SQA Advanced Unit Specification

General information for centres

Unit title: Applications of Signal Processing and Conditioning

Unit code: HP3F 48

Unit purpose: This Unit is designed to give candidates knowledge and understanding and apply a number of signal processing techniques to the solution of filtering and control problems for implementation on a digital signal processor (DSP), microprocessor, or microcontroller based system. Outcome 1 has been written to introduce the principles of sampling and reconstruction, and through practical experiment deduce the requirement for anti-aliasing and reconstruction filters. Outcome 2 then introduces a variety of approaches to digital filtering, and includes integration and differentiation which are required later. Outcome 3 applies signal processing techniques to three term control.

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

1. Demonstrate an understanding of the process of signal sampling and its limitations
2. Design, implement and test a digital filter to give a specified frequency response
3. Design, implement and test 3-term control software for closed loop of a system

Credit value: 1 SQA Credit at SCQF level 8: (8 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: Candidates should have a basic knowledge and understanding of computer programming. This may be evidenced by possession of one of the following SQA Advanced Units, High Level Engineering Software or MCU/MPU Assembly Language Programming. The centre may elect to take advantage of various computer packages and IT applications, in which case possession of D75X 35: Information Technology: Applications Software 1 will also prove useful.

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

Context for delivery: This Unit was developed for the SQA Advanced Diploma in Electronics award. If this Unit is used in another group award(s) it is recommended that it

should be taught and assessed within the context of the particular group award(s) to which it contributes.

Assessment: It is recommended that this Unit is assessed on an Outcome by Outcome basis, although centres may find it advantageous to combine teaching of the Unit with that of High Level Language: External I/O Transfer and High Level Engineering Software.

It is recommended that assessment takes the form of laboratory experiment, followed up by a written report. Centres should supply candidates with guidelines on the necessary standard of documentation. Practical exercises should be undertaken under controlled, supervised conditions. Candidates should submit written reports within 14 days of the practical work being completed.

Centres should take every reasonable effort to ensure that reports are the candidates' own work. It may be possible to issue each candidate with a slightly different specification, or alternatively where there is a suspicion of copying or plagiarism, an appropriate response may be to interview candidates. A check list may be used to record oral evidence of the candidates' understanding.

Unit specification: statement of standards

Unit title: Applications of Signal Processing and Conditioning

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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

Demonstrate an understanding of the process of signal sampling and its limitations.

Knowledge and/or skills

- Use of computer software to utilise analogue to digital and digital to analogue converters to sample and reconstruct a signal
- Design, construction and test of reconstruction filters
- Design, construction and test of anti-aliasing filters

Evidence requirements

All parts of the knowledge and skills listed above shall be assessed. Evidence will be provided in the form of a written report. The candidate's response will be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

- operate or simulate computer software to sample a signal using an analogue to digital (A/D) converter and reconstruct it with a digital to analogue (D/A) converter.
- record output of a system for an appropriate range of input signals
- demonstrate the requirement for a reconstruction filter
- design, construct, and test a reconstruction filter
- demonstrate the requirement for an anti-aliasing filter
- design, construct, and test an anti-aliasing filter
- write a report which includes the following:
  - a listing of the program used
  - details of test signals and outputs
  - circuit diagrams of filters
  - comparisons of results with and without anti-aliasing filter
  - conclusions

There is no requirement for candidates to write software from scratch. They may be permitted to combine elements of existing programmes, or adapt them to, for example, a different sampling rate or signal source.

Assessment guidelines

Centres are recommended to develop appropriate checklists to support the assessment requirements for each of the knowledge and skills items. Centres are also recommended to produce a marking schedule indicating clearly the required content of the report. Candidates who do not meet the standard should be obliged to correct and resubmit their work.

Outcome 2

Design, implement and test a digital filter to give a specified frequency response.

