SQA Advanced Unit Specification

General information for centres

Unit title: Applications of Programmable Logic Controllers

Unit code: HT1K 47

Unit purpose: This Unit is designed to introduce candidates to Programmable Logic Controllers (PLCs) and enable them to understand how PLCs are applied to control industrial processes. The Unit allows candidates to develop the necessary knowledge and skills to allow them to understand the basic construction and operation of PLCs. The Unit also provides candidates with the opportunity to develop practical programming skills to enable them to apply a PLC to simulate control of a specified industrial process.

On completion of the Unit the candidate should be able to:

1. Explain and classify PLC hardware.
2. Describe the operation of PLC software.
3. Simulate the safe control of an industrial process by the application of PLC technology.

Credit value: 1 SQA Credit at SCQF level 7: (8 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from National 1 to Doctorates.*

Recommended prior knowledge and skills: Candidates should possess a basic knowledge and understanding of electrical principles and combinational logic. This may be evidenced by the possession of a Higher in Electrical Engineering and/or SQA Advanced Units Single Phase AC Circuits, Combinational Logic.

Core skills: There may be opportunities to gather evidence towards Core Skills in this Unit, although there is no automatic certification of Core Skills or Core Skills components.

Context for delivery: This Unit was developed for the SQA Advanced Certificate/Diploma in Electronics awards. If this Unit is delivered as part of a group award(s), it is recommended that it should be taught and assessed within the subject area of the group award(s) to which it contributes.

Assessment: The assessment for Outcomes 1 and 2 in this Unit should be combined together into one written assessment paper. This paper should be taken by candidates at one single assessment event that should last one hour and thirty minutes. The assessment paper should be composed of a suitable balance of short answer, restricted response and structured questions. This assessment should be conducted under controlled, supervised conditions.

Outcome 3 should be assessed by an assignment in which candidates are asked to complete a series of tasks to enable them to apply a PLC to simulate the safe control of a specified industrial process. The assignment tasks should involve devising the control strategy, writing PLC software, programming of the PLC, verifying correct operation of the program and documentation of the final solution. Candidates should complete the assignment in eight hours. Candidates should have access to a PLC and be allowed to use any relevant course notes, textbooks and reference material for the PLC.

Both the written assessment and the practical assignment should be carried out at the end of the delivery of the Unit.

It should be noted that candidates must achieve all the minimum evidence specified for each Outcome in order to pass the Unit.

Unit specification: statement of standards

Unit title: Applications of Programmable Logic Controllers

Unit code: HT1K 47

The sections of the Unit stating the Outcomes, knowledge and/or skills, and evidence requirements are mandatory.

Where evidence for Outcomes is assessed on a sample basis, the whole of the content listed in the knowledge and/or skills section must be taught and available for assessment. Candidates should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

Outcome 1

Explain and classify PLC hardware

Knowledge and/or skills

- Architecture of a PLC
- Function of the element parts of a PLC
- Causes and consequences of failures within a PLC controlled system
- Classification of PLC systems (in terms of memory capacity, number of input and output terminals, complexity of programming functions, and typical application)
- Benefits of PLC control systems

Evidence requirements

Evidence for the knowledge and/or skills in this Outcome will be provided on a sample basis. The evidence may be provided in response to specific questions. Each candidate will need to demonstrate that they can answer questions based on a sample of the items shown above. In any assessment of this Outcome three out of five knowledge and/or skills items should be sampled.

In order to ensure that candidates will not be able to foresee what items they will be questioned on, a different sample of three out of five knowledge and/or skills items is required each time the Outcome is assessed. Candidates must provide a satisfactory response to all three items.

Where sampling takes place, a candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to: -

- draw an annotated block diagram of a PLC showing the element parts and arrows indicating the flow of information between elements
- describe the function of the element parts of a PLC
- explain three possible causes and the corresponding consequences of failure in a PLC control system

- describe two examples of how PLC systems can be classified in terms of memory capacity, number of input/output terminals and availability of advanced features, and give examples of practical applications
- state four advantages of PLC control compared to traditional hard-wired relay control systems and conventional computer control systems

Evidence should be generated through assessment undertaken in controlled, supervised conditions. Assessment should be conducted under closed-book conditions and as such candidates must not be allowed to bring any textbooks, handouts or notes to the assessment.

Assessment guidelines

Questions used to elicit candidate evidence should take the form of an appropriate balance of short answer, restricted response and structured questions.

