



National Unit Specification: general information

UNIT Robotics and Automated Systems (SCQF level 6)

CODE F5H6 12

SUMMARY

This Unit may form part of a National Qualification Group Award or may be offered on a free-standing basis.

This Unit is designed to allow candidates to develop their knowledge, understanding and skills of the anatomy, senses, control mechanisms and programming of industrial robots. During the delivery of the Unit candidates will compare the anatomy of robotic devices. They will develop the knowledge and understanding to analyse sensory systems in robotic devices and describe control strategies used in automated systems. Candidates will also learn to programme a robotic system to perform repeatable actions.

This Unit is suitable for candidates training to be manufacturing, mechanical, fabrication and welding, or multi-disciplinary engineering technicians.

OUTCOMES

- 1 Describe and compare the anatomies of given robotic devices.
- 2 Analyse the sensory systems used in given robotic devices.
- 3 Describe the control strategies used in given automation systems.
- 4 Programme a given robotic system to carry out repeatable actions.

Administrative Information

Superclass: VE

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National Unit Specification: general information (cont)

UNIT Robotics and Automated Systems (SCQF level 6)

RECOMMENDED ENTRY

While entry is at the discretion of the centre, candidates would normally be expected to have attained one of the following, or equivalent:

- ◆ Standard Grade in Technological Studies at credit level
- ◆ Standard Grade in Physics at credit level
- ◆ Intermediate 2 in Technological Studies
- ◆ Intermediate 2 in Physics

CREDIT VALUE

1 credit at SCQF level 6 (6 SCQF credit points at SCQF level 6*).

**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 Access 1 to Doctorates.*

CORE SKILLS

There is no automatic certification of Core Skills in this Unit.

The Unit provides opportunities for candidates to develop aspects of the following Core Skills:

- ◆ Communication (SCQF level 5)
- ◆ Problem Solving (SCQF level 5)

These opportunities are highlighted in the Support Notes of this Unit Specification.

National Unit Specification: statement of standards

UNIT Robotic and Automated Systems (SCQF level 6)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit Specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

OUTCOME 1

Describe and compare the anatomies of given robotic devices.

Performance Criteria

- (a) Describe correctly the anatomies of given robots and the motion of each joint.
- (b) Describe correctly the work envelope volume and its implications for reach and safety for a robot.
- (c) Describe correctly the operation of an end-effector type.
- (d) Compare correctly the suitability of robot drive systems for a specified application.

OUTCOME 2

Analyse the sensory systems used in given robotic devices.

Performance Criteria

- (a) Describe correctly the operation of an encoder used in a robot system.
- (b) Compare accurately coding systems in terms of their derivation, efficiency (bit length) and relative advantages in use especially as regards errors.
- (c) Calculate correctly positional accuracy in terms of resolution and effective bit length.
- (d) Explain correctly the operation of a tactile sensor.

OUTCOME 3

Describe the control strategies used in given automation systems.

Performance Criteria

- (a) Describe correctly a sequential control strategy.
- (b) Compare accurately open-loop and closed-loop control systems with respect to cost of application, complexity, stability and accuracy.
- (c) Describe correctly, using a time domain plot, the output responses of control systems using on/off and proportional control.
- (d) Describe correctly the influence of the constituent elements of a Proportional + Integral + Derivative (PID) control strategy with respect to speed of response, stability and accuracy.

National Unit Specification: statement of standards (cont)

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OUTCOME 4

Programme a given robotic system to carry out repeatable actions.

Performance Criteria

- (a) Describe correctly one programming method for a robot.
- (b) Analyse correctly the tasks required for a given ‘pick and place’ sequential operation.
- (c) Translate correctly from task analysis into functional software.
- (d) Verify correct software operation on hardware.

EVIDENCE REQUIREMENTS FOR THIS UNIT

Evidence is required to demonstrate that candidates have achieved all Outcomes and Performance Criteria.

Written and/or recorded oral and performance evidence supplemented with an assessor observation checklist (s) should be produced to demonstrate that a candidate has achieved all Outcomes and Performance Criteria.

Outcomes may be assessed on an individual basis, as a combination of Outcomes (eg Outcomes 1, 2, 3 and 4 pc (a) together and Outcome 4 Performance Criterion (b), Performance Criterion (c) and Performance Criterion (d) together) or as a single, holistic assessment covering all four Outcomes.

