## SQA Advanced Unit Specification

## General information for centres

**Unit title:** Continuous and Computer Control of Engineering Systems

**Unit code:** HV6E 48

**Unit purpose:** This Unit is designed to enable candidates to gain knowledge and understanding in predicting the response of industrial control systems and determining the parameters of controllers to suitably modify the response.

On completion of the Unit candidates should be able to:

1 Analyse control system block diagram models.
2 Analyse the transient and steady state time response of first and second order control systems.
3 Analyse the effect of two and three term controllers to control systems.
4 Explain the effects of sampling in a digital control system.
5 Analyse digital control system time response.
6 Analyse the effect of two and three term controllers in digital control systems.
7 Analyse frequency response methods of control systems.
8 Apply computer control to distributed control systems.

**Credit points and level:** 2 SQA Credit at SCQF level 8: (16 SCQF credit points at SCQF level 8*)

**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:** Access to this Unit will be at the discretion of the centre and the following recommendations are for guidance only. Candidates should have a wide knowledge of industrial measurement and control engineering. This could be evidenced by the possession of the following SQA Advanced Units: HV63 47 Distributed Control Systems, HV67 47 Measurement Systems 1, HT9X 47 Process Control, HV61 47 Complex Control Systems.

**Core Skills:** There are opportunities to develop the Core Skill(s) of Written Communication (Writing), Written Communication (Reading) and Problem Solving (Critical Thinking) at SCQF level 5 in this Unit, although there is no automatic certification of Core Skills or Core Skills components.

**Context for delivery:** 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.

**Assessment:** Outcomes 1, 2, 3, 4, 5, 6, 7 and 8 can be assessed separately by individual assessment papers lasting one hour for each Outcome.

Alternatively, Outcomes 1, 2, 3 and Outcomes 4, 5, 6 can be combined to form two assessment papers, each lasting 2 hours.

Alternatively, all eight Outcomes can be combined to form one assessment paper lasting no more than three hours.

The assessment papers should be composed of a balance of short answer, restricted response and structured questions. The assessments should be conducted under controlled supervised conditions.

The integrated assessment should be carried out towards the end of the Unit delivery.

Candidates must achieve all minimum evidence specification for each Outcome in order to pass the Unit.

# Unit specification: statement of standards

## Unit title: Continuous and Computer Control of Engineering Systems

## Unit code: HV6E 48

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

Analyse control system block diagram models

### Knowledge and/or skills

- Block diagram symbols and system models
- Systems with more than one input
- Systems with major and minor loops and their reduction

### Evidence Requirements

Candidates must provide a satisfactory response to all three knowledge and/or skills items by showing the candidate is able to:

- analyse series and parallel block arrangements and gain expressions or output, error and closed-loop gain in feedback systems
- analyse reduction techniques and systems with more than one input
- analyse systems with major and minor loops and their reduction including take-off point shift

Evidence should be generated through assessment undertaken in controlled supervised conditions.

### Assessment guidelines

Assessment should be conducted under closed-book conditions and as such candidates must not be allowed any textbooks, handouts or notes in the assessment.

Questions used to elicit candidate evidence may take the form of short answer, restricted response or structured questions.

This evidence can be assessed separately or integrated with Outcomes 2 and 3.

## Outcome 2

Analyse the transient and steady state time response of first and second order control systems

### Knowledge and/or skills

- First and second order proportional control systems
- Transient and steady state response of first and second order control systems
- Effect of proportional gain change

### Evidence Requirements

Candidates must provide a satisfactory response to all three knowledge and/or skills items by showing the candidate is able to:

- analyse transfer functions for closed-loop, error and output in terms of system input, forward gain and open-loop gain for first and second order systems using s-transform tables including the final value theorem
- analyse system output and error steady state and transient time response to standard inputs for first and second order proportional systems, including the use of the final value theorem
- explain the effect of gain changes on steady state and transient time response for first and second order systems

Evidence should be generated through assessment undertaken under controlled supervised conditions.

### Assessment guidelines

Assessments should be conducted under closed-book conditions and as such candidates must not be allowed to bring textbooks, handouts or notes to the assessment. A data sheet will be provided where relevant.

Questions used to elicit candidate evidence may take the form of short answer questions, restricted response and structured questions. This Outcome may be assessed separately or integrated with Outcomes 1 and 3.

