SQA Advanced Unit specification

General information

Unit title: Fundamentals of Control Systems and Transducers (SCQF level 7)

Unit code: HT1R 47

Superclass: VE

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Version: 01

Unit purpose

This Unit is designed to provide learners with a fundamental knowledge of control systems and their components. It allows learners to study the structure and general behaviour of different types of control systems including open and closed loop types. This Unit also enables learners to develop the knowledge and skills to allow them to understand the operation and application of a range of transducer devices. Learners are provided with the opportunity to construct circuits and systems that incorporate transducers. This Unit acts as a good foundation Unit for more in depth studies in the specialist area of control systems behaviour.

Outcomes

On successful completion of the Unit the learner will be able to:

1 Explain control system elements and signals.
2 Explain the operation and application of a range of transducers used in control systems.
3 Describe the structure and behaviour of control systems.
4 Demonstrate the application of transducers in control systems.

Credit points and level

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

Recommended entry to the Unit

Learners should have a general knowledge and understanding of electrical and electronic concepts. This may be evidenced by possession of the SQA Advanced Units: HP46 47 *DC and AC Principles*, HT7J 46 *Analogue Electronics: An Introduction* and HT7L 47 *Digital Electronics*. However, entry requirements are at the discretion of the centre.

Core Skills

Opportunities to develop aspects of Core Skills are highlighted in the Support Notes for this Unit specification.

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

Context for delivery

This Unit has been developed for the SQA Advanced Certificate and SQA Advanced Diploma in Electrical Engineering. If this Unit is delivered as part of a Group Award, it is recommended that it should be taught and assessed within the subject area of the Group Award to which it contributes.

The Assessment Support Pack (ASP) for this Unit provides assessment and marking guidelines that exemplify the national standard for achievement. It is a valid, reliable and practicable assessment. Centres wishing to develop their own assessments should refer to the ASP to ensure a comparable standard. A list of existing ASPs is available to download from SQA's website **(http://www.sqa.org.uk/sqa/46233.2769.html)**.

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**.

Unit specification: Statement of standards

Unit title: Fundamentals of Control Systems and Transducers (SCQF level 7)

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.

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. Learners 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 control system elements and signals.

Knowledge and/or skills

- Functions of control system elements and signals
- Characteristics of analogue and digital signals
- Transmission of analogue signals
- Transmission of digital signals
- Functions of signal conditioning devices

Outcome 2

Explain the operation and application of a range of transducers used in control systems.

Knowledge and/or Skills

- Operation and application of a range of transducers suitable for measuring the following variables: temperature, flow, displacement, velocity, pressure, strain, position, level and light
- Properties of transducers
- Identification of suitable transducers for various control systems

Outcome 3

Describe the structure and behaviour of control systems.

Knowledge and/or Skills

- Sequence control systems
- On-off control systems
- Block diagram representation of open and closed loop systems
- Transient and steady state behaviour of open loop systems in response to the application of a Unit step input
- Transient and steady state behaviour of closed loop systems in response to the application of a Unit step input
- The use of controllers to modify open loop system responses
- The use of controllers to modify closed loop system responses

Outcome 4

Demonstrate the application of transducers in control systems.

Knowledge and/or Skills

- Construct and demonstrate circuits and systems that incorporate transducers
- Operation of circuits and systems that incorporate transducers
- Measurement of transducer transfer characteristics

Evidence Requirements for Outcomes 1–3

Written and/or Oral recorded evidence is required for outcomes 1–3 which will be provided on a sample basis. In any assessment of the Outcomes **three out of five** Knowledge and/or Skills items should be sampled from Outcome 1, **two out of three** Knowledge and/or Skills items from Outcome 2, and **four out of seven** Knowledge and/or Skills items from Outcome 3.

In order to ensure that learners 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 from Outcome 1, two out of three Knowledge and/or Skills items from Outcome 2, and four out of seven Knowledge and/or Skills items from Outcome 3 is required each time the Unit is assessed. Learners must provide a satisfactory response to all items.