Knowledge and/or skills

- Frequency response of low pass, high pass, band pass, and band stop filters
- Frequency response of differentiators and integrators
- Impulse response of low pass and high pass filters
- Derivation of finite impulse response (FIR) coefficients from impulse response
- Derivation of infinite impulse response (IIR) coefficients
- Implementation of differentiators and integrators

Evidence requirements

Evidence for the knowledge and skills listed above shall be assessed on a sample basis. Two filters from the list above must be implemented, one as an FIR filter and the other as IIR. Evidence will be presented in the form of a written report. The candidate's response will be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

- determine suitable FIR coefficients for a filter to meet a given specification
- determine suitable IIR coefficients for a filter to meet a given specification
- design and construct filters using these coefficients
- record output of the filter for an appropriate range of input signals
- implement an integrator or differentiator and record its output for a range of input signals
- write a report which includes the following:
  - a listing of the programme used
  - a description of the process by which the filter coefficients were determined
  - details of test signals and outputs
  - circuit diagrams of filters
  - comparisons of results with and without anti-aliasing filter
  - conclusions

The candidate should be issued with a specification for an FIR filter selected from the list in the knowledge and skills section above. The IIR filter should be of a different type. Where candidates are unable to complete the Outcome and need to be reassessed, the specifications should be different each time.

There is no requirement for candidates to write software from scratch. They may be permitted to combine elements of existing programmes, or adapt them to, for example, a different sampling rate or signal source. Similarly, candidates should be permitted to apply suitable software packages to determine filter coefficients, rather than calculate them from first principles. Candidates are not required to perform mathematical calculations manually, for example in the derivation of FIR coefficients.

Assessment guidelines

Centres are recommended to develop appropriate checklists to support the assessment requirements for each of the knowledge and skills items. Centres are also recommended to produce a marking schedule indicating clearly the required content of the report. Candidates who do not meet the standard should be obliged to correct and resubmit their work.

Outcome 3

Design, implement and test 3-term control software for closed loop of a system.

Knowledge and/or skills

- Effect of proportional, integral, and derivative terms in 3-term control
- Simulation of system under closed loop control
- Testing a 3-term control system
- Tuning a 3-term control system

Evidence requirements

All parts of the knowledge and skills listed above shall be assessed. Evidence will be provided in the form of a written report. The candidate's response will be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

- simulate a system under closed loop control
- write software to control a system using 3 term control
- record the output of the control system for an appropriate range of test inputs
- tune their control system to improve its performance
- record the output of the control after tuning
- write a report which includes the following:
  - results of simulation exercise
  - a listing of the programme used
  - details of test procedures and results
  - comparisons of results before and after tuning
  - conclusions

There is no requirement for candidates to write software from scratch. They may be permitted to combine elements of existing programmes, or adapt them to, for example, different systems parameters or desired closed loop response. Control theory is not a part of this Unit, so candidates may be permitted to tune their control programmes by trial and error.

Assessment guidelines

Centres are recommended to develop appropriate checklists to support the assessment requirements for each of the knowledge and skills items. Centres are also recommended to produce a marking schedule indicating clearly the required content of the report. Candidates who do not meet the standard should be obliged to correct and resubmit their work.

Administrative information

Unit code: HP3F 48

Unit title: Applications of Signal Processing and Conditioning

Superclass category: XL

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

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

Unit specification: support notes

Unit title: Applications of Signal Processing and Conditioning

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

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

Guidance on the content and context for this Unit

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

(1) the process of signal sampling and reconstruction
(2) requirement for anti-aliasing and reconstruction filters
(3) the design, implementation and test of digital filters
(4) the design, implementation and test of 3-term control software for closed loop control of a system

This Unit was designed to permit successful candidates to apply signal processing skills to engineering solutions. The emphasis should be on practical application of theory, rather than on mathematical theorems and their derivation.

For example, the lecturer may wish to supply a spreadsheet or program which calculates filter coefficients given the sample rate, breakpoint, and number of filter taps. Applications packages are available for this purpose, but this Unit does not specify particular programmes so as not to place unnecessary demands on centres.

Similarly, for a control system the candidate may be issued with initial values for control parameters and then be asked to tune the system by trial and error. Alternatively, a control simulation package may be used to determine suitable system behaviour if required.

This Unit was developed as one of four SQA Advanced Diploma options and is at SCQF level 8. Successful completion of this Unit will depend on the candidate's IT skills, and programming ability may also be required. It is anticipated that centres will choose to use either a high level language or assembly language depending on which programming options were offered at level 7. Centres will need to bear this in mind, and may need to offer bridging material to those students who have not elected to take the appropriate level 7 option.

In designing this Unit the Unit writers have identified the topics they would expect to be covered by lecturers. The writers have 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 a centre to use this list of topics it is strongly recommended that they do so to ensure continuity of teaching and learning across the Engineering Computing group of Units.

