivering a 1 kg mass between two points that are 5 m apart, avoiding any obstacles. The design should include an alternative solution and explain how the automated vehicle will fulfil the stated purpose and the user requirements. Any constraints that impact on the design should be covered. Prepare a justification for the customer to explain why you have designed the system the way you have, and what you considered.	• A description of purpose and user requirements • System hardware diagram(s) • A control program specification • A description of alternative solutions • A list of any predefined code • Test plan.
1C.4, 1C.5 2C.P4, 2C.P5, 2C.M3, 2C.M4, 2C.D3	Develop and Test the Automated Vehicle	Develop and test the prototype automated vehicle. The control program must allow the automated vehicle to travel between two points that are 5 m apart to deliver a 1 kg mass and avoid any obstacles. Refine the prototype, based on feedback from the customer or your manager where appropriate, to improve the performance of the system. For example, you might reduce the time taken to deliver the 1 kg mass or make the vehicle adapt to different external conditions, for example the nature of the terrain.	• Video of the automated guided vehicle • Annotated control program • Test results • Feedback from the customer or manager.

Criteria covered	Assignment title	Scenario	Assessment evidence
1D.6 2D.P6, 2D.M5, 2D.D4	Review the Automated Vehicle	Review the prototype automated vehicle, describing its strengths and potential further improvements. Consider the extent to which the automated system meets the original requirements and addresses feedback given from the customer. Justify how your design has changed during the development, including what has changed following feedback, and explain how you would improve the prototype system further.	• Evaluation report • Feedback from the customer • Annotated design documents.