Unit 46: Principles and Applications of Engineering Measurement Systems

Unit code: J/600/0322

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to give learners the knowledge and skills they need to carry out measurement and testing in engineered systems.

Unit introduction

There is now a wide range of systems and methods used to measure performance and operations within engineered systems.

This unit is designed to develop learners' knowledge and understanding of the use of measurement and testing in engineered systems whilst providing them with opportunities to explore both traditional and modern methods. The unit explains the physical principles used in transducers and shows the way that these principles are exploited in practice across a range of industrial measurement applications.

The selection of correct measurement systems is key to the optimum performance and operation of an industrial plant. The unit gives learners an insight into the main elements of a measurement system and shows how these elements working together provide a required function.

The unit describes recording and display devices and their operational characteristics, so that learners will be able to use and make informed choices between similar devices on technical grounds. Modern display and recording techniques are discussed and learners' are given the opportunity to use and design virtual instrumentation systems using computer software.

Learning outcomes

On completion of this unit a learner should:

1   Know about the applications of common measurement systems

2   Understand the operation of measurement system components

3   Be able to use testing, recording and display equipment for a measurement application

4   Be able to test and calibrate a measuring system

Unit content

1 Know about the applications of common measurement systems

Main purpose of measurement: producing or obtaining data; carrying out inspection and testing; monitoring health and safety; checking outputs eg meeting specifications, quality control, condition monitoring; controlling processes; carrying out statistical analysis

Measurement system elements: block diagrams; elements eg transducers, signal conversions, signal conditioning, recording and display, transmission links; common measurement systems eg pressure transmitter, level transmitter, temperature transmitter, flow transmitter

Measurement system performance: performance terms eg accuracy, error, linearity, reliability, repeatability, sensitivity, resolution, range, transfer function, static and dynamic characteristics, electrical noise, calibration

2 Understand the operation of measurement system components

Transducer types: output of common measurement transducers eg temperature, pressure, flow, level, vibration, weight, displacement; physical principles eg resistive, capacitive, piezo-electric, inductive, opto-reflective, static pressure, elasticity

Signal converters: conversion process eg voltage to current, pressure to current, current to pressure, frequency to voltage, analogue to digital (ADC), digital to analogue (DAC); signal converter types eg Wheatstone bridge, V/I converter, P/I converter, I/P converter, F/V converter, ADC, DAC

Signal processors: types eg voltage and current amplifiers, mechanical amplifiers, simple signal filters, multiplexers, decoders; specification requirements eg voltage amplitude, current amplitude, signal frequency, noise reduction

3 Be able to use test, recording and display equipment for a measurement application

Test equipment: electrical/mechanical types eg multimeters, handheld oscilloscope, signal generator, logic testers, earth loop impedance meter, pressure injector, 4-20mA loop calibrators, insulation tester, optical alignment; safety; functions and operation; specification eg output, input, range of operation, resolution

Recording and display devices: computer elements in monitoring and recording eg data acquisition, interface cards, software; specification eg acquisition speed, resolution, input type; plotters and chart recorders

Virtual instrumentation: software available eg NI LabVIEW, Visual Basic, Discovery; mimics; trending; alarms

4 Be able to test and calibrate a measuring system

Test and calibrate: calibration of measurement equipment eg pressure, level, temperature, flow, nucleonic, position, speed; calibration parameters (component specification, system requirements)

System specification and function: measurement system specifications; characteristics and limitations of measuring systems eg operating range, environment

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:	To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:
P1 describe the main purpose of measurement	M1 design a common measurement system, confirming that it meets a customer's requirement specification	D1 evaluate the performance of a given common measurement system.
P2 use block diagrams to help describe the main elements within three given common measurement systems	M2 design a graphic display for a system using a given software package.	
P3 describe the performance of a given common measurement system		
P4 explain the operation of three different types of transducer in terms of their physical principles		
P5 describe the conversion process that takes place within three given signal converters		
P6 select a signal processor to meet a given specification		
P7 use appropriate test equipment to test the function and operation of a common measurement system against specification [IE1]		
P8 identify an appropriate recording or display device to meet a given specification		