## Outcome 3

Analyse the effect of two and three term controllers to control systems

### Knowledge and/or skills

- Controller gain, proportional band, integral action time, derivative action time
- Control loop time response
- Open and closed-loop controller tuning methods

### Evidence Requirements

Candidates must provide a satisfactory response to all three knowledge and/or skills items by showing the candidate is able to:

- apply gain, proportional band, integral action time and derivative action time to controllers with standard inputs
- analyse loop time responses with two and three term controllers to standard inputs using s-transform tables
- apply open and closed-loop controller tuning methods

Evidence should be generated through assessment undertaken under controlled supervised conditions.

### Assessment guidelines

Assessments should be conducted under closed-book conditions and as such candidates must not be allowed to bring textbooks, handouts or notes to the assessment. A data sheet will be provided where relevant.

Questions used to elicit candidate evidence may take the form of short answer questions, restricted response questions and structured questions. The Outcome may be assessed separately or integrated into Outcomes 1 and 2 and could include a practical on controller tuning.

## Outcome 4

Explain the effects of sampling in a digital control system

### Knowledge and/or skills

- Characteristics of sample and hold devices
- Shannon's sample theorem
- Aliasing and its effect

### Evidence Requirements

Candidates must provide a satisfactory response to all three knowledge and/or skills items by showing the candidate is able to:

- explain characteristics of sample and hold devices
- explain Shannon's sample theorem
- explain aliasing and its effect on sampled data

Evidence should be generated through assessment undertaken in controlled supervised conditions.

### Assessment Guidelines

Assessments should be conducted under closed-book conditions and as such candidates must not be allowed.

Questions used to elicit candidate evidence may take the form of short answer questions, restricted response and structured questions. The Outcome may be assessed separately or integrated with Outcome 5 and 6.

## Outcome 5

Analyse Digital Control System Time Response

### Knowledge and/or skills

- First and second order proportional control systems
- Transient and steady state response of first and second order systems
- System stability

### Evidence Requirements

Candidates must provide a satisfactory response to all three knowledge and/or skills items by showing the candidate is able to:

- analyse the transfer function for output, error and closed-loop gain in terms of system input, forward gain and open-loop gain for first and second order systems using z-transform tables
- analyse transient and steady state time domain response of digital proportional control systems to standard inputs using z-transform tables and long division, including the final value theorem and the effect of gain change on the time domain response
- analyse system stability as a function of open-loop gain and sample period and evaluate the sample period and/or the gain at the point of instability using the characteristic equation

Evidence should be generated through assessment undertaken in controlled supervised conditions.

### Assessment Guidelines

Assessment should be conducted under closed-book conditions and as such candidates must not be allowed to bring textbooks, handouts or notes to the assessment. A data sheet will be provided where necessary.

Questions used to elicit candidate evidence may take the form of short answer questions, restricted response and structured questions. The Outcome may be assessed separately or integrated with Outcome 4 and 6.

## Outcome 6

Analyse the effect of two and three term controllers in digital control systems

### Knowledge and/or skills

- Sample data controllers
- Transient and steady state time response
- Methods of controller tuning

### Evidence Requirements

Candidates must provide a satisfactory response to all three knowledge and/or skills items by showing the candidate is able to:

- apply z — transfer functions to standard two and three term controllers using rectangular and trapezoidal numerical integration
- analyse the effect of standard two and three term controllers on the transient and steady state sampled data output and error responses of digital control system performance
- apply methods of controller tuning in digital control systems

Evidence should be generated through assessment undertaken in controlled supervised conditions.

### Assessment Guidelines

Assessments should be conducted under closed-book conditions and as such candidates must not be allowed to bring textbooks, handouts or notes to the assessment. A data sheet will be provided where relevant.

Questions used to elicit candidate evidence may take the form of short answer questions, restricted response and structured questions. The Outcome may be assessed separately or integrated with Outcomes 4 and 5.

## Outcome 7

Analyse frequency response methods of control systems

### Knowledge and/or skills

- Frequency response function
- Polar charts
- Nicols charts and stability factors

### Evidence Requirements

Candidates must provide a satisfactory response to all three knowledge and/or skills items by showing the candidate is able to:

- apply frequency response functions using substitution $s = (j\omega)$ and $z = \cos\omega T + j\sin\omega T$
- construct open-loop loci on a Polar chart and estimate gain and phase margins
- analyse closed-loop data from Nicols chart and estimate maximum closed-loop gain, resonant frequency, bandwidth and gain/phase margins

Evidence should be generated through assessment undertaken in controlled supervised conditions.