Outcomes 1, 2, 3 and 4 Performance Criterion (a) (Written and/or Oral Recorded Evidence)

The total assessment time for Outcomes 1, 2, 3 and 4 Performance Criterion (a) must not exceed 2 hours. Assessment of Outcomes 1, 2, 3 and 4 Performance Criterion (a) must be conducted under controlled, supervised, closed-book conditions in which candidates may use reference materials provided by the centre but are not allowed to bring their own notes, handouts, textbooks or other materials into the assessment. Candidates must be allowed to use a scientific calculator during the assessment event.

Outcome 4 Performance Criterion (b), Performance Criterion (c) and Performance Criterion (d) (Written and/or Oral Recorded and Performance Evidence)

Assessment time for Outcome 4 Performance Criterion (b), Performance Criterion (c) and Performance Criterion (d) must be sufficient to allow candidates to understand the task, familiarise themselves with the robot in terms of its capability, control instruction commands and programme entry/operation procedures. Outcome 4 (b), (c) and (d) must be assessed under supervised, open-book conditions where candidates have free access to robot documentation, course notes, relevant materials and safety advice.

National Unit Specification: statement of standards (cont)

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With regard to Outcome 1 candidates must:

- ◆ describe two robot anatomies from the following: Cartesian, cylindrical, polar, revolute and SCARA
- ◆ describe the work envelope volume and the implications for reach and safety for one robot anatomy from the following: Cartesian, cylindrical, polar, revolute and SCARA
- ◆ describe the operation of one end effector gripper type from the following types: mechanical, magnetic (permanent and electro-) or pneumatic
- ◆ compare a minimum of two drive systems (from pneumatic, hydraulic or electrical) with respect to four factors from the following: range, movement, position control, safety, cost, force, speed or maintenance

With regard to Outcome 2 candidates must:

- ◆ describe one linear or one rotary incremental or absolute encoder
- ◆ compare any two out of the three codes from the following: Pure Binary Codes (PBC), Binary Coded Decimal (BCD) and Gray code

With regard to Outcome 3 candidates must:

- ◆ describe one time-based or event based sequential control strategy

With regard to Outcome 4:

- ◆ candidates must describe one programming method from lead-by-nose or walkthrough (point to point) programming methods
- ◆ for Outcome 4 Performance Criterion (b), Performance Criterion (c) and Performance Criterion (d) one pick and place sequential task must be analysed, translated into functional software and verified for correct operation by loading onto hardware and operated. Flowcharts or equivalent structured methodology must be used to document sequences and decision making.

An assessor checklist must be used to record evidence that candidates have verified correct software operation on hardware.

National Unit Specification: support notes

UNIT Robotic and Automated Systems (SCQF level 6)

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.

Safety should be emphasised throughout the delivery of this Unit. In particular, safety in the application of robotic and automated systems should be reviewed prior to their use.

GUIDANCE ON CONTENT AND CONTEXT FOR THIS UNIT

This Unit forms part of the National Qualification Group Award (NQGA) in Manufacturing Engineering at SCQF level 6, but may also be offered on a free-standing basis.

The aim of this Unit is to allow candidates to develop their knowledge, understanding and skills of typical robotic and automated systems. On successful completion of the Unit candidates will be able to compare the anatomy of robotic devices. They will have the knowledge and understanding to analyse sensory systems in robotic devices and describe control strategies used in automated systems. Candidates will also be capable of programming a robotic system to perform repeatable actions.

In Outcome 1 candidates should learn to differentiate between different robotic anatomies such as Cartesian, cylindrical, polar, revolute and SCARA anatomies. Candidates should also develop the knowledge and understanding to describe what the term ‘work envelope volume’ means and how it will differ between various anatomies. The obvious implications for reach (the area the robot can reach and therefore can do useful work) and safety (the area that needs to be clear of people and other equipment during operation) should be emphasised. The operation of mechanical, magnetic (permanent and electro-) and pneumatic end-effector gripper types is best taught by means of sketches and descriptions in addition to ‘hands-on’ experience of laboratory or industrial examples. Candidates should also explore the suitability of pneumatic, hydraulic and electrical drive systems to provide appropriate motion for specified applications. Candidates should also examine the suitability of different robotic drive systems with respect to range of movement, position control, safety, cost, force, speed and maintenance. While it needs to be recognised that there will almost always be exceptions to any rule at this level it is reasonable to teach that pneumatic drives provide less force than an equivalent hydraulic drive and hydraulic systems require more maintenance than pneumatic and electrical ones.

Outcome 2 focuses on how the position of a robot can be sensed and hence controlled. The differences between incremental and absolute encoders should be explored including the effects of the loss and restoration of power. Pure Binary Codes (PBC), Binary Coded Decimal (BCD) and Gray codes should be explained in terms of their derivation, efficiency (bit length) and relative advantages in use especially as regards errors. The relationship between an applied code and the linear resolution for a linear system and the angular resolution for a rotary system should be explained. Positional accuracy should be explored in terms of resolution and effective bit length though the differences between ‘ 2^n ’ and ‘ 2^n-1 ’ need not be emphasised. Basic tactile sensing should be described and both advantages and disadvantages briefly examined.