The assessment of this Outcome should be combined with that of Outcome 2 to form a single assessment paper, details of which are given under Outcome 2.

Outcome 2

Describe the operation of PLC software

Knowledge and/or skills

- Function and operation of a timer within a PLC program
- Function and operation of a counter within a PLC program
- Function and operation of a latching circuit within a PLC program
- Function and operation of a shift register within a PLC program
- Function and operation of auxiliary relays within a PLC program
- Interpretation of PLC programs
- Method of program execution

Evidence requirements

Evidence for the knowledge and/or skills in this Outcome will be provided on a sample basis. The evidence may be provided in response to specific questions. Each candidate will need to demonstrate that they can answer questions based on a sample of the items above. In any assessment of this Outcome four out of seven knowledge and/or skills items should be sampled.

In order to ensure that candidates will not be able to foresee what items they will be questioned on, a different sample of four out of seven knowledge and/or skills items is required each time the Outcome is assessed. Candidates must provide a satisfactory response to all four items.

Where sampling takes place, a candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

- state the function of a PLC timer and describe the operation of a simple ladder diagram containing a timer
- state the function of a PLC counter and describe the operation of a simple ladder diagram containing a counter

- state the function of a PLC latch contact and describe the operation of a simple ladder diagram containing a latch
- state the function of a PLC shift register and describe the operation of a simple ladder diagram containing a shift register
- state the function of a PLC auxiliary relay and give two examples of special functions that could be performed by PLC auxiliary relays
- describe the operation of a small given PLC program
- describe how a user program is executed in a PLC (reference should be made to mass I/O copying)

Evidence should be generated through assessment undertaken in controlled, supervised conditions. Assessment should be conducted under closed-book conditions and as such candidates must not be allowed to bring any textbooks, handouts, manuals or notes to the assessment.

Assessment guidelines

The assessment of this Outcome should be combined with that of Outcome 1 to form a single assessment paper. The single assessment paper should be taken at a single assessment event lasting one hour and thirty minutes and be carried out under supervised, controlled conditions. Such a paper should be composed of an appropriate balance of short answer, restricted response and structured questions. This assessment should be carried out at the end of the delivery of the Unit.

The number of inputs and outputs required in the PLC program should be limited to the following: inputs minimum 2, maximum 3 and outputs minimum 3, maximum 4.

Outcome 3

Simulate the safe control of an industrial process by the application of PLC technology

Knowledge and/or skills

- Preparation of a PLC program to simulate safe control of an industrial process
- Allocation of PLC inputs and outputs
- Entering a program into a PLC
- Editing a PLC program
- Verifying correct operation of a PLC program
- Demonstrating the operation of a PLC program
- Documentation of control strategy and software

Evidence requirements

This is a practically based Outcome and all of the knowledge and/or skills items above should be assessed. The evidence should be presented in response to a practical assignment in which the candidate is set the task of applying a PLC to simulate the safe control of an industrial process.

A candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

- design software that is valid and that simulates the safe control of the industrial process
- correctly allocate PLC input and output addresses
- correctly enter the program into the PLC
- edit the PLC program
- demonstrate effective testing procedures
- demonstrate the correct operation of the PLC program via the PLC indicating LEDs or an existing mimic panel
- produce a report that includes the following:
  - a description of the process to be controlled
  - allocation of PLC inputs and outputs
  - a ladder diagram of the PLC program
  - an instruction code listing (where applicable)
  - an explanation of the operation of the program
  - an explanation of the safety features that have been incorporated in the application of the PLC

The control problem in this assignment should be based on an industrial process but it is not intended that the physical process should be controlled. The operation of the program should be mimicked by either using I/O LEDs on the PLC or by connecting the PLC to an existing mimic panel. However, if a real or simulated process is available at the centre, then the candidate should be encouraged to test his/her final program by connecting to the hardware.

Candidates should have access to relevant programming notes, textbooks and reference manuals for the PLC. If the candidate's program does not function properly then the candidate should be allowed to correct the faults and retest the operation of the program. Centres should make every reasonable effort to ensure that the control solution is the candidate's own work.

Centres should provide candidates with details of the required report format that should include, as a minimum, the items listed under Evidence requirements bullet point six. If they so desire, candidates should be permitted to use software packages to produce documentation for their reports. Whilst candidates are not required to produce their reports under controlled, supervised conditions, Centres should make every reasonable effort to ensure that reports are the candidates' own work.