Assessment and grading criteria

To achieve a pass grade the evidence must show that the learner is able to:	To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:	To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:
P9 use virtual instrumentation software to mimic a measurement system in terms of recording, displaying and trending an output from a given measurement system		
P10 test and calibrate a given common measurement system to meet the requirements of the system specification, ensuring its performance limitations are not exceeded. [IE1]		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

This unit may be delivered as a stand-alone unit or integrated with others in the qualification. Wherever possible, a practical approach should be adopted in which the underpinning knowledge is consolidated using practical workshop investigations and demonstrations.

It is expected that learners will have access to industrial standard process rigs and measurement systems or educational equivalents. Practical workshop activities should be used extensively to ensure that learners have experience of industrial standard measurement equipment and measurement methods.

It is important that learners are given opportunities to use computer software that enables them to explore modern measurement techniques and to develop bespoke measurement solutions.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • introduction to unit, scheme of work and assessment • introduce and explain the main purpose of measurement in relation to engineering • explain and demonstrate the main measurement system elements and common measurement systems • introduce and explain the main performance terms for measurement systems.
Whole-class teaching: • introduce transducer types and explain the output of common measurement transducers and their physical principles • explain and demonstrate the process of signal conversion and the operation of a range of types of signal converters • explain and demonstrate the use of a range of signal processors to meet specification requirements. *Practical workshop activities:* • investigate the function and operation of a range transducers, signal converters and signal processors.
Preparation for and carrying out **Assignment 1: Measurement Systems and System Components** (P1, P2, P3, P4, P5, P6, M1 and D1)

Topic and suggested assignments/activities and/assessment
Whole-class teaching/workshop demonstration: • explain the correct safety procedures that need to be followed when working with test equipment • explain and demonstrate the function, operation and use of a range of electrical/mechanical types of test equipment • explain and demonstrate the use computer elements in monitoring and recording • explain and demonstrate the use of instrumentation software.   *Practical workshop activities:* • practise use of test equipment, recording and display devices and virtual instrumentation software for a measurement application.   *Industrial visit:* • visit to local company to view process rigs and measuring systems in an industrial setting.
Preparation for and carrying out **Assignment 2: Testing and Calibrating Measurement Systems** (P7 and P10)
Whole-class teaching/workshop demonstration: • explain and demonstrate the calibration of measurement equipment to meet system specification.   *Practical workshop activities:* • practise calibration of measuring equipment to meet parameters.
Preparation for and carrying out **Assignment 3: Recording and Display Equipment** (P8, P9 and M2)
Feedback, unit evaluation and close.

Assessment

Assessment evidence for the first six pass criteria (P1–P6) could be produced through a written assignment. After describing the various purposes of measurement systems (P1), learners could be asked to describe the main elements of three different measurement systems using block diagrams (P2), given manufacturers' data sheets for each of the given systems.

The block diagram could provide learners with a basis to explain, select and describe the functionality and performance of the transducer, signal converter and signal processor elements (P3, P4, P5 and P6). The assignment must include reference to common performance terminology.

A practical workshop assessment could be used to assess pass criteria P7 and P10. Firstly, learners could be provided with a measurement system and data sheets. They could then be provided with details of the required output tests that must be carried out to ensure it can be checked for function and operation. Learners will need to select an appropriate test instrument that meets the test requirements, and perform the test(s). A written report could be produced presenting the results clearly with appropriate conclusions. A witness statement/observation record could be used to confirm the safe use of the test equipment for P7 and that testing and calibration was carried out successfully (P10).

The final assessment could be a combined practical and written assignment which asks learners to use a computer with previously produced screen mimics and interfaces to record and display data from the output of a measurement system (P9). Learners could then be asked to compare this display/recording/trending system with alternatives, select an alternative and provide reasons for the selection (P8).

