

Unit 53: Electronic Measurement and Testing

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| Unit code: | Y/600/0373 |
| QCF Level 3: | BTEC Nationals |
| Credit value: | 10 |
| Guided learning hours: | 60 |

● Aim and purpose

This unit will give learners the knowledge and skills needed to carry out a range of measurements on electronic circuits and equipment.

● Unit introduction

Practical electronic engineering demands the extensive use of electronic test equipment and measurement techniques. These range from basic measurements of parameters such as voltage, current and resistance to highly sophisticated software-controlled measurements based on advanced mathematical techniques such as Fast Fourier Transformation (FFT).

This unit will give learners an understanding of a variety of electronic measurement equipment such as voltmeters, ammeters, analogue/digital multimeters and oscilloscopes. The unit also examines a range of electronic test equipment such as signal generators, digital counter/frequency meter, alternating current (AC) bridge, logic probe, logic pulser and current tracer.

Learners will develop an understanding of the function, features and characteristics of electronic measurement and test equipment. They will also gain practical experience of their use when carrying out electronic testing and measurements in a wide range of electronic engineering applications. This will include selecting, connecting and operating different types of test equipment and applying measurement techniques.

Learners will demonstrate that they can apply common testing methods and be able to assess errors inherent in the instruments used. Particular attention is paid to ensure that the test procedure, as well as the test and measurement equipment used is fit-for-purpose and properly calibrated. Learners will be expected to explain the effects of instrument characteristics such as accuracy, display resolution and loading and how these affect the measured quantity.

Finally, learners will be introduced to the use of virtual test instruments and software to make measurements and analyse measurement data. They will examine equipment such as a digital storage oscilloscope, spectrum analyser, digital voltmeter, digital frequency meter, arbitrary waveform generator or logic analyser. Learners will be expected to make measurements using virtual instruments and analyse the captured data using appropriate software.

● Learning outcomes

On completion of this unit a learner should:

- 1 Know the function, features and characteristics of electronic measurement and test equipment
- 2 Be able to select and use electronic measurement and test equipment to make meaningful measurements on an electronic circuit
- 3 Know the principles of calibration and configuration of electronic test equipment
- 4 Be able to select and use virtual test instruments and software to make measurements and analyse measurement data.

Unit content

1 Know the function, features and characteristics of electronic measurement and test equipment

Function of equipment: as appropriate to the measurement and test equipment eg accurate measurement of alternating current (AC) and direct current (DC) voltage and current, resistance, waveform and distortion measurement, accurate measurement of waveform parameters (period, duty cycle, on-time, off-time, rise time, fall time, frequency, pulse repetition frequency (PRF), impedance, logic level)

Features of equipment: as appropriate to the measurement and test equipment eg displays and display technology, input and output connectors, attenuators, manual and automatic range selection (auto ranging), in-built calibration facilities, portability, power sources, external bus interfaces

Characteristics of equipment: measurement and test equipment specifications eg input impedance, output impedance, resolution, accuracy, distortion, bandwidth, input signal range, output level, sample rate, trigger sources

Measurement instruments: meters (voltmeter, ammeter); analogue/digital multimeter; oscilloscope

Electronic test equipment: signal generator eg audio frequency (AF), radio frequency (RF) and pulse generators, waveform/function generators; digital counter/frequency meter; AC bridge; logic probe; logic pulser; current tracer

2 Be able to select and use electronic measurement and test equipment to make meaningful measurements on an electronic circuit

Selection of equipment: selection based on instrument specifications, characteristics and limitations eg output, level, input sensitivity, frequency range, accuracy, resolution and distortion

Measurement techniques: test-point voltage and waveform measurement; supply voltage and current measurement; power, impedance and phase angle measurement using variable loads; frequency and PRF measurement; rise and fall time measurement; distortion and noise measurement (qualitative only); use of test specifications eg in the case of a variable DC power supply, measurement of the actual output voltage delivered at a specified load current when the power supply has been set to a specified voltage under no-load conditions; in the case of an audio amplifier, measurement of the output power delivered to an externally connected load of specified resistance, using a specified test frequency and waveform and at a specified level of distortion