Assessment guidelines

The assessment of this Outcome should take the form of an assignment and be carried out at the end of the delivery of the Unit. The time that should be allocated for the assignment, including the writing of the report, is eight hours in total. It is recommended that Centres develop checklists to support the assessment requirements for each of the knowledge and/or skills items.

It is essential that Centres ensure that evidence generated is the candidate's own work. Centres can choose to issue each candidate either with a different process to be simulated or the same process to be simulated. If each candidate is issued with a different process specification then the degree of difficulty for each one should be equal. If the same process specification is assigned to each candidate then the specification should be such that each candidate is required to interpret it and offer his/her unique design solution.

Administrative information

Unit code: HT1K 47

Unit title: Applications of Programmable Logic Controllers

Superclass category: XL

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SQA acknowledges the valuable contribution that Scotland's colleges have made to the development of SQA Advanced Qualifications.

FURTHER INFORMATION: Call SQA's Customer Contact Centre on 44 (0) 141 500 5030 or 0345 279 1000. Alternatively, complete our Centre Feedback Form.

Unit specification: support notes

Unit title: Applications of Programmable Logic Controllers

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

This Unit has been written in order to allow candidates to develop knowledge, understanding and skills in the following areas: -

1. PLC hardware and its classification.
2. The operation of PLC programs.
3. The application of PLCs to safely control industrial related processes.

This Unit is at SCQF level 7 and has been devised as an optional Unit within the new SQA Advanced Certificate and SQA Advanced Diploma in Electronics award. However this does not preclude the use of this Unit in other awards where award designers feel this to be appropriate.

In designing this Unit, the Unit writer has identified the range of topics that they would expect to be covered by lecturers. The writer has also given recommendations as to how much time should be spent on each Outcome. This has been done to help lecturers to decide what depth of treatment should be given to the topics attached to each of the Outcomes. Whilst it is not mandatory for centres to use this list of topics, it is recommended that they do so since the assessment exemplar pack for this Unit is based on the knowledge and/or skills and list of topics in each of the Outcomes.

A list of topics for each Outcome is given below. Lecturers are advised to study this list in conjunction with the assessment exemplar pack so that they can get a clear indication of the standard of achievement expected of candidates in this Unit.

Outcome 1
Explain and classify PLC hardware (6 hours)

The following topics are general in nature but should be put into context by reference to the specific PLC available at the Centre.

- Purpose of a PLC
- Examples of the use of PLCs in industrial control
- Basic architecture of a PLC shown in block diagram format. The diagram should include the following:
  - control unit
  - program memory

- work memory
- input module
- output module
- power supply unit
- programming device

Description of the functions carried out by the following hardware elements:

- ♦ Control unit (scanning input states, executing program steps, setting or clearing the internal relays and outputs in response to program logic. Also managing timers, counters and other special functions).
- ♦ Program memory (ROM for operating system. ROM, EPROM, EEPROM or battery backed RAM for user's program).
- ♦ Work memory (partially battery backed RAM to store auxiliary relay states, timers and counters states, I/O states and arithmetic and logic calculation results).
- ♦ Input modules with opto-isolation
- ♦ Output modules (a) with opto-isolation and solid-state switches (b) with electromechanical relays
- ♦ Power supply Unit and battery back-up of certain PLC auxiliary relay contacts and program memory where this is in volatile RAM.
- ♦ Programming devices e.g. hand-held programmer or host computer

Hardware failures
(a) within the PLC e.g. input and output circuits, internal power supply, processor, memory
(b) outwith the PLC e.g. sensors and actuators

- ♦ Environmental failures e.g. dust, vibration, temperature and electrical interference.
- ♦ Failures due to programming errors.
- ♦ Consequences of the various types of failures within a PLC controlled system.
- ♦ Memory capacity, number of I/O ports and availability of advanced features for PLCs that are classified as (a) micro, (b) small, (c) medium and (d) large.
- ♦ Typical applications of micro, small, medium and large PLCs.
- ♦ Advantages of PLC control compared to traditional hard-wired relay control systems and conventional computers.

Outcome 2
Describe the operation of PLC software (10 hours)

The following topics are general in nature but should be put into context by reference to the specific PLC available at the centre.

