Unit 25: Selecting and Using Programmable Controllers

Unit code: D/600/0276

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will give learners an understanding of the use and applications of programmable logic controllers (PLCs), the hardware and software that makes up a PLC and the interaction needed between the component parts.

Unit introduction

The automation of machines, process control and conveyor lines has resulted in the ever-increasing consistency of quality, speed and cost savings within complex processes. Consumers have come to expect high standards of quality in the manufactured goods they use, but to an engineer these are the challenges that make the profession interesting.

This unit will consider programmable logic controllers (PLCs), control devices which aid the automation of these processes. The capabilities of PLCs have developed over the years, with performance, reliability and operational resilience being key attributes to their continued success. In order to achieve automated monitoring and control, these devices can be used on their own or in conjunction with others through communication systems/links, which are themselves becoming more versatile.

The unit will introduce learners to the use and applications of PLCs, the hardware and software that makes up a PLC and the interaction needed between the component parts. Learners will develop their ability to use programming techniques to produce programs for modern PLCs. They will also gain an understanding of the different types of communication media used to link larger numbers of PLCs together, the networking architecture used and the associated standards and protocols.

Learning outcomes

On completion of this unit a learner should:

1 Understand the selection, hardware and software requirements of a programmable controller

2 Be able to use programming techniques to produce a program for a modern programmable controller

3 Understand complex programmable controller applications

4 Understand data communications media and networks used with modern programmable controllers.

Unit content

1 Understand the selection, hardware and software requirements of a programmable controller

Programmable controller selection: types (unitary, modular, rack-mounted); criteria eg cost, versatility and scanning time; internal architecture eg central processing unit (CPU), arithmetic and logic unit (ALU), flags, registers, memory and types (volatile, non-volatile); scan cycle (self-test, input/logic/output scans)

System hardware and software requirements: manufacturers' specification of input/output (I/O) units (digital and analogue); power supply; use of operating system; configuration of inputs and outputs; number systems eg binary, octal, hexadecimal, binary-coded decimal (BCD); input/output devices; mechanical switch relays (electromechanical and solid state); transducers eg temperature, pressure, flow, smart sensors, simple motors and drives

2 Be able to use programming techniques to produce a program for a modern programmable controller

Programming techniques: eg ladder and logic diagrams, statement listing, functional diagrams, graphical programming languages, mimic diagrams, sequential function charts (SFCs)

Produce, store and present program: human computer interface (HCI) eg handheld input pad, personal computer, text, graphical touch screens; use of system software to write, edit, delete, save, restore, create reports, load/unload, search; use of fault diagnostic indicators; print copies of program; storage eg scanning, memory organisation, continuous updating, back-up copies, supervisor control and data acquisition (SCADA)

Instruction types: production of program using relay, bit, branch, timer/counter, comparison, logical, arithmetic instructions; proportional integral derivative (PID) controller loops

3 Understand complex programmable controller applications

Program documentation: hardware considerations (environmental, operational, maintainability); instruction types; documentation for testing eg software debug instructions, diagnostic indicators, data monitors, search, force facilities; complex engineering applications eg machine, process control, conveyor

Health and safety with programmable controller: safe working practices for personnel and with equipment eg tools and equipment risk assessment, job safety analysis (JSA), housekeeping practices for work areas, personal protective equipment (PPE), restriction of non-participants from areas; health and safety standards (local, national, international) eg local safety agreements between employees and employers, Health and Safety Executive (HSE), Health and Safety at Work Act 1974, regulations for the use of display screens; avoiding haphazard operations eg risk management, planning considerations, testing (usability, unit, component, acceptance), 'what If' scenarios, commissioning

4 Understand data communications media and networks used with modern programmable controllers

Communication media: selection criteria, description of features, frequency ranges, technology eg analogue, digital, wireless; cable eg twisted pairs, coaxial, fibre-optic, shielded/unshielded, categories, operational lengths; connector eg Bayonet-Neill-Concelman (BNC), registered jack (RJ-45), straight tip (ST), universal serial bus (USB) type A and type B; opto-isolator eg photodiode, phototransistor, thyristors, triacs

Network: network architecture (fieldbus, distributed intelligence, 'open' communications networks); network standards/protocols eg International Organisation for Standardisation (ISO), Institute of Electrical and Electronic Engineers (IEEE), Manufacturing Automation Protocol (MAP), Electronics Industry Association (EIA-485), Factory Instrumentation Protocol (FIP)

