Next Generation Higher National Unit Specification

Instrumentation and Control: Control Systems (SCQF level 7)

Unit code: J6D5 47

SCQF level: 7 (24 SCQF credit points)

Valid from: session 2023–24

Prototype unit specification for use in pilot delivery only (version 1.0) August 2023

This unit specification provides detailed information about the unit to ensure consistent and transparent assessment year on year.

This unit specification is for teachers and lecturers and contains all the mandatory information required to deliver and assess the unit.

This edition: August 2023 (version 1.0)

Unit purpose

When studying this unit, learners develop knowledge and skills in the fundamentals of modern distributed control systems (DCSs), networks and communications, programmable logic controllers (PLCs), and instrumentation in hazardous areas.

It is aimed at learners who have an interest in:

- studying qualifications that develop core engineering principles and skills to support an industrial career in a wide range of industries (including oil and gas, process, utilities, renewables, and food and beverage)
- the practical, personal and professional skills required for a successful career as an instrumentation and control engineering technician

Entry is at your centre's discretion. However, we recommend that learners have achieved one or more of the following:

- the Instrumentation and Control: Measurement Systems unit at SCQF level 7
- Higher Physics or qualifications in Electrical, Electronics, Mechanical, and Engineering Systems at SCQF level 6
- relevant, equivalent workplace experience

On completing this unit, learners can progress to further study or employment in a wide range of engineering industries such as: oil and gas, process, utilities, renewables, and food and beverage.

Unit outcomes

Learners who complete this unit can:

1 demonstrate knowledge and understanding of the fundamentals of DCSs
2 demonstrate knowledge and understanding of networks and communications
3 apply knowledge and skills of PLC technology
4 demonstrate knowledge and understanding of instrumentation in hazardous areas

Evidence requirements

Assess this unit holistically, using a portfolio of evidence generated by learners.

They must produce a reflective report for each outcome, evaluating the knowledge and skills they have gained. Learners must generate evidence under unsupervised, open-book conditions. They should have access to engineering software, online help facilities and other appropriate materials, including relevant standards.

To successfully achieve this unit, learners must provide evidence demonstrating that they have developed the knowledge and skills of each outcome. This should be in the context of one or more overarching instrumentation and control engineering scenarios.

The standard of evidence should be consistent with the SCQF level of this unit.

You can find further information in the 'Additional guidance' section.

Outcome 1

- Compare and contrast DCSs, supervisory control and data acquisition (SCADA) and PLCs.
- Select and justify control strategies for a particular application.
- Make use of an appropriate diagram to show a DCS structure indicating communication paths and signal levels.
- Explain the DCS from field devices to commercial data processing.
- Explain a DCS typical reporting system.
- Identify the basic DCS controller configuration.
- Apply control algorithms: proportional (P), proportional and integral (PI), and proportional, integral and derivative (PID).
- Evaluate controllers for batch and continuous processes.
- Configure a typical DCS hardware and software.
- Make use of a suitable DCS software package to create a simple program.
- Produce an output for the created and simulated DCS program.
- Contrast types of alarm systems management for DCS.
- Identify the basic structure of data acquisitions systems and various types of signals and describe how they are conditioned and processed in a data acquisition system.
- Describe human-machine interfaces (HMIs) and alarms.

Outcome 2

- Examine the basic communication principles and protocols for DCS, PLC and SCADA.
- Distinguish network communication standards.
- Distinguish applications of field interfaces and networks.
- Identify network redundancy.
- Recognise cybersecurity.

Outcome 3

- Identify basic requirements of interfacing devices to PLCs.
- Develop programmes to operate a variety of engineering systems interfaces to a PLC.
- Develop a programme to operate actuators interfaced to a PLC.

Outcome 4

- Identify active and passive barriers of intrinsic safety.
- Apply active and passive barriers of intrinsic safety.
- Sketch the fire triangle.
- Distinguish flash point, fire point and auto-ignition temperature.
- Discuss flammable and explosive range, lower explosive and upper explosive limits.
- Identify hazards associated with oxygen enrichment.
- Distinguish hazardous areas for gas and for flammable dusts.
- Identify gas grouping.
- Recognise heat sources.
- Identify electrical and chemical sources of ignition.
- Explain how spontaneous combustion could occur.
- Identify Ex protection for devices intended for use in explosive atmospheres under the ATEX 100a Directive (94/9/EC) and the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).
- Apply Ex protection to ATEX 100a and DSEAR.

