Unit 25: Electronics for Science Technicians

Unit code: R/502/5570

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

The aim of this unit is to enable learners to become familiar with electronic components, their applications and the essential principles associated with discrete and logic circuit construction.

Unit introduction

The technological advances in electronic circuitry appear to easily outpace the manufacturing process which converts the drawing board designs into a reality. This unit is designed to illustrate how an understanding of essential circuit theory can lead to the development and construction of electronic devices so important in our lives today. The skills and knowledge gained are essential for science technicians and workers in associated industries and may form the foundations of development in a programme of further education.

During the study of this unit, learners can explore:

- the development of domestic devices from simple circuits
- the transfer of fault-finding skills to all electrical applications
- materials for electrical conduction, insulation and semi-conduction
- the differences between working in the electrical industry and the computer industry for service engineers.

Learners will be introduced to the terminology and relationships fundamental to electrical understanding. The general electrical laws will be demonstrated throughout the unit by thorough application of known circuit theory in practical circuit construction.

Learners will develop a fluency in their use of electrical measurement equipment and will be given essential guidance on circuit constructional techniques leading to effective fault diagnosis in a range of circuits. The theory and uses of analogue and digital integrated circuits will be studied in sufficient detail for learners to be able to relate the circuit design to its uses, and to appreciate that the simplicity of logic gates can soon give way to a complex array of both circuit types forming the building blocks of the technological age.

Learning outcomes

On completion of this unit a learner should:

1 Know principal discrete electronic components and circuit theory

2 Be able to measure suitable electrical values using test equipment

3 Be able to construct and test analogue and digital circuits safely

4 Be able to construct and test circuits containing analogue, digital and integrated circuit components.

Unit content

1 Know principal discrete electronic components and circuit theory

Terminology, units and symbols: current (ampere – A, symbol – I); potential difference (volt – V); resistance (ohm – Ω, symbol – R); electrical power (watt – W, symbol – P); capacitance (farad)

Essential components: resistors (colour code, power rating); capacitors (charge stored by capacitors Q = CV, voltage rating, colour code, ceramic, electrolytic, units and sub-units of capacitance, charging and discharging; diodes (characteristic curve, forward and reverse biasing, maximum forward current, peak inverse voltage (PIV), importance of correct polarity, half-wave and full-wave rectification, use for device protection, eg relays and zener diodes)

Bipolar transistor: identification of leads; biasing; small signal current gain (hFE); transistor circuits (amplifier and switch, astable)

Transducers: thermistor; light dependent resistor (LDR), light emitting diode (LED), photo diode; reed switch

Circuit theory and electrical relationships: Ohm's law (V = IR); potential dividers; Kirchoff's laws applied to series and parallel circuits; simple RC charge/discharge circuits and the time constant T = RC; use of capacitors as a filter in AC circuits; calculations of resistance and capacitance in series and parallel circuits; power as P = IV; nature of AC voltage as changing polarity with instantaneous values varying sinusoidally

2 Be able to measure suitable electrical values using test equipment

Test equipment: multimeter; oscilloscope; signal generator; logic probe

Measurements: potential difference (V, mV); current (A, mA, uA); period (s, ms); frequency (Hz, kHz, MHz)

Testing: set up test equipment; checking connections; estimated test values/signals

3 Be able to construct analogue and digital circuits safely

Constructional techniques: matrix board, strip board, printed circuit board (PCB); soldering (anti-static handling techniques, good soldered joints, avoiding excess solder, overheating and dry joints)

Layout design: translate circuit diagram into layout diagram; logical layout of components; correct polarity of components; calculation of limiting resistor values, eg LED use; PCB construction (direct and photographic); construction of test circuits, eg light sensor, temperature sensor, touch sensor, burglar alarm with lamp, delay circuit, time operated switch

4 Be able to construct and test circuits containing analogue, digital and integrated components

Analogue circuits: operational amplifier as inverting and differential amplifier (comparator), single stage amplifier circuit, feedback, gain; 555 timer (astable, monostable); estimating and calculating component values

Digital integrated circuits: logic gates, eg AND, OR, NOT, NAND, NOR; symbols; combinational logic circuits and truth tables

Digital sequential systems: flip-flop (from NAND gates, D-type); block diagrams; binary counters; frequency counters; decoders; seven segment displays