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 describe the selection criteria and a practical application for a unitary, a modular and a rack-mounted programmable controller	**M1** explain the benefits and limitations of a programmable controller for a specific application	**D1** evaluate program documentation used to control an automated machine/process and make recommendations for improvement
P2 explain the system hardware and software requirements for a programmable controller application	**M2** justify the choice of a specific programming method and the methods used to produce, store and present the program	**D2** compare the current capabilities and limitations of a programmable controller and identify possible areas of future development.
P3 use a programming technique to produce, store and present a program that demonstrates the full range of instruction types [IE4]	**M3** compare two different networks used for a modern programmable controller system.	
P4 explain the program documentation that has been used for a complex engineering application		
P5 describe the importance of health and safety when working with programmable controlled equipment		
P6 explain how one example of each of the three types of communication media would be selected for a specific programmable controller application		
P7 describe a network and relevant standards and protocols used for a modern programmable controller system.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

This unit could be delivered as a stand-alone unit or be integrated with other units such as *Unit 58: Construction and Application of Digital Systems* and *Unit 65: Principles and Applications of Microcontrollers*. An integrated approach to delivery will give learners an opportunity to consider the wider aspects of hardware and software development within modern integrated applications. Delivery and learning will be maximised through a strong, practically based learning programme.

PLC capabilities and their range of uses within the control industry has grown considerably over recent years, meaning that there is a wide variety of PLCs available. However, it is important that learners recognise the limitations of earlier models (in terms of hardware and software) and the potential of newer models for longer life cycles and advanced characteristics and features.

In order to ensure breadth of learning, centres should ideally work with employers to introduce real work-based applications of PLC technology. Educational visits to appropriate events such as exhibits, trade fairs and system manufacturers are an important method to inspire learning.

Practical work should ensure that learners can recognise a range of PLC units, interfaces and connections, programming techniques and large system integration, for both existing and future demands. This will enable them to appreciate how the various aspects fit together to produce an efficient, reliable and safe control method that is capable of fitting within a range of operational environments. In some cases, this will include the need for portability and an operationally sustainable energy source.

Appropriate attention must be given to health, safety and welfare arrangements throughout the delivery of this unit.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • introduction to unit content, scheme of work and method of assessment • explain and describe the purpose and criteria for the selection of PLCs • describe PLC internal architecture and scan cycle • explain specification of I/O units and power supply • describe and demonstrate the use of an operating system, configuring inputs and outputs and the purpose and use of different number systems • explain the purpose and basic function of I/O devices, switch relays and transducers. *Individual research and group activity*: • investigate the selection of PLCs for different given applications.
Preparation for and completion of **Assignment 1: Selection and Applications of PLCs** (P1, P2 and M1).
Whole-class teaching: • explain and demonstrate the use of programming techniques • explain and demonstrate forms of HCI and the use of system software • demonstrate use of fault diagnostic indicators and means of storing programs • explain and demonstrate the full use of instruction types. *Practical learner activity*: • practise and use programming techniques to produce PLC programs.
Preparation for and completion of **Assignment 2: Using Programming Techniques** (P3 and M2).
Whole-class teaching: • explain the need for and use of different program documentation required for complex engineering applications. *Individual learner work*: • researching documentation relevant to different engineering applications. *Whole-class teaching*: • explain the safe working practices to be followed when working with PLCs and relevant applicable health and safety standards • explain risk management techniques and means of avoiding haphazard operations. *Group activity*: • using case study material to examine health and safety requirements for situations involving programmable controllers.
Preparation for and completion of **Assignment 3: Applications of Programmable Controllers** (P4, P5 and D1).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • describe the different types of communication media, their main features and their applications • describe the different forms of connector used and opto-isolators and the selection criteria • explain the different forms of network architecture and the standards and protocols that apply to networks.
Preparation for and completion of **Assignment 4: Data Communications Media and Networks** (P6, P7, M3 and D2).
Feedback on assessment, unit evaluation and close.

Assessment

PLCs involve a complex mixture of computer technology, communication interfaces and software programming techniques.

The assessment strategy for this unit should consist of a mix of written technical reports and hands-on practical work. Annotated photographic evidence could also be a valuable tool to capture 'on-site' information and support learners' written work.

Where the grading criteria refer to an 'application' this is intended to mean a real-world situation wherever possible. Although a different application could be used for different criteria it would be reasonable to use the same or closely related applications throughout.

P1 and P2 are closely linked. P1 requires learners to describe the selection criteria and a practical application for a unitary, a modular and a rack-mounted programmable controller. In doing so, learners need to demonstrate their ability to recognise the different approaches to PLC operational activities. In describing the selection criteria learners should consider things such as cost, versatility and scanning time, together with relevant descriptions of the internal architecture (eg central processing unit (CPU), arithmetic and logic unit (ALU) etc) and a practical application of each.

For P2, a comprehensive range of hardware and software requirements should be considered. For example, the power supply available may have quite different consequences for an application involving a field monitoring system as opposed to an installation in a factory. The amount of coverage of content for this criterion will be determined by the actual programmable controller application considered but it is expected that the learner should have at least four or five system hardware and software requirements indicated and explained.

P3 requires learners to use a programming method to produce, store and present a program that demonstrates the full range of instruction types. Learners are not expected to be fully competent programmers but their programs should be printed out, annotated where appropriate and stored.