Measurements: use of test points, test leads and probes; minimisation of loading effects; use of appropriate instrument ranges; precautions to be taken when measuring high voltages and currents; effect of DC levels on AC signals and waveforms; effect of signals present at DC test points; effect of drift and temperature; need for calibration; relevant test specification and measurement techniques eg sampling, averaging

Electronic equipment: industrial/consumer electrical and electronic equipment including low-voltage DC power supplies eg linear, switched-mode types; amplifiers eg AF, RF, small-signal, power; oscillators eg sinusoidal, square wave, crystal controlled; radio equipment eg radio receivers, low-power transmitters and transceivers; digital electronic equipment eg microcontrollers, microcomputers, programmable logic controllers; video equipment eg television and video players/recorders

3 Know the principles of calibration and configuration of electronic test equipment

Calibration principles: procedures eg check, adjust, systematically standardise measuring instrument, set-up arrangement; reference standards eg Weston cadmium standard cell, standard resistors, standard inductor; theory eg accuracy, uncertainty; impact of calibration on quality, productivity and safety; applications eg during manufacture, following installation, periodic scheduled maintenance, in response to identified deviation, after repair or change in environment; terminology eg zero shift, range (or span) error, combined zero shift and range error, non-linearity

Health and safety issues: eg precautions to be observed when setting and adjusting mains supply voltages, replacing/charging/disposing of batteries, dismantling and reassembling equipment, removal/replacement of external and internal covers, making adjustments on 'live' equipment, continuity of earth (grounding or bonding) of electrical equipment, safety cut-outs and residual current device (RCD), earth leakage circuit breaker (ELCB)

Configuration issues: pre-conditions and checks to ensure that system/equipment is safe to test and instruments safe to use; test equipment set-up eg use of the equipment manufacturer's procedures, using commissioning guides

4 Be able to select and use virtual test instruments and software to make measurements and analyse measurement data

Virtual measurement and test system: eg digital storage oscilloscope, spectrum analyser, digital voltmeter, digital frequency meter, arbitrary waveform generator, logic analyser

Measurement techniques, connection, hardware and software: tests carried out on electronic equipment using virtual test and measuring instruments; instrument connection eg external/internal PC interface, instrument connection standards (parallel port, serial port, USB, PCI/PXI bus, IEEE-488, PCMCIA); use of hardware and software to carry out measurements eg voltage, frequency, frequency spectra measurements (for sinusoidal and non-sinusoidal waveforms); measurement software, data storage and data transfer eg to a spreadsheet, automated measurement/data collection techniques

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 function, features and characteristics of a measurement instrument | M1 explain the importance of resolution, accuracy, sensitivity bandwidth and input impedance on the performance of a piece of test equipment | D1 evaluate the accuracy of own test measurements and relate them to limitations of the test equipment, test procedures, or possible emerging fault conditions |
| P2 describe the function, features and characteristics of three different pieces of electronic test equipment | M2 use a manufacturer's recommended procedure together with laboratory instruments and standards to calibrate and configure an item of electronic test equipment | D2 devise and demonstrate a calibration procedure for an item of electronic test equipment. |
| P3 select and use test equipment and measuring techniques to take measurements from three different pieces of electronic equipment [IE1, SM2, SM3] | M3 use appropriate software to display and analyse voltage/ time data captured from a virtual oscilloscope. | |
| P4 explain the importance of test specifications as an aid to ensuring the validity and consistency of measurements | | |
| P5 describe the principles and need for the calibration of an item of electronic test equipment | | |
| P6 describe the health, safety and configuration issues that need to be considered when connecting test equipment to an item of electronic equipment that requires testing | | |

| 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: |
| P7 use a virtual measurement and test system to carry out a test on a piece of electronic equipment [IE1, SM2, SM3] | | |
| P8 describe the measurement techniques, instrument connection, hardware and software used. | | |

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.