A list of topics is given below. Lecturers are advised to study this so they can get a clear indication of the standard of achievement expected of candidates taking this Unit.

Outcome 1
Demonstrate an understanding of the process of signal sampling and its limitations (10 hours)

- Computer software to utilise analogue to digital and digital to analogue converters to sample and reconstruct a signal
- Reconstruction filters
- Aliasing
- Anti-aliasing filters

Areas for experimental work may include:

- Construction and test of software
- Investigation of requirement for low pass reconstruction filter by examining output
- Design, construction and test of reconstruction filter
- Investigation of aliasing, its causes and effects
- Design, construction and test of anti-aliasing filter

Outcome 2
Design, implement and test a digital filter to give a specified frequency response (20 hours)

- Frequency responses
- Desired filter properties — low pass, high pass, band pass, band stop, differentiation and integration
- Impulse response of low pass and high pass filters
- Deriving FIR coefficients from impulse response
- Derivation of IIR coefficients
- Differentiators and integrators

Areas for experimental work may include:

- Use of computer packages for calculating filter coefficients
- Computer simulation of filter behaviour
- Building digital filters and measuring frequency response

Outcome 3
Design, implement and test 3-term control software for closed loop of a system (10 hours)

- Effect of P, I and D terms in 3-term control
- Simulation of system under closed loop control
- Testing a 3-term control system
- Tuning a 3-term control system

Areas for experimental work may include:

- Simulation of a control system
- Testing control system with actual hardware
- Adjusting P, I and D terms and recording the effect

Guidance on the delivery and assessment of this Unit

It should be noted that this Unit can be delivered on a free standing basis, or combined with one or more Engineering Programming Units. This provides course planners with the flexibility to keep Units separate or combine them for teaching and learning and assessment purposes. It may, for example, be possible to make more efficient use of time by using signal processing examples in a programming class.

It is appreciated that centres will have access to a limited range of computer hardware and software. The Unit has been written in such a way that the choice of computer packages and hardware has been left open for the centre. Simulations could be performed using spreadsheets, a maths package, a control simulation package, or by writing a programme in a high level language.

Filtering programmes could be implemented in high level language or assembly language, using a DSP, microcontroller or PC, although lecturers should be aware that some operating systems intercept calls to input/output devices and interrupt user programs, leading to technical difficulties which may hinder candidate learning.

It is recommended that lecturers supply candidates with pre-written code where appropriate, and require candidates only to calculate filter coefficients and modify existing programmes. The emphasis of this Unit is on designing signal processing software based on specifications, rather than writing computer programmes from scratch.

It is recommended that this Unit be delivered towards the end of the SQA Advanced Diploma in Electronics award, as extensive numeracy, IT and programming skills are required. Mathematics for Engineering 3 covers Fourier series, which candidates may find helpful for parts of this Unit, but theoretical justification of the methods used in signal processing is not necessary for this Unit.

Open learning

Due to the practical content of this Unit it is unsuitable for open or distance learning.

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

Equality and inclusion

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

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

General information for candidates

Unit title: Applications of Signal Processing and Conditioning

Signal processing is used in a wide variety of applications – mobile phones, digital cameras, medical imaging, etc.

The purpose of this Unit is to give you the ability to apply signal processing knowledge to engineering systems. Although the mathematical basis of these tools is quite complex, there is no need to fully understand the theory. A wide selection of computer packages is available to simplify the process by performing the mathematics for you. By comparison, implementing digital filters is a simple process.

You will have the opportunity to study at first hand the sampling and reconstruction process at the heart of many digital systems, followed by experimenting with a variety of filtering applications, and finally applying signal processing to a control problem.

These three parts of this Unit will be assessed mostly by laboratory reports. The lecturer will also be completing check lists to ensure that you have completed all necessary parts of the exercises. You may also be required to submit to brief oral examination to ensure that the work you have submitted is your own and that you fully understand the material.

The centre where you are studying may choose to combine this Unit with Engineering Programming Units such as High Level Language: External I/O Transfer and MCU/MPU I/O Hardware Control. This will have the benefit of reducing the amount of assessment you have to undertake. It will be the responsibility of the centre to ensure that all parts of the Unit are still covered.