National Unit Specification: support notes (cont)

UNIT Robotic and Automated Systems (SCQF level 6)

Outcome 3 provides opportunities for candidates to explore different control strategies used in typical automation systems. Candidates should be taught to describe how time based and event based sequential control strategies work and how they differ from each other. They should also learn to be able to distinguish between open-loop and closed-loop control systems with respect to cost of application, complexity, stability and accuracy. While it needs to be recognised that there will almost always be exceptions to any rule, at this level it is reasonable to teach that a closed loop system will cost more to apply (as it has more elements), be more complex, may not be as stable but should provide increased accuracy if correctly set up when compared with an equivalent open loop system. Terms such as set point/desired value, offset/steady state error and overshoot should be introduced. The exploration of control strategies and systems should be treated on a qualitative, descriptive and conceptual basis and does not need to be mathematical or numerical. Terms such as damping and critical damping should be explained but need not be mathematically expressed. Basic statements such as ‘time based means elapsed time intervals exceeding that needed to complete an action’, ‘event based means use of sensors to detect operation completion’, ‘closed loop means information about output and errors is fed back to control the system’, etc would suffice for explanation purposes. The use of time domain plots to explain the output responses of control systems using on/off and using proportional control is likely to assist candidate learning.

The influence of the constituent elements of a PID control strategy with respect to speed of response, stability and accuracy should be explored making sure the initial response to a P system is clearly appreciated before I (to reduce offset) and D (to change speed of response) are introduced. As before the treatment should be qualitative, descriptive and conceptual not requiring the need for a mathematical or numerical treatment. Such an approach should be sufficient to allow candidates to choose the most suitable control strategy for a particular robotic application.

Outcome 4 represents the culmination of the Unit. It begins with a comparison of two exemplar programming approaches and candidates should learn to describe ‘lead-by-nose’ and ‘walkthrough’ programming in terms of the programming process (eg, lead-by-nose — an operator skilled in a task manually performs a task and the robot records the sequence of actions for reproduction/replay later) and typical applications (eg, lead-by-nose — paint spraying). It would be appropriate to include modern programming tools and approaches (such as operator actions being captured using high speed cameras and the use of graphical interfaces) alongside more traditional approaches.

The main part of Outcome 4 is where candidates should be given a specific repetitive pick and place task and be required to break down the task into the constituent robotic movements and thus derive a sequence for the task. Once the sequence has been derived and proven, the candidates should convert it into the functional code for the particular robotic system available at the centre. Verification of the software may consist of ensuring the robotic system performs the original task given to the candidates. Typical repetitive pick and place tasks that may be considered as part of this Unit may include: picking and stacking of blocks in certain order (and/or the unstacking), picking and/or placing specified objects in different locations, assembling a simple assembly from a number of component parts (and/or disassembly). The emphasis should be on the whole process rather than individual stages and there would be no need to have a multitude of repetitive steps once the principle of analysis, translation, programming and verification/operation has been established. The required accuracy, repeatability, load, etc. should reflect the capability and precision of the robot being used and should not be unrealistically arduous.

National Unit Specification: support notes (cont)

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GUIDANCE ON LEARNING AND TEACHING APPROACHES FOR THIS UNIT

It is recommended that the Unit is delivered in the same sequence the Outcomes are presented in the National Unit Specification: statement of standards section of the Unit. This Unit may be delivered by a combination of lectures, tutorial work, investigations using paper based and electronic sources, computer simulation, industrial visits and practical exercises. The use of laboratory robots, illustrations of industrial robots and/or software graphical simulations will help candidates appreciate the differences between anatomies and the differing motions of linear and rotary joints. Practical exercises may include candidates operating and exploring robotic systems and their components to study their constructional features and principle of operation. Centres may also wish to allow candidates to perform some basic experiments on robotic systems and their components to investigate some of their performance characteristics. Computer simulation software may also be used to allow candidates to explore robotic systems and their components beyond what is possible on the robotic systems used at the centre. It should be noted that the Internet contains a rich source of information on Robotics and automated systems and their constituent parts.

Industrial and/or commercial visits to see robots in operation can be both informative and inspirational.

OPPORTUNITIES FOR CORE SKILL DEVELOPMENT

Candidates may have opportunities to develop the Reading Communication Core Skill component at SCQF level 5 in all four Outcomes while undertaking paper based and electronic investigations into Robotics and Automated systems and sub-systems.