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

Delivery

Delivery of this unit should concentrate on the practical application of electronic measurement and testing of electronic equipment and systems. Learners should be introduced to the applications of various types of test equipment by using them to make measurements on laboratory made-up circuits or rigs. It is important to note that, in the context of this unit, the term 'electronic test equipment' includes instruments for making measurements (such as voltmeters) as well as instruments that provide standard inputs for electronic circuits (such as signal generators).

It is expected that learners will already have a working knowledge of most of the measurement instruments covered by this unit (voltmeter, ammeter, analogue/digital multimeters, oscilloscope). If this is the case then more time can be spent on the other aspects of the unit. However, it is appreciated that some learners may not have this experience and tutors will need to make allowances for this in their delivery planning.

Proper equipment calibration processes should be emphasised throughout delivery. Learners should refer to calibration standards and standard signal sources and explain how they are used in the calibration process. They should also appreciate that an instrument's calibration is only as accurate as the calibration of the reference standards used.

Learners should be given opportunities to select and correctly use as many of the types of test equipment listed in the content as possible, and make decisions on the measuring techniques to be applied. It is also important that learners experience as wide a range of available instrument functions and ranges as possible. As a result, it is important to allocate sufficient hands-on time in order to develop the relevant skills and understanding.

Ideally measurements will be made on real electronic or electronically controlled systems/equipment. Examples might be power supplies, consumer electronic equipment (such as video and audio equipment), computers and peripheral devices, radio receivers and transceivers, power controllers, programmable logic controllers etc. The type of equipment used could be chosen to meet local industrial requirements. All measurements and test results should be recorded in an appropriate logbook.

Due to the hazardous nature of equipment operated from an AC mains supply and the presence of high voltages in certain types of equipment, attention must be given to health and safety arrangements throughout the delivery of this unit.

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 |
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| <p><i>Whole class teaching:</i></p> <ul style="list-style-type: none">• introduction to unit, scheme of work and method of assessment• introduce a range of measurement instruments and test equipment and describe its function• describe and discuss the features of a range of measurement instruments and test equipment• describe and discuss the characteristics of a range of measurement instruments and test equipment. |
| <p>Prepare for and carry out Assignment 1: Measurement Instruments and Test Equipment (P1, P2)</p> |
| <p><i>Whole class teaching/practical demonstration:</i></p> <ul style="list-style-type: none">• describe and demonstrate the selection, applications and use of different measurement and test equipment• describe and demonstrate a range of measurement techniques• describe and demonstrate the range of different measurements to be made on a variety of different electronic equipment. <p><i>Practical workshop activities:</i></p> <ul style="list-style-type: none">• learners practise the use of a range of measurement and test equipment and techniques to carry out measurements on a range of different electronic equipment. |
| <p><i>Whole class teaching:</i></p> <ul style="list-style-type: none">• describe the principles and procedures to be used and followed when carrying out calibration of electronic test equipment• describe the health and safety issues that apply and precautions to be taken when calibrating electronic test equipment• describe the issues relating to pre-conditions and checks to be made to ensure that the system is safe to test and instruments safe to use. |
| <p>Prepare for and carry out Assignment 2: Selecting, Using and Calibrating Electronic Test Equipment (P3, P4, P5, P6, M1, M2)</p> |
| <p><i>Whole class teaching/practical demonstration:</i></p> <ul style="list-style-type: none">• describe and demonstrate the use of virtual measurement and test equipment• describe and demonstrate tests carried out on electronic equipment using virtual test and measuring instruments. <p><i>Practical workshop activities:</i></p> <ul style="list-style-type: none">• learners practise the use of virtual test instruments and software to make measurements and analyse data. |
| <p>Prepare for and carry out Assignment 3: Virtual Testing (P7, P8)</p> |
| <p>Feedback, unit evaluation and close.</p> |

Assessment

To achieve P1 and P2, learners will need to describe the function, features and characteristics of one measurement instrument and three different pieces of electronic test equipment. The evidence for this could be block diagrams/sketches (with appropriate annotation) and short notes. The actual function, features and characteristics described will be dependent on the electronic test equipment selected but examples of the types of things to consider are provided in the unit content.