Knowledge and skills

The following table shows the knowledge and skills covered by the unit outcomes:

Knowledge	Skills
Outcome 1 Learners should: ♦ demonstrate knowledge and understanding of modern control systems ♦ outline the structure of modern DCSs ♦ illustrate the operation of DCS controllers ♦ demonstrate an understanding of basic DCS programming ♦ demonstrate knowledge and understanding of alarm management for DCSs ♦ outline the fundamentals of SCADA systems and HMIs	**Outcome 1** Learners can: ♦ explore automated systems for controlling processes ♦ identify the structure of modern DCSs ♦ examine the operation of DCS controllers ♦ create and execute basic DCS programs ♦ identify alarm management techniques ♦ examine the basic structure of data acquisitions systems ♦ examine the operation of a typical SCADA system and the principles of HMI
Outcome 2 Learners should: ♦ demonstrate knowledge and understanding of communication technologies ♦ demonstrate knowledge and understanding of networks technologies ♦ demonstrate knowledge and understanding of network redundancy ♦ demonstrate knowledge and understanding of cybersecurity	**Outcome 2** Learners can: ♦ identify and contrast various types of communication technologies ♦ identify networks technologies ♦ identify network redundancy ♦ identify innovative cybersecurity technologies to protect industrial assets, operations and people from digital threats
Outcome 3 Learners should: ♦ demonstrate knowledge and understanding of PLC technology ♦ demonstrate knowledge and understanding of ladder logic or function block programming	**Outcome 3** Learners can: ♦ identify modern PLC technology ♦ perform ladder logic or function block programming

Knowledge	Skills
Outcome 4 Learners should: ♦ demonstrate knowledge and understanding of active and passive barriers of intrinsic safety ♦ demonstrate knowledge and understanding of hazardous atmospheres and hazardous area classification ♦ demonstrate knowledge and understanding of sources of ignition ♦ demonstrate knowledge and understanding of Ex protection of ATEX 100a and DSEAR	**Outcome 4** Learners can: ♦ analyse active and passive barriers of intrinsic safety ♦ analyse hazardous atmospheres and hazardous areas classification ♦ identify elements of sources of ignition ♦ identify Ex protection of ATEX 100a and DSEAR

Meta-skills

Throughout the unit, learners develop meta-skills to enhance their employability in the engineering sector.

Self-management

Learners develop self-awareness, ethics and self-control through learning activities and project assignments. They develop their self-learning skills and critically reflect on their own learning performance. Learners also develop their self-motivation and the ability to make decisions and take responsibility for their own learning.

Learners develop their sense of responsibility when conducting project work and they learn to follow through on commitments and be proactive. They develop decision-making skills using intuition and careful thought.

Learners can provide evidence of these skills in their portfolio, logbook and reports.

Social intelligence

Learners develop their communication skills when accessing the unit material, keeping a portfolio or logbook, and writing technical reports. They also develop their teamworking and collaboration skills when engaging with fellow learners and teachers or lecturers throughout. These skills can be monitored or evidenced from the learners' portfolios, logbooks and reflective reports.

Innovation

Learners develop their curiosity, sense-making, creative and critical thinking skills when carrying out their learning activities. They can provide evidence of these skills in their portfolio, logbook and reports.

Literacies

Learners develop core skills in the following literacies:

Numeracy

Learners develop their numeracy skills using physical principles governing signals, signal conditioning and processing, and PID controllers.

Communication

Learners develop their communication skills during teamworking and collaboration, and when engaging with fellow learners, teachers or lecturers.

Digital

Learners develop their digital literacy when using a broad range of engineering software and digital testing equipment, and accessing the course material through a virtual learning environment (VLE).

Delivery of unit

This unit is part of the Higher National Certificate (HNC) in Engineering. The framework includes mandatory and optional units, and you can tailor the combination of units to specific engineering pathway needs.

While the exact time allocated to this unit is at your centre's discretion, the notional design length is 120 hours.

The amount of time you allocate to each outcome is at your discretion, however we suggest you spend approximately 30 hours on each outcome, including assessment.

Additional guidance

The guidance in this section is not mandatory.

Content and context

This unit provides learners with the fundamental knowledge and skills needed to support a career in instrumentation and control engineering or to pursue higher education in related fields.

It develops the principles established in instrumentation and control engineering, and extends understanding of the principles used in:

- the analysis and application of modern DCSs
- networking and communications technology
- PLCs
- instrumentation in hazardous areas

The unit examines the technologies and processes that are specific to instrumentation and control engineering, and commonly used within a broad range of industries, including the oil and gas, chemical, food and beverage, manufacturing and renewable technology sectors.