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 outline the function of electronic components	**M1** describe the operation of analogue and digital electronic circuits	**D1** explain the mode of operation of principal electronic components
P2 outline essential circuit laws and electrical relationships	**M2** describe essential circuit laws and electrical relationships	**D2** use suitable circuit examples to explain essential circuit laws and electrical relationships
P3 select appropriate test equipment [RL3]	**M3** carry out tests on electronic circuits and measure suitable electrical quantities with precision and accuracy	**D3** assess the functions and mode of operation of electrical test equipment
P4 set up test equipment and measure suitable electrical quantities [SM3]		
P5 assemble analogue and digital circuits from given circuit diagrams, demonstrating safe and effective practice [IE1; CT5; TW1,2; EP3]	**M4** carry out tests on constructed analogue and digital circuits, to identify circuit faults	**D4** rectify faults in constructed analogue and digital circuits
P6 construct circuits containing analogue, digital and integrated circuit components. [IE1; CT5; TW1,2; SM3].	**M5** test circuits containing analogue, digital and integrated circuit components, to identify circuit faults.	**D5** rectify faults in constructed circuits containing analogue, digital and integrated circuit components.

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

As an introduction to learning outcome 1, learners should be given the essential definitions of electronic terms and shown the electrical relationships by theory and practical demonstration. The multimeter should also be introduced at this stage. Learners may then develop simple series and parallel circuit construction and progress to circuits using capacitors. The time constant can be discussed following demonstration of the charge/discharge of a capacitor through a filament lamp.

Diodes and alternating current (AC) can then be introduced together with the functional characteristics of the oscilloscope and signal generator.

Transistor characteristics, eg typical switch on voltage, and uses will need clear explanation for use in later circuit construction and learners should be able to calculate the values of resistors needed for the simple biasing of a transistor amplifier. After measuring the hFE of a transistor and calculating the values of the resistors needed to bias it, learners should build and test their transistor amplifier. Using an AC input signal to measure its gain, learners can acquire experience of using a signal generator and oscilloscope.

Learning outcome 2 develops the introduction to test equipment further and links very closely with learning outcomes 3 and 4. It is sensible to include detailed information of the operation of these instruments and practical setup to ensure that learners become very familiar with important aspects of testing and measurement at the earliest point in the unit. Testing can be carried out on learner or tutor constructed circuits, or both.

The use of testing equipment should increase with the simple design and construction of both analogue and digital circuits in learning outcome 3. Learners should construct circuits on strip board or PCB and test them. Learners must take precautions when soldering components on the board, to safeguard both themselves and circuit components from harm. A variety of useful and contextual circuits should be taken from design, adapted to layout and built. Testing and experimentation with circuit components must be carried out throughout the development of each circuit.

In learning outcome 4, the increasingly important role of digital technology could be discussed before basic logic gates are introduced to learners, who should be able to predict the output of combinational logic circuits using truth tables, and check their truth tables by building and testing the circuits on a suitable breadboard. NAND gates may be used to build and test a SR flip-flop. This will lead to building circuits using D-type flip-flop integrated circuits. After introducing block diagrams, learners should be able to use D-type flip-flops, decoders and seven segment displays to build simple counting circuits. A large multi-stage circuit may eventually be produced.

When building circuits, learners should be encouraged to use test equipment. For example, the output of a 555 astable can be heard through a loudspeaker and seen on an oscilloscope. Learners should be shown how to use test equipment to locate faults in their circuits. Some circuit diagrams provided to learners could include deliberate faults that learners can track down using test equipment and rectify themselves.

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
Outline unit introduction, content and programme of assignments.
1. *Electrical terms and relationships:* definitions, practical and research. Use of units, electrical relationships, component identification and basic circuit construction. **Assignment 1 – Essential Circuitry (P1, M1, D1)** Individual and group learning time, magazine production, techniques of circuit building, visit to component manufacturer. Demonstration of exponential charge/discharge for capacitors. Simple circuit design and build for current pathways, ie resistance circuits. **Assignment 2 – Putting Laws to the Test (P2, M2, D2)** Building from assignment 1 circuit development, individual learning time, using circuit laws and testing by simple measurement and calculation.
2. *Use of measurement devices from tutor or learner constructed circuits*. Correct assembly of test equipment, operation and unit selection. Positioning of probes for sample current and voltage. Combination circuits, measurement of quantities using digital and analogue devices. **Assignment 3 – Practice Makes Perfect (P3, P4, M3, D3)** Use and choice of equipment, precision based practical testing which can be used in conjunction with assignment 2. Individual learning.
3. *Construction of analogue and digital circuits:* circuit testing. Suitable circuit construction and component selection, circuit production methods. Digital applications as depicted by circuit switches. Circuit sensors in circuits, fault finding at each stage using measurement devices. **Assignment 4 – Common Sense (P5, M4, D4)** Practical development of sensing circuits and switching. Fault detection and rectifying.
4. *Theoretical and investigative:* integrated circuit use. Understanding current pathways and operation of analogue types in group. work with integrated and amplifier circuit building, timers, displays. Theoretical – truth tables and counters. **Assignment 5 – The Full Monty (P6, M5, D5)** Individual learning time, visit to local electronics manufacturer, development of fault finding techniques through construction of circuits containing analogue, digital and integrated circuits, project based learning.
Review of unit and programme of assignments.