P3 requires learners to select and use test equipment and measuring techniques to take measurements from three different pieces of electronic equipment. These can be low-voltage dc power supplies, amplifiers, oscillators, radio equipment, digital electronic equipment or video equipment. Further examples of each of these are provided in the unit content.

Learners will need to perform practical measurements in an electronic laboratory or electronic workshop. Given a particular measurement requirement (for example, to investigate the frequency range of an oscillator) learners should then be able to select the appropriate items of test and measurement equipment to carry out the task. Both the selected item(s) of test equipment and the measuring technique(s) should be appropriate to each measured quantity. For example, an oscilloscope and $\times 10$ probe would not be appropriate for the accurate measurement of the output frequency produced by an oscillator. The three different pieces of electronic equipment should enable as wide a range of test equipment and measuring techniques to be applied as possible. All three pieces could come from one category (eg consumer electrical and electronic equipment) as long as the chosen equipment provided for the use of a sufficient range of test equipment and measuring techniques. It is expected that all the content listed under measurement techniques and measurements will have been covered by the time learners has carried the measurements on all three pieces of equipment.

Evidence for P3 is likely to take the form of tutor observations and learner records of the selection and use of equipment and techniques employed. Suitably annotated photographic records could also be used (eg a photograph of the equipment being tested, the test equipment and the test set-up, all suitably labelled to highlight the key features of the test/measurements).

For P4, learners should provide a written or verbal presentation to explain the importance of test specifications as an aid to ensuring the validity and consistency of measurement. Centres should ensure that learners have access to a variety of test specifications for common measurements (eg determining the output impedance of a power supply by voltage/current measurement when a suitably rated variable load is applied). The achievement of this criterion could be effectively linked with the practical work in any one of the tests carried out for P3.

P5 requires learners to describe the principles and need for calibration of an item of electronic test equipment. Again, one of the tests undertaken for P3 could provide the focus for this criterion. The description, which is likely to be a written report, must include the electronic test equipment calibration procedures that need to be carried out, the reference standards required and any relevant theory. Examples of each of these and typical applications are given in the unit content. As an aid to understanding the calibration process, centres should demonstrate the calibration procedures for equipment used in the laboratory (eg oscilloscopes, digital multimeters, signal generators, etc).

For P6, learners must be able to describe the health, safety and configuration issues that need to be considered when connecting test equipment to an item of electronic equipment that requires testing. The health and safety issues considered will depend upon the equipment being tested. The configuration issues considered must, as a minimum, enable the learner to take into account the required pre-conditions and checks to ensure that it is safe to test the system/equipment. For example the selection of an adequately rated load in terms of both impedance and power rating when testing an audio amplifier or the need to check that an oscilloscope probe is correctly matched to the oscilloscope that it is to be used with. Learners will also need to ensure instruments are safe to use (eg use of a high-voltage probe when measuring DC voltages in excess of 500 V) and test equipment set-up correctly eg use of equipment manufacturer's procedures, using commissioning guides. Again it would make sense to link this criterion to one of the tests undertaken for P3.

To satisfy P7 and P8 learners should use a virtual measurement and test system to carry out a test on a piece of electronic equipment. They should provide a written or verbal description of the procedure used, explaining the connections made, the software settings, and the measuring techniques used. A typical example would be the use of a virtual digital storage oscilloscope used in conjunction with a personal computer (PC). Learners should connect and configure the instrument in conjunction with the software running on the PC and select, for example, appropriate sampling rates, input ranges and display and data capture settings. Evidence of individual learner's work can most conveniently be presented in the form of a selection of screen dumps that have been suitably annotated by the learner.

To achieve M1 learner need to explain the importance of resolution, accuracy, sensitivity bandwidth and input impedance on the performance of a piece of test equipment. This could be achieved as a natural extension to one of the tasks carried out for P3.

For M2, learners are required to calibrate and configure a test instrument (such as a waveform generator), using the manufacturer's recommended procedures and appropriate laboratory instruments and standards. Learners should be supplied with relevant documentation (eg manufacturer's handbook) and laboratory standards (such as a standard frequency or time generator). Evidence is likely to be a logbook record of the calibration exercise or a technical report of the calibration activity. Tutor observation records should be used to support either of these forms of evidence. There is a clear link between this merit criterion and P5.