The explanation required for P4 needs to cover all the related unit content including hardware considerations, instruction types and documentation for testing. A 'complex engineering application' in this context is intended to mean some form of machine, a manufacturing process control operation or a conveyor system based on a real-life situation. Learners will need to provide some details of the complex application and go on to explain the documentation, for example the program instructions, testing documentation and forced facilities etc associated with it. Ideally this would be a work-based application, although learners could be provided with a case study of a complex application.

P5 requires learners to describe the importance of health and safety when working with programmable controlled equipment. A range of 'what if' scenarios for various applications could be used to cover the full requirements of the unit content.

P6 requires learners to explain how one example of each of the three types of communication media (cable, connector, opto-isolator) would be selected for a specific programmable controller application. The key point here is for learners to recognise the media, understand how each one is selected, describe the main features and consider aspects such as frequency ranges and the technology to which they are being applied.

For P7, there is a possibility that the description of a network and relevant standards and protocols could become overly complex and involve a wide range of issues. Therefore, learners need to be restricted to describing just the general network architecture of perhaps an Ethernet, and provide details of the associated standards and what they generally imply.

M1 builds on the work carried out for pass criteria P1 and P2, as learners need to consider a specific application and apply their understanding of the selection criteria already used. The important point is that they can demonstrate ability in selecting an appropriate PLC type and have knowledge as to why it is an appropriate choice.

M2 can be clearly linked to pass criteria P3 and P4. To achieve M2, learners need to reflect on their choice of programming methods. In their justification learners should identify why one programming method has been chosen and make it clear why the others have been rejected.

M3 builds on the work undertaken to achieve P7 and P8. It requires learners to compare two different networks used for a modern programmable controller system. This should include details of the networks, standards and key differences. Learners need to demonstrate that they realise the important differences between networks and how they may influence the associated PLC systems.

To achieve D1, learners must consider the wider implications of the work carried out for P4 and M2. Learners need to be able to appraise the material and suggest improvements. These improvements should not simply be related to the amount of material documentation. Learners should also consider the documentation in light of their ability to recognise the hardware considerations, work with the range of instruction types and use the documentation for testing. As with the related pass criterion, this must be set within a complex engineering application.

Finally, D2 requires learners to reflect on the unit as a whole. The comparison could include aspects such as memory capacity, the types of PLC available, the growing development in networking technologies (for example wireless implications), the use of smart sensors and how this may impair the programme and feedback loops, how processor power may influence the programming method etc. Satisfactory achievement of this criterion will require learners to have considered the range of issues covered by the unit content and undertaken some independent research of trends and potential benefits.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2 and M1	Selection and Applications of PLCs	A written assignment requiring learners to demonstrate an understanding of PLC selection and application.	A series of three written tasks. Learners provide a description of the selection and application of PLCs and explain hardware and software requirements. Learners are then given an application for which they choose a suitable PLC.
P3 and M2	Using Programming Techniques	Learners are required by their employer to produce a program for a specific programmable controller to meet a customer's needs.	A practical programming task. Learners should produce a program, which should be printed out, annotated and stored.
P4, P5 and D1	Applications of Programmable Controllers	Learners investigate an industrial application of programmable controllers, and explain the documentation and health and safety considerations that relate to it.	A series of written descriptions/ explanations.
P6, P7, M3 and D2	Data Communications Media and Networks	Learners investigate the different forms of media, their selection criteria and their applications.	A series of written descriptions/ explanations.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with the following unit titles in the Engineering suite:

Level 1	Level 2	Level 3
		Construction and Application of Digital Systems

The unit has links with the SEMTA Level 3 National Occupational Standards in Engineering Technical Support, particularly:

- Unit 30: Loading and Proving Computer Control Programs
- Unit 32: Producing Off-line Programs for Programmable Logic Controller Equipment.

Essential resources

Centres will need access to a range of PLCs, communication media and interface devices. Software packages and tools should also be available to permit programming and implementation of device/applications for circuit performance and debugging. Learners will require access to a range of relevant manuals, reference data and manufacturers' information.

Employer engagement and vocational contexts

Much of this unit can be set in an industrial context and centres should make the most of local opportunities to demonstrate complex engineering applications of programmable controllers, such as manufacturing process control operations or a conveyor systems.

Indicative reading for learners

Textbooks

Bolton W – *Instrumentation and Control Systems* (Newnes, 2004) ISBN 0750664320

Bolton W – *Programmable Logic Controllers* (Newnes, 2006) ISBN 0750681128

Hooper J – *Introduction to PLCs* (Carolina Academic Press, 2004) ISBN 0890893896

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	using and evaluating the information used for programming controllers.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Reflective learners	reviewing their progress and acting on the outcomes
Self-managers	working towards clear, common goals and organising their own thinking in a coherent form.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	programming controllers for different applications
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	investigating and researching programmable logic controllers
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining selection, hardware and software requirements.