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

Where sampling takes place, a learner's response can be judged to be satisfactory where the evidence shows the learner can:

Outcome 1

- Describe the function of five of the following: controller, error detector, regulator, actuator, transducer, manipulated variable, controlled variable, set point, external output
- Describe the characteristics of analogue and digital signals, and compare the advantages/disadvantages of each
- Describe the effects of a transmission path on an analogue signal, and describe the desirable properties of a suitable cable used for transmitting analogue signals in a control system
- Explain the difference between serial and parallel data transmission, state at least three interface standards and, for each standard, state an appropriate application
- Explain the function of three signal conditioning devices

Outcome 2

- Explain the operation and application of transducers suitable for measuring two variables from the following list: temperature, flow, displacement, velocity, pressure, strain, position, level and light
- Explain four of the following properties of a transducer: range, accuracy, repeatability, sensitivity, resolution, linearity, hysteresis
- State a suitable transducer for a given control system

Outcome 3

- State an example of a sequence control system and describe the component parts
- Describe the behaviour of an on-off type of control system and give an example of an application
- Draw a block diagram of a specified closed loop control system consisting of a controller, external input (set point), error detector, error signal, actuator, regulator, manipulated variable, process, controlled variable, feedback loop, transducer and any appropriate signal conditioning devices
- Draw a voltage/time graph showing the transient and steady state response of an open loop system in response to a Unit step input. The graph should be labelled with final value, steady state error, and time to settle
- Draw a voltage/time graph showing the transient and steady state response of a closed loop system in response to a Unit step input. The graph should be labelled with steady state error, time to peak, time to settle, overshoot and final value
- Draw labelled graphs showing the effect of increasing and decreasing gain in an open loop system
- Draw labelled graphs showing over damped, under damped, and critically damped behaviour in a closed loop system

Evidence Requirements for Outcome 4

This is a practically based Outcome and **all** of the Knowledge and/or Skills items should be assessed. The evidence should be presented in response to a practical, laboratory assignment in which each learner is set the task of constructing and demonstrating the operation of a circuit or system that incorporates a transducer.

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

- Construct and demonstrate correct operation of a circuit or system that incorporates a transducer
- Describe the operation of the circuit or system that has been constructed
- Measure and plot on a graph, the transducer's output in response to changes at its input

Evidence of the practical aspects of this assignment should be recorded by centres in the form of a checklist for each learner. Each learner is required to construct a circuit or system independently, and then demonstrate to the Assessor its correct operation. If the learner's circuit or system does not operate properly, then the learner should be allowed to correct the faults and retest the operation at the same assessment event.

On completion of the practical laboratory exercise, learners are required to submit a written laboratory report. This report should include the following sections of information:

- purpose of the circuit or system, and relevant circuit or system diagram
- brief description of method of construction
- description of operation of the circuit or system
- record of measured input and output values for the transducer
- graph of transducer's transfer characteristic (o/p versus i/p values)
- record of observations of the operation of the circuit or system
- analysis of recorded values, graph and observations
- conclusion conveying the success of the operation of the circuit or system

Centres should provide learners with details of the required report format. Although it should be encouraged, it is **not** a requirement that learners use software packages to produce documentation for their reports. Centres should make every reasonable effort to ensure that each report is the learner's own work.

The circuit or system that the learner is required to construct and demonstrate can be built using discrete components, pre-constructed modules or a combination of both. Learners should be issued with the circuit or system diagram along with a brief description of its purpose. The circuit or system should be constructed in the laboratory under controlled, supervised conditions, and the written report can be completed outwith the laboratory in the learner's own study time.

Unit Support Notes

Unit title: Fundamentals of Control Systems and Transducers (SCQF level 7)

Unit Support Notes are offered as guidance and 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 to in order to allow learners to develop knowledge, understanding and skills in the following areas:

1 Explain control system elements and signals.
2 Explain the operation and application of a range of transducers used in control systems.
3 Describe the structure and behaviour of control systems.
4 Demonstrate the application of transducers in control systems.

This Unit is at SCQF level 7 and is included within the SQA Advanced Certificate in Electronics and SQA Advanced Diploma in Electronics. 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 expected 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 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 learners in this Unit.

1 Explain control system elements and signals (10.5 hours)

The following topics could be covered whilst referring to a variety of specific control system examples:

- Purpose of a control system
- Practical examples of the requirement for a control system
- Element parts of a control system – controller, error detector, actuator, regulator, process, feedback loop and transducer
- Signals in a control system – external inputs and outputs, set point, error signal, manipulated variable, controlled variable, and disturbance variables
- Characteristics of analogue and digital signals
- Comparative advantages/disadvantages of analogue and digital signals
- Transmission of analogue and digital signals over short and long distances, and in industrial environments
- Serial and Parallel methods of digital signal transmission
- Serial and Parallel Standards (eg RS 232, RS 423, RS 422, RS 485, IEEE 488 and IEEE 1284) and their applications
- Need for, and functions of signal conditioning devices eg amplifier, filter, A/D and D/A, linearisation circuit, V/I and I/V conversion

2 Explain the operation and application of a range of transducers used in control systems (8 hours)

Basic construction, operation and application of a range of transducers suitable for measuring variables such as temperature, flow, displacement, velocity, pressure, strain, position, level and light.