### Assessment Guidelines

Assessment should be conducted under closed-book conditions and as such candidates must not be allowed to bring textbooks, handouts or notes into the assessment. Data sheets will be provided where relevant.

Questions used to elicit candidate evidence may take the form of short answer questions, restricted response and structured questions.

The Outcome may be assessed separately or integrated into an end of Unit assessment.

## Outcome 8

Apply computer control to distributed control systems

### Knowledge and/or skills

- Multi-loop input/output systems
- Control of multivariable systems
- Supervisory control systems

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 two out of three 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 two out of three knowledge and/or skills items is required each time the Outcome is assessed.

Candidates must provide a satisfactory response to all two items. When sampling takes place a candidate response can be judged satisfactory where evidence provided is sufficient to meet the requirement for each item by showing the candidate is able to:

- explain direct digital control in multi-loop input/output systems, interfacing and signal processing around the loop
- explain control of multivariable systems, system start-up, loop tuning, closed-loop operation and system shut down
- explain set point control/management to meet required specification

Evidence should be generated through assessment undertaken in controlled supervised conditions.

## Assessment Guidelines

Assessments should be conducted under closed-book conditions and as such candidates must not be allowed to bring textbooks, handouts or notes to the assessment.

Questions used to elicit candidate evidence may be take the form of short answer questions, restricted response questions or structured questions. The Outcome may be assessed separately or integrated into an end of Unit assessment.

## Administrative information

**Unit code:** HV6E 48

**Unit title:** Continuous and Computer Control of Engineering Systems

**Superclass category:** VE

**Original date of publication:** November 2017

**Version:** 01

**History of Changes:**

| Version | Description of change | Date |
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**Source:** SQA



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# Unit specification: support notes

## Unit title: Continuous and Computer Control of Engineering Systems

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 80 hours.

## Guidance on the content and context for this Unit

The Unit has been written in order to allow candidates to develop knowledge, understanding and skill in the following areas.

1 The analysis of block diagram models.
2 The analysis of transient and steady state time response of first and second order control systems.
3 The analysis of the effect of two and three term controllers to control systems.
4 The explanation and effect of sampling in a digital control system.
5 The analysis of digital control system time response.
6 The analysis of the effect of two and three term controllers in digital control systems.
7 The analysis of frequency response methods of control systems.
8 The application of computer control to distributed control systems.

The Unit is at SCQF level 8 and the Unit has been developed as part of the SQA Advanced Diploma in Measurement and Control Engineering Awards. However, this does not preclude the use of the Unit in other awards where award designers feel it is appropriate.

In designing this Unit, the 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 is done to assist lecturers to decide what depth of treatment should be given to the topics attached to each Outcome.

A list of topics for each Outcome is given below. Lecturers are advised to study the list in conjunction with the assessment exemplar pack so that they can get a clear indication of the standards of:

**Outcome 1**

**Analyse control system block diagram models (5 hours including assessment)**

- Symbols used — rectangular block, summing junction and take-off point. Gains of series and parallel block elements. Standard feedback models and expressions for output, error and closed-loop gain.
- Single loop system gains with more than one input.
- Feedback systems with major and minor loops and their reduction to expressions for output, error and closed-loop gain, including take-off point shift.

**Outcome 2**

**Analyse the transient and steady state time response of control systems (15 hours including assessment)**

- Use of s-form standard tables and standard system inputs — impulse, step and ramp. Transfer lag and time constant, s-form gain of first and second order transfer lags. Distance/velocity lag. System s-form gains for output, error and closed-loop of feedback proportional control system. Final value theorem.
- Use standard inputs and s-form tables to obtain the transient time domain and steady state response of first and second order proportional control systems. Use of final value theorem for steady state response. Use of inverse transform tables.
- Effect of gain change on transient and steady state response for proportional control systems ie initial rate of change, overshoot, time to first peak, damped frequency, settling time and steady state error.

**Outcome 3**

**Analyse the effect of two and three term controllers to control systems (10 hours including assessment)**

- Response of control mode to standard inputs. Define gain, proportional band, integral action time and Derivative action time.
- Standard s-form of two and three term controllers. The time domain response of first and second order systems with two and three term controllers.
- Estimation of controller constants from open and closed-loop methods of controller tuning.