We recommend that you use the following list of topics, as it provides the level and depth of treatment that you should give to each outcome.

Demonstrate knowledge and understanding of the fundamentals of DCSs (outcome 1)

Learners cover the basics of modern distributed control systems, and identify and explain the structure of DCSs, including:

- DCS structure: field device level, controller level, management level
- DCS communication methods and devices linking the levels
- DCS operation
- the latest DCS trends:
  - monitoring and control in the field
  - industrial internet of things
  - mobile and remote devices
  - monitoring and control in the Cloud
- DSC applications and case studies (for example oil and gas)

Learners cover the fundamentals of the operation of DCS controllers, and analyse and explain:

- control algorithms:
  - proportional (P)
  - proportional and integral (PI)
  - proportional, integral and derivative (PID)
- basic DCS controller configuration
- sequential controllers for batch processing
- controllers for continuous processes: function blocks

Learners cover the fundamentals of DCS programming, creating and executing basic DCS programs.

They also cover various alarm management techniques and identify and explain:

- alarm types:
  - absolute
  - rate of change
  - deviation
- alarm priority:
  - emergency
  - high-low
- alarm system functions
- alarm philosophy, control and management

Learners explain the fundamentals of SCADA systems and HMIs. They learn the basics of data acquisition systems, identify and contrast various types of electrical measurement quantities, and describe how these signals are conditioned, processed and communicated in an industrial process monitoring system. This includes:

- data acquisition systems and data acquisition equipment
- electrical measurements:
  - signals: mV, mA, volt, Ohm, pulse and frequency safety concerns
  - direct current (DC) and alternating current (AC) voltage
  - current
  - resistance
  - Wheatstone bridges
- signal conditioning:
  - linearisation of millivolt and milliamp signals
  - instrumentation amplifiers
  - instrumentation attenuators
  - instrumentation isolation

- signal conversion:
  - analogue signals, such as a 4–20 mA DC loop
  - digital signals
  - analogue to digital conversion
  - digital to analogue conversion
- communications:
  - multiplexing and demultiplexing
  - analogue
  - digital
  - optical
  - radio
  - microwave
- a brief overview of SCADA
- comparing DCS, PLC and SCADA
- HMIs:
  - HMI introduction, features and requirements
  - plant mimic and animation
  - interface categories
  - recorders, loggers, trend displays and data archiving
  - HMIs in the control room and in the field: mobile and remote devices

Demonstrate knowledge and understanding of networks and communications (outcome 2)

Learners gain a broad understanding of communications technologies, networks and network redundancy technologies, and cybersecurity. This covers:

- communications technologies:
  - bits and bytes
  - binary numbering
  - resolution
  - hexadecimal
  - American Standard Code for Information Interchange (ASCII)
  - universal asynchronous receiver-transmitters (UARTs)
  - synchronous and asynchronous transmission protocols
  - communication standards
  - Fieldbus operation: Foundation Fieldbus, Profibus
  - wide area network (WAN) communications: Modbus

- network technologies:
  - data communication and networking
  - signal transmission
  - physical network structures
  - logical networking structures
  - wide area network (WAN) communications: Modbus
- network redundancy
- cybersecurity:
  - integration of cybersecurity into DCS and SCADA
  - preparedness for a cyber attack at every stage
  - built-in security in modern control systems

Apply knowledge and skills of PLC technology (outcome 3)

Learners are equipped with practical skills by creating and executing either ladder logic or function block PLC programming:

- PLC technology:
  - a brief overview of PLC technology
- ladder logic or function block programming

Demonstrate knowledge and understanding of instrumentation in hazardous areas (outcome 4)

Learners analyse and describe:

- active and passive barriers of intrinsic safety
- hazardous atmospheres and hazardous area classification
- sources of ignition
- explosion protection of ATEX 100a, and DSEAR

Learners require specialised equipment and software to complete this unit. However, you should provide this as part of the instrumentation and control engineering course.

Approaches to delivery

We suggest you deliver outcomes 1 and 2 first. You can deliver outcomes 3 and 4 in any order.

Do this in a learning space or VLE, depending on the requirements of the learning activity. You should teach primarily using problem-based-learning (PBL) techniques, such as case studies and mini projects, supported by other methods. The holistic teaching format of PBL encourages learners to consider the deeper context of the theory.

Approaches to assessment

We recommend that you assess this unit holistically. Learners should generate evidence under unsupervised, open-book and untimed conditions, and collate it in their individual portfolios. Your centre should have appropriate supervision and safety procedures in place.