Assessment evidence for M1 is likely to be an extension to the assignment covering pass criteria P1-P6. Learners could be asked to design a new measurement system (block diagram form may be sensible) to meet a given measurement specification. The specification will need to include a transducer, a signal converter and a signal processor. This type of activity could be supported through simulation software to confirm that the specification has been met.

Assessment evidence for M2 could be achieved through an extension to the assignment covering criteria P8 and P9. Learners will need to be provided with a computer interfaced to the previous measurement system. They could then be asked to design a software graphic, input the measured data and display in an appropriate form to meet a given specification.

Assessment evidence for D1 could be achieved through an extension of the assignment covering criteria P1-P6 and M1. Learners could be asked to evaluate the performance of a measurement system that is measuring a variable within an industrial process plant. This evaluation will consider the operation and performance of the system. Learners could be asked to suggest improvements to the system or suggest an alternative, having identified and discussed advantages and limitations.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, P4, P5, P6, M1, D1	Measurement Systems and System Components	Learners need to produce an information booklet detailing the purpose of measurement and the function of the main elements within a measurement system.	A written assignment including a task requiring learners to describe the purpose of measurement and a series of descriptions, based on block diagrams, of the main elements within a measurement system.
P7, P10	Testing and Calibrating Measurement Systems	Learners need to use suitable equipment to test and calibrate a measurement system.	A practical assignment supported by observation records and a written report in which learners select equipment, perform tests to meet requirements and calibrate a measurement system.
P8, P9, M2	Recording and Display Equipment	Learners need to record and display data from a measurement system and write a report comparing the system used with alternatives.	A mixed practical and written assignment. Learners are to use a computer with previously produced screen mimics and interfaces to record and display data from the output of a measurement system. They should then compare this display/recording/trending system with alternatives and select an alternative.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with the following unit titles in the Engineering suite:

Level 1	Level 2	Level 3
		Industrial Process Measurement
		Industrial Plant and Process Control

The unit can also contribute skills, knowledge and understanding towards the evidence requirements in several units of the following Level 3 NVQ qualifications:

● Level 3 NVQ in Engineering Maintenance – Unit 40: Maintaining Instrumentation and Control Systems

● Level 3 NVQ in Installation and Commissioning – Unit 24: Commissioning Instrumentation and Control Equipment and Systems.

Essential resources

Process rigs and associated measurement and test equipment are essential for the delivery and assessment of much this unit. Learners should have access to relevant workshop or laboratory facilities including:

● process plant or system simulators

● measurement and data acquisition software

● measurement and data acquisition hardware (PCs and interface cards)

● data books and manufacturers' specifications

● measurement and test equipment manuals

● appropriate tools.

Employer engagement and vocational contexts

This unit should be delivered and assessed in a vocational context. Much of the practical work can be set in the context of learners' work placements or be based on local employers. Further information on employer engagement is available from the organisations listed below:

● Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI, University of Warwick) – www.warwick.ac.uk/wie/cei

● Learning and Skills Network – www.vocationallearning.org.uk

● Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk

● National Education and Business Partnership Network – www.nebpn.org

● Local, regional Business links – www.businesslink.gov.uk

● Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbook

Bolton W – *Instrumentation and Control Systems* (Newnes, 2004) ISBN 0750664320

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are …
Independent enquirers	identifying questions to answer when choosing appropriate test equipment and problems to resolve when calibrating measuring equipment.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are …
Creative thinkers	generating ideas and exploring possibilities when designing a common measurement system
Reflective learners	setting goals with success criteria for their development and work
Self-managers	organising time and resources and prioritising actions.

Functional Skills – Level 2

Skill	When learners are …
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	using computer systems and virtual instrumentation software to mimic a measurement system designing a graphic display for a system using a given software package
ICT – Find and select information	
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	selecting and using information when researching the different elements of a measurement system
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating the different elements of a measurement system
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing the performance, function and operation of measurement systems.