**Outcome 4**

**Explain the effect of sampling in a digital control system (5 hours including assessment)**

- Sampler characteristics — sample period, sample rate. Sampler output — zero and first order hold devices.
- Sample Theorem — sampling of over damped, critically damped, underdamped and oscillatory signals. Sample period to ensure no information is lost.
- Aliasing — hidden element in the sample signal and information loss when sampling sinusoidal signals.

**Outcome 5**

**Analyse digital control system time response (15 hours including assessment)**

- Use of z-form standard tables and standard system inputs — impulse, step and ramp. Transfer lag and time constant, z-form gain of first and second order transfer lags. Distance/velocity lag. System z-form gains for output, error and closed-loop gain of feedback proportional control systems.
- Use of standard inputs and z-form standard tables to obtain the transient time domain and steady state response of first and second order proportional systems. Use final value theorem for steady state response. Determination of sampled data response via long division effect of gain changes on transient response.
- Characteristic equation $1+GH(z) =0$ and evaluation of sample period for point of instability ie $z = -1$

**Outcome 6**

**Analyse the effect of two and three term controllers in digital control systems (10 hours including assessment)**

- Use rectangular and trapezoidal numerical integration to determine the z-form of standard three term controllers.
- Inclusion of integral action to eliminate offset (steady state error) and modify transient response. Derivative action to affect overshoot and settling time.
- Open/closed-loop methods of controller tuning to include the effect of sample period and sample rate.

**Outcome 7**

**Analyse frequency response methods of control systems (12 hours including assessment)**

- Using the substitutions $s=j\omega$ and $z=\cos\omega T + \sin\omega T$ transform a system open-loop gain(s) and gain (z) respectively to the complex gain $G(j\omega)$
- Plot the complex open-loop gain $G(j\omega)$ on a Polar chart, determine the system stability and estimate the gain and phase margins.
- From the Nicols chart determine the system data ie stability condition in the closed-loop and gain/phase margins.
- From the Nicols chart plot closed-loop gain against frequency and determine the maximum closed-loop gain, resonant frequency and bandwidth.

**Outcome 8**

**Apply computer control to distributed control systems (8 Hours including assessment)**

- Interfacing and signal processing-types of inputs-4-20mA, mV (T/C), pulse and resistance(R/T) and 4-20mA outputs. Hart communications and Fieldbus input/outputs.
- Start-up/shut down of distributed systems, methods of loop tuning in sample data systems and closed-loop operation (auto/manual) changeovers.
- Management of set points for quality operation of plant. Methods set point optimisation.

## Guidance on the delivery and assessment of this unit

This Unit is a mandatory Unit in the SQA Advanced Diploma in Measurement and Control Engineering Group Award and is designed to provide the candidate with technical knowledge and skills in the principles, behaviour, stability and time domain response of analogue, sample data and distributed control systems.

In these circumstances the Unit is likely to be delivered at the beginning of the SQA Advanced Diploma (second year) programme.

Assessments should be conducted under controlled, supervised conditions and candidates may not bring textbooks, handouts or any material prepared by themselves.

Delivery can be supported where relevant by practical activities.

***Opportunities for developing Core Skills***

There are opportunities to develop the Core Skills of Written Communication (Writing), Written Communication (Reading) and Problem Solving (Critical Thinking) at SCQF level 5 in this Unit, although there is no automatic certification of Core Skills or Core Skill components.

## Open learning

This Unit could be delivered by distance learning, which may incorporate some degree of on-line support. 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 assessments were conducted under controlled, supervised conditions. For information on open learning, please refer to *SQA guide assessment and quality assurance of open and distance learning (A1030, Feb 2001).*

## 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: Continuous and Computer Control of Engineering Systems

This Unit has been designed to provide you with knowledge, understanding and skills in the principles of continuous, sample data and distributed control systems which is the basis of all modern process control.

The early part of the Unit deals with block diagrams and the time domain response of analogue control systems with PID control. The rest of the Unit deals with the time domain response and stability of sample data control systems and the generation of PID control in computer based distributed systems.

By the end of the Unit you will understand how continuous and sample data control systems function and behave and their application to process control.

The assessment can be carried out at the end of the Unit or alternatively on an Outcome by Outcome basis.