Examples of devices that could be covered are potentiometers, capacitive displacement transducers, tacho-generators, strain gauges, flow meters, manometers, bourdon tubes, bellows, resistance thermometers, thermocouples, shaft encoders, linear variable differential transformers, photo diodes, light dependant resistors, piezo-electric transducers.

Transducer properties including range, accuracy, repeatability, sensitivity, resolution, linearity and hysteresis

Selection of transducers suitable for specific example control systems.

This Outcome should be taught through practical demonstrations and ‘hands on’ experience of the practical use of transducers in model control systems. This Outcome could be delivered in conjunction with Outcome 4.

3 Describe the structure and behaviour of control systems (12 hours)

- Operation of and examples of sequence control systems eg plc control of industrial processes
- Behaviour and example applications of on-off control systems
- Behaviour and examples of open loop systems
- Behaviour and examples of closed loop systems
- Representation in block diagram format of open and closed loop systems
- Transient and steady state behaviour of open loop systems in response to the application of a Unit step input:
  - Draw a voltage/time graph showing the transient and steady state response of an open loop system in response to a Unit step input. The graph should be labelled with final value, steady state error, and time to settle
  - The use of controllers to modify open loop system responses
  - Draw labelled graphs showing the effect of increasing gain in an open loop system
- Transient and steady state behaviour of closed loop systems in response to the application of a Unit step input:
  - Draw a voltage/time graph showing the transient and steady state response of a closed loop system in response to a Unit step input. The graph should be labelled with steady state error, time to peak, time to settle, overshoot and final value
- The use of controllers to modify closed loop system responses:
  - Draw labelled graphs showing over damped, under damped, and critically damped behaviour in a closed loop system
  - Show that controllers can be used to obtain any desired closed loop performance (with respect to peak, overshoot, settling time, steady state error etc.)
- Throughout this Outcome, practical illustrative examples of control systems should be available in the laboratory to allow learners the opportunity to observe their operation and obtain some 'hands on' experience. These could be actual or model control systems that allow the learners to observe and analyse the effects of gain changes, input condition changes etc.

4 Demonstrate the application of transducers in control systems (6 hours)

This is a practically based Outcome. Laboratory exercises are required to allow learners to:

- Construct and then investigate the operation of simple control circuits and systems that incorporate transducers
- Measure the output of transducers in response to changes in the input quantity
- Plot the transfer characteristics for transducers (graphs of output values versus input values)
- From the graphs identify any non-linear characteristics and hysteresis

The circuits and systems can be built using discrete components, pre-constructed modules, or a combination of both.

Unit Assessment:

Written Paper	2 hours
Practical Laboratory Assignment	2 hours

Guidance on approaches to delivery of this Unit

Throughout the delivery of this Unit, reference should be made to practical examples of control systems. A range of transducers should be available for learners to view. Practical demonstrations and/or laboratory exercises showing the operation of transducers and model control systems should be provided throughout the Unit.

This Unit has been developed as part of the SQA Advanced Certificate and SQA Advanced Diploma in Electrical Engineering awards. Where this Unit is incorporated into other Group Awards it is recommended that it be delivered in the context of the specific occupational area(s) that the award is designed to cover.

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 learners.

The written assessment paper should take place after delivery of the Unit is complete.

The practical laboratory assignment can be carried out during the delivery of the Unit.

Guidance on approaches to assessment of this Unit

Evidence can be generated using different types of assessment. The following are suggestions only. There may be other methods that would be more suitable to learners.

Centres are reminded that prior verification of centre-devised assessments would help to ensure that the national standard is being met. Where learners experience a range of assessment methods, this helps them to develop different skills that should be transferable to work or further and higher education.

The assessment for all Outcomes 1, 2 and 3 in this Unit should be combined together into one written assessment paper. This paper should be taken by learners at one single assessment event that should last two hours. The assessment paper should be composed of a suitable balance of short answer, restricted response and structured questions. This assessment should be carried out at the end of the delivery of the Unit and be conducted under controlled, supervised conditions.