The Written Communication Core Skill component at SCQF level 5 may be developed in Outcomes 1, 2, 3 and 4(a) while candidates provide technical responses to questions on various aspects of robot anatomy, operation and control.

Candidates may have opportunities to develop the Critical Thinking Core Skill component at SCQF level 5 in Outcome 1 while comparing the suitability of pneumatic, hydraulic and electrical drive systems for a specified application and in Outcome 4 while analysing the tasks required for a given pick and place sequential operation.

Candidates may have opportunities to develop the Review and Evaluation Core Skills component at SCQF level 5 in Outcome 4 while verifying the correct software operation of robotic hardware carrying out given pick and place sequential operations.

National Unit Specification: support notes (cont)

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GUIDANCE ON APPROACHES TO ASSESSMENT FOR THIS UNIT

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or e-checklists. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003)*, *SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

Formative assessment exercises involving candidates in recognising and describing:

- ◆ the different anatomies of the typical robotic devices including the motions of each joint and their work envelope volumes
- ◆ the operation of mechanical, magnetic (permanent and electro-) and pneumatic end-effector grippers
- ◆ incremental and absolute encoders
- ◆ tactile sensing
- ◆ sequential control strategies using time based and event based approaches
- ◆ time domain plots as a way of showing the output responses of control systems using on /off and proportional control
- ◆ the influence of the constituent elements of a PID control strategy
- ◆ lead-by-nose and walkthrough (point to point) programming methods

and in comparing:

- ◆ pneumatic, hydraulic and electrical drive systems
- ◆ Pure Binary Codes (PBC), Binary Coded Decimal (BCD) and Gray codes
- ◆ open-loop and closed-loop control systems

and in calculating:

- ◆ positional accuracy in terms of resolution and effective bit length for encoded systems

will play a particularly important role in building candidate knowledge, understanding and confidence of Unit content.

The programming exercise (Outcome 4 Performance Criterion (b), Performance Criterion (c) and Performance Criterion (d)) could usefully be approached by formative exercises involving task analysis for everyday events (eg, safely starting a car), task analysis of demonstrations of existing working systems, considerations of structured sequence descriptions (eg, flowcharts) and modifications to existing working programmed systems to see the effect and scope of changes.

National Unit Specification: support notes (cont)

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For Outcomes 1, 2, 3 and 4 Performance Criterion (a)

Outcomes 1, 2, 3 and 4 Performance Criterion (a) may be assessed by an assessment paper comprising a balance of short answer, restricted response and structured questions taken at a single assessment event lasting 2 hours.

Outcome 4 Performance Criterion (b), Performance Criterion (c) and Performance Criterion (d)

Outcome 4 Performance Criterion (b), Performance Criterion (c) and Performance Criterion (d) may be assessed by a practical exercise involving the programming of a robotic system to carry out repeatable actions. Prior to assessment candidates should have been provided with ‘hands on’ opportunities to familiarise themselves with the programming and operation of the chosen robotic system. It is recommended that candidates are given 45 minutes to perform the initial task analysis and between 1 and 2 hours (depending on the particular robotic equipment, programming interface and task complexity) to translate the task analysis into functional software. The verification of the correct software operation on hardware may involve elements of debugging and adjustment to ensure performance within expected limits.

Candidates should prepare basic documentation to show the task analysis (such as a flowchart or equivalent) and the translated software (such as a commented software listing) and the final verification of the correct software operation on hardware should be demonstrated to the supervisor/assessor who may use a checklist to record performance.

The documentation may be prepared in the candidate’s own time. Centres should make every reasonable effort to ensure that the documentation is the candidate’s own work. Where copying or plagiarism is suspected candidates may be interviewed to check their knowledge and understanding of the subject matter. A checklist should be used to record oral evidence of the candidate’s knowledge and understanding.

Task selection for Outcome 4 Performance Criterion (b), Performance Criterion (c) and Performance Criterion (d) is important to ensure an appropriate level of challenge and complexity which enables candidates to demonstrate their knowledge and understanding at the appropriate standard. A too simple task will not achieve this but neither would a very repetitive task with little variation (eg placing and unplacing a single block on top of another 20 times). Variation should be preferred to repetition. Variation, for example, in sequencing or location can also be used to give different but equally complex tasks to each candidate and hence discourage copying or imitation. At all times the selected task should be well matched to the capability of the available equipment in terms of load, accuracy, repeatability, access, work envelope and safety.

DISABLED CANDIDATES AND/OR THOSE WITH ADDITIONAL SUPPORT NEEDS

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website www.sqa.org.uk/assessmentarrangements