- ♦ normally open contacts
- ♦ normally closed contacts
- ♦ output relays
- ♦ timers
- ♦ counters
- ♦ latching circuits
- ♦ shift registers
- ♦ auxiliary relays including those with special functions

- ladder diagrams
- statement lists or logic symbols (whichever is appropriate for the specific PLC available)
- principle of program execution including
  - input scan
  - program execution
  - output scan

Outcome 3
Simulate the safe control of an industrial process by the application of PLC technology (15 hours)

It is intended that the following topics be undertaken using the specific PLC available at the centre. A range of industrial related control problems should be studied.

- safety aspects including fail safe conditions, guards for machines and the use of emergency stops, watchdog timers
- designing software to control a process
- allocation of PLC inputs and outputs
- entering a program into the PLC
- editing a program
- effective testing procedures to verify correct operation of a program
- use of any diagnostic tools in the PLC e.g. monitor, trace and search
- demonstrating correct operation of a program via PLC led indicators or supplied mimic panel
- relevant documentation including I/O charts, program listing, ladder diagram and description of program operation
- demonstration of the use of relevant software packages that can be used to produce documentation of programs

Note, it is not intended that the physical process be controlled, simply that its operation is mimicked either by using the PLC I/O LEDs or by connecting the PLC to an existing mimic panel. However, if real or simulated processes are available at the centre, then the candidate will benefit from witnessing demonstrations of the application of the PLC to control the process.

Unit Assessment

Written paper	1 hour and 30 minutes
Practically based assignment	8 hours

Guidance on the delivery and assessment of this Unit

It is intended that this Unit is presented by at all times referring to the specific PLC available, and that technical and programming manuals for the PLC are readily available to the candidate.

In the delivery of this Unit, candidates should be provided with the opportunity to gain as much "hands on" experience as possible. Ideally each candidate should have a PLC to work with but

if, due to resource constraints, this is not possible then, for non-assessment purposes, candidates could work in small groups. If candidates are working in small groups it is essential that each candidate participates in the exercises and gets the opportunity to enter and edit programs.

Details on approaches to assessment are given under Evidence requirements and Assessment guidelines under each Outcome in the SQA Advanced Unit specification: statement of standards section. It is recommended that these sections be read carefully before proceeding with assessment of candidates.

Open learning

This Unit could be delivered by distance learning, which may incorporate some degree of on-line support. The candidate would require access to a suitable PLC. With regard to assessment, planning would be required of the centre concerned to ensure the sufficiency and authenticity of candidate evidence. Arrangements would be required to be put in place to ensure that written assessment was conducted under controlled, supervised conditions. Arrangements would also need to be made to ensure that the candidate could practically demonstrate the operation of his/her solution to the practical assignment required as assessment evidence. This could involve the candidate attending the centre or utilising video conferencing. Alternatively, special arrangements could be made for the candidate to demonstrate the practical work to a designated, responsible person local to the candidate.

For information on normal open learning arrangements, please refer to the SQA guide *Assessment and Quality Assurance of Open and Distance Learning* (SQA 2000).

Equality and inclusion

This unit specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence.

Further advice can be found on our website www.sqa.org.uk/assessmentarrangements

General information for candidates

Unit title: Applications of Programmable Logic Controllers

This Unit has been designed to provide you with the knowledge and skills that will enable you to understand the basic construction and operation of programmable logic controllers (PLCs).

You will study PLC hardware and software, and you will learn to write programs that could be used to control simple industrial processes.

This Unit will also allow you to develop practical skills that will enable you to enter and edit programs within a PLC. You will have the opportunity to gain "hands on" experience of operating and programming a PLC and by the end of the Unit, you should be able to apply a PLC to simulate safe control of an industrial process.

The formal assessment for this Unit will consist of both a written assessment and a practical assignment.

The written assessment paper will last for one hour and thirty minutes and take place under controlled, supervised conditions. It will be carried out under closed book conditions in which you will not be allowed to take notes, handouts, textbooks etc into the assessment.

Your practical skills will be assessed by means of the assignment in which you will be required to satisfactorily complete a series of tasks that will enable you to apply a PLC to safely control a specified industrial process. You will be presented with a description of an industrial process and you will be required to design software that could be used in the PLC to safely control the process. You will then be required to enter and edit your program in the PLC, demonstrate the correct operation of your programme and finally, submit a report documenting your assignment. This assignment should normally be completed within eight hours. Your centre will provide you with access to a PLC and you should be allowed to use any relevant course notes, textbooks and reference manuals for the PLC.

Both the written assessment and practical assignment will normally be carried out at the end of the delivery of the Unit.