Outcome 4 should be assessed by a practical, laboratory assignment in which each learner is set the task of constructing and demonstrating the operation of a circuit or system that incorporates a transducer. On successful completion of the practical aspects of this assignment, learners should be required to submit a written laboratory report. The time that should be allocated in the laboratory for this assignment is 2 hours. However, learners should be allowed to complete the written report outwith the laboratory in their own study time. The assessment for Outcome 4 should be carried out at a suitable time during the delivery of the Unit.

Assessment Guidelines

Outcomes 1–3

The assessment for Outcomes 1, 2 and 3 should be combined together to form one assessment paper. This single assessment paper should be taken at a single assessment event lasting two hours 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 taken at the end of the Unit.

Outcome 4

The assessment of this Outcome should take the form of a practical, laboratory assignment which can be carried out at a suitable time during the delivery of the Unit. The time that should be allocated in the laboratory for this assignment is 2 hours. However, learners should be allowed to complete the written report outwith the laboratory in their own study time. 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 learner's own work. Centres can choose to issue each learner with the same circuit or system to be constructed, or a different circuit or system to be constructed. If different circuits or systems are issued then each one must possess the same degree of difficulty.

Opportunities for 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 social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all learner evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. The most up-to-date guidance on the use of e-assessment to support SQA's qualifications is available at **www.sqa.org.uk/e-assessment**.

Opportunities for developing Core and other essential skills

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

- Written Communication (Reading) at SCQF level 6
- Written Communication (Writing) at SCQF level 6
- Using Graphical Information at SCQF level 6
- Critical Thinking at SCQF level 6
- Working with Others at SCQF level 4

History of changes to Unit

Version	Description of change	Date

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.

General information for learners

Unit title: Fundamentals of Control Systems and Transducers (SCQF level 7)

This section will help you decide whether this is the Unit for you by explaining what the Unit is about, what you should know or be able to do before you start, what you will need to do during the Unit and opportunities for further learning and employment.

A control system consists of a number of components (which can be electrical, mechanical, thermal or hydraulic) that act together to maintain a desired output in a process. Control systems are used extensively in industries such as oil refining, electrical generation, chemical processing, and manufacturing and production. Our homes and offices also use control systems to regulate temperature and air conditioning. This Unit has been designed to enable you to develop the necessary knowledge and skills so you to understand the structure and general behaviour of different types of control systems.

The Unit takes a non-mathematical approach to control systems. You will learn how to explain control system concepts, use block diagrams to model systems, and use graphical methods to describe their behaviour.

You will begin the Unit by learning about the types of component parts that make up control systems. You will also learn how information is transferred between the component parts by means of analogue and digital signals. You will discover that the operation of a control system is heavily influenced by its environment, and that the choice of equipment and signal types depends on the location of the system. The need for signal conditioning devices such as filters and amplifiers will be covered.

As you progress through the Unit, you will learn about different methods of controlling the output of a process. Basic methods such as open loop control will be covered. However, these have limitations and disadvantages. Therefore, you will learn about the need for closed loop control systems which have the facility to measure the output variable being controlled, so as to sense changes and enable corrective action to be taken to ensure that the output of the system is maintained at the desired value. Such control systems include temperature control and flow control of liquids. You will also develop knowledge and skills to enable you to understand how controllers can be used to modify the way open and closed loop control systems respond (with respect to speed of response, damping, and transient and steady state response).

Closed loop control systems incorporate devices called transducers. These accept energy in one form eg heat and produce output energy in some other form such as an electrical signal. You will study the operation and application of a range of transducers suitable for measuring variables such as temperature, flow, displacement, velocity, pressure, strain, position, level and light. In addition, you will have the opportunity to construct circuits and systems that incorporate transducers. You will measure the characteristics of transducers, and study the overall operation of the circuits and systems that you build.

By the end of this Unit you should possess the knowledge and skills to enable you to: explain control system elements and signals; explain the operation and application of a range of transducers; describe the structure and behaviour of control systems; and demonstrate the application of transducers in control systems.

The formal assessment for the Unit will consist of a both a written assessment paper lasting two hours and a laboratory assignment lasting two hours.

The written assessment paper will be conducted under closed-book conditions and you will **not** be allowed to take notes, textbooks etc into the assessment. You will sit this assessment paper at the end of the delivery of the Unit.

The laboratory assignment will require you to construct and demonstrate the operation of a circuit or system that incorporates a transducer. This will be carried out during a two hour laboratory session at a suitable time during the delivery of the Unit. On successful completion of the practical aspects of this assignment, you will be required to submit a written laboratory report.