Learners should demonstrate evidence of all knowledge and skills in the context of one or more overarching control systems scenarios.

For case studies and project assignments, you can assess knowledge and skills using coursework exercises.

Learners can keep a linear reflective account to assess their meta-skills, digital literacy, professional skills and wider employer-desired skills, and record this in their portfolios. You should provide learners with support, guidance and feedback on areas of development, and signpost developmental opportunities.

In addition, you can use observation, anecdotal comments and a checklist as evidence. These are valid ways of gathering evidence of learning. The actual amount of evidence is not critical, it is the quality that is important. Learners should demonstrate evidence of all knowledge and skills in the context of one or more overarching instrumentation and control engineering scenarios.

You should give learners access to online facilities, reference materials, appropriate software packages and other appropriate support materials.

As the assessment is open-book, you must take care to ensure authenticity. You can do this by using variable values in the coursework, making use of oral questioning and using originality-checking software.

Equality and inclusion

This unit is designed to be as fair and as accessible as possible with no unnecessary barriers to learning or assessment.

You should take into account the needs of individual learners when planning learning experiences, selecting assessment methods or considering alternative evidence.

Guidance on assessment arrangements for disabled learners and/or those with additional support needs is available on the assessment arrangements web page: www.sqa.org.uk/assessmentarrangements.

Information for learners

Instrumentation and Control: Control Systems (SCQF level 7)

This information explains:

- what the unit is about
- what you should know or be able to do before you start
- what you need to do during the unit
- opportunities for further learning and employment

Unit information

This unit provides you with knowledge and skills specific to instrumentation and control engineering. It is aimed at those who want to become instrumentation and control engineering technicians.

Before starting this unit, we recommend that you have one or more of the following:

- the Instrumentation and Control: Measurement Systems unit at SCQF level 7
- Higher Physics or qualifications in Electrical, Electronics, Mechanical, and Engineering Systems at SCQF level 6
- relevant, equivalent workplace experience

You gain knowledge and develop your skills in the fundamentals of distributed control systems (DCSs), networks and communication technologies, programmable logic controllers (PLCs) and instrumentation in hazardous areas.

Outcome 1 provides a broad understanding and skills development in data acquisition systems, the structure of modern DCSs, operation of DCS controllers, basic DCS programming, alarm management, and the fundamentals of supervisory control and data acquisition (SCADA) and human-machine interfaces (HMIs).

Outcome 2 provides a broad understanding and skills development in communication technologies, networks and network redundancy technologies, and cybersecurity, that are paramount in modern industry and commerce.

Outcome 3 provides a broad understanding and skills development in PLC. You apply this understanding to create and execute either ladder logic, or function block type PLC programming.

Outcome 4 provides a broad understanding and skills development in a range of intrinsic safety devices and passive barriers, hazardous atmospheres and hazardous area classifications, sources of ignition and Ex Protection from ATEX 100a and DSEAR.

There is a holistic approach to assessment, where you demonstrate evidence of all knowledge and skills in the context of one or more overarching control systems scenarios.

You are assessed using a variety of ways, including review of case study reports and project assignment reports. You should collate all evidence in your individual portfolio.

On completion of this unit, you can:

- demonstrate knowledge and understanding of the fundamentals of a DCS
- demonstrate knowledge and understanding of networks and communications
- apply knowledge and skills of PLC technology
- demonstrate knowledge and understanding of instrumentation in hazardous areas

This unit provides you with suitable knowledge and skills to progress to further study or employment in a wide range of engineering industries such as: oil and gas, process, utilities, renewables, and food and beverage.

Meta-skills

Throughout the unit, you can develop a wide range of personal skills to enhance your employability in the engineering sector. These skills include self-management, social intelligence and innovation.

Self-management

You develop self-awareness, ethics and self-control as you conduct your learning activities and project assignments. You develop your self-learning skills and critically reflect on your learning performance. You also develop your self-motivation and the ability to make decisions and take responsibility for your own learning.

You develop your sense of responsibility when conducting project work and you learn to follow through on commitments and be proactive. You develop skills at making decisions using intuition and careful thought.

Social intelligence

You develop your communication skills when accessing the unit material, keeping a portfolio or logbook, and writing technical reports. You also develop teamworking and collaboration skills when engaging with fellow learners or lecturers throughout the unit.

Innovation

You develop the skills of curiosity, sense-making, and creative and critical thinking when carrying out your learning activities.

Administrative information

Published: August 2023 (version 1.0)

Superclass: VE

History of changes

Version	Description of change	Date

Note: please check SQA's website to ensure you are using the most up-to-date version of this document.