To satisfy M3, learners should use a virtual storage oscilloscope (using a PC with appropriate interface hardware and software) to display and analyse a waveform. Note that the emphasis should be on the analysis of the waveform rather than its display. A typical example might involve the production of a frequency spectrum for the sampled waveform using FFT techniques. Once again, learners should keep a record of their work in a logbook, supported by tutor observation records. Relevant screen dumps and print outs that have been suitably annotated by the learner could also be incorporated.

The learner's work towards D1 should require them to evaluate the accuracy of their own test measurements and relate them to limitations of the test equipment, test procedures, or possible emerging fault conditions. For example, learners should be aware of the inability of an oscilloscope to accurately display a transient pulse due to the oscilloscope's own finite rise-time and bandwidth. Another example would be the need to be aware of the effects of aliasing on the captured and displayed waveform when sampling a fast waveform.

For D2, learners need to be able to devise and demonstrate a calibration procedure for an item of electronic test equipment. A typical example might be a procedure to calibrate a 'x10' oscilloscope probe using a fast-rise time square wave generator, a high-speed oscilloscope, and a matching 'x10' probe. Evidence is likely to be in the form of a technical report although it would be beneficial if the devised calibration could be linked into the work done for P2, P3, P4 and M2.

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 | Measurement Instruments and Test Equipment | An information poster/leaflet for new staff. | Written assignment. |
| P3, P4, P5, P6, M1, M2 | Selecting, Using and Calibrating Electronic Test Equipment | Learners have been asked to show a new apprentice how to take measurements from electronic equipment and talk them through the calibration of test equipment and relevant health, safety and configuration issues. | A practical assignment with additional written tasks. |
| P7, P8 | Virtual Testing | Learners have been asked by their employer to carry out tests on a piece of electronic equipment. | A practical assignment. |

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 |
|---------|---------|--|
| | | Electronic Circuit Design and Manufacture |
| | | Principles and Applications of Electronic Devices and Circuits |

SEMTA Level 3 National Occupational Standards in Engineering Maintenance, particularly:

- Unit 17: Testing Electronic Equipment and Circuits
- Unit 40: Maintaining Instrumentation and Control Systems.

Essential resources

Centres will need to provide access to an electronics laboratory fitted with a range of electronic test and measurement equipment (such as multimeters, signal generators, oscilloscopes, etc). A limited number of specialist items of electronic test equipment and calibration sources (eg standard cells and off-air signal sources) should also be available. Specialist items of electronic equipment (such as AC bridges, earth continuity testers, logic analysers, component testers, etc) may be required as appropriate to the needs of local industry.

A small number of computer-based virtual instruments should also be available together with the appropriate hardware and software (eg LabVIEW, DASyLab, DADiSP, MATLAB etc). Test and measurement applications should be installed on these systems.

Employer engagement and vocational contexts

Much of the work for this unit 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

Textbooks

Hughes E, Hiley J, Brown K and Mackenzie-Smith I – *Electrical and Electronic Technology* (Prentice Hall, 2004) ISBN 0131143972

Tooley M – *Electronic Circuits: Fundamentals and Applications* (Newnes, 2006) ISBN 0750669233

Tooley M – *PC Based Instrumentation and Control* (Newnes, 2005) ISBN 0750647167

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 and problems to resolve when carrying out tests and measurements on a piece of electronic equipment |
| Self-managers | working towards goals and organising time and resources when carrying out tests and measurements on a piece of electronic 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 | asking questions to extend their learning |
| Reflective learners | reviewing progress and acting on the outcomes |
| Team workers | collaborating with other when working in small groups during practical activities. |

● 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 virtual instruments, hardware and software to make measurements and analyse measurement data |
| English | |
| Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts | describing the function, features and characteristics of measurement and test equipment and related health, safety and configuration issues |
| Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions | researching and investigating the function, features and characteristics of electronic measurement and test equipment |
| Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively | describing the function, features and characteristics of measurement and test equipment and related health, safety and configuration issues. |