Assessment

The strategies for assessment will focus on the many opportunities to include practical and investigative forms of evidence within this unit. Wherever possible, learners must be encouraged to produce evidence which demonstrates that they have taken an analytical approach to assignment completion.

For P1 and P2, learners could produce a table in which they briefly describe the function of the electronic components listed in the *Unit content* section and the essential electrical relationships used. Practical evidence must include brief details of tests involved and the use of electrical relationship calculations. Measurements made must be recorded with the correct units. M1 grade learners need to describe the operation of analogue and digital circuits comprehensively and describe the use of electrical relationships. D1 and D2 grade learners should demonstrate an understanding of the operation of circuit components and independently explain the current pathways and electrical relationships by means of calculation and practical records.

To achieve P3 and P4 learners will test circuits that are either self or tutor constructed using appropriate test equipment from learning outcome 2. Learners may check that the voltage at the collector of a common emitter amplifier is half that of the supply voltage in the absence of an input signal, or use an oscilloscope to measure the frequency output of a 555 astable circuit. Evidence gathered will be aided by the tutor. For M2, learners should show more independence setting up test equipment and show effective measurement technique on constructed circuits. D1 grade learners should assess how test equipment functions and how it operates to investigate circuits. This could be achieved as a piece of written work. Learners could produce an instruction leaflet for each piece of test equipment, or they could give a practical demonstration of the function and operation of the equipment evidenced by a video recording or a witness statement from the tutor.

To achieve P5 learners must build circuits from supplied circuit diagrams. Learners must build a range of analogue and digital circuits to gain experience of using a wide range of components. Supplied circuit diagrams could vary in complexity so that more able learners have the opportunity to build more complex circuits. Essential circuit building techniques are required in order to achieve this criterion. Where possible, a context should be given for each circuit. A witness statement from the tutor could confirm that the learner successfully built circuits in the practical books. Some photographic evidence, showing the layout of components for some circuits, is desirable. M4 grade learners must test the circuits to identify possible errors in the construction and faults when testing is applied. The construction of circuits should be methodical and completed with accuracy and precision. They should adhere to health and safety aspects throughout. D4 grade learners should demonstrate a high degree of independent circuit construction from design. Faults should be rectified through logical problem solving. Learners' evidence may include a report that includes a schematic circuit diagram, calculations of components used, a description of how the circuit operates, details of how the circuit was tested, faults located and how these were corrected.

Learning outcome 4 involves the further construction of analogue and digital circuits and the inclusion of integrated circuits. P1 grade learners should be able to build a circuit that uses one 555 timer. A suitable circuit may be a monostable timer such as an egg timer. Other circuits which should be constructed include an inverting amplifier or digital decoder using gates. Testing of these circuits should produce sufficient data records. M1 grade learners should design and build suitable circuits with precision. Faults should be identified at the required stages and a wide range of components must be used effectively. The underlying design and construction of each circuit must be well planned and executed. D1 grade learners should demonstrate more independence and be able to rectify faults by correct diagnosis of circuit problems using test equipment. Learners can compare the actual performance of circuits that they designed with the expected performance. For example, they could comment on whether the gain of an inverting amplifier circuit met expectations, and whether it would do the job for which it had been designed, or whether a temperature operated switch activated or deactivated an output at the required temperatures. Suggestions for improving the performance of the circuit should be included where appropriate.

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, M1, D1 P2, M2, D2	Essential Circuitry Putting Laws to the Test	Electronics magazine research junior producing a guide to components and technical terms.	Evidence includes: • informative booklet • illustrated display (for website or catalogue) • practically produced calculations.
P3, P4, M3, D3	Practice Makes Perfect	Electronics manufacturer of circuit board quality control.	Written, diagrammatical or investigative: • identification and cut-away diagrams of instruments • diagram of circuit test points • practical results from test circuit.
P5, M4, D4	Common Sense	Electronic servicing assistant technician.	Practical and investigative: • circuit assembly and testing • health and safety considerations • report explaining full procedures of development and fault finding.
P6, M5, D5	The Full Monty	Research technician in the innovation and development department of an electronics organisation.	Practical and investigative: • booklet showing logic aspects • circuit design • constructed and tested circuit with full written account of development.

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

This unit forms part of the BTEC Applied Science sector suite. This unit has particular links with the units shown below in the BTEC Applied Science suite of qualifications:

Level 2	Level 3
Electronics in Action	Fundamentals of Science
	Electrical Circuits and their Applications

Essential resources

Learners need access to breadboards, circuit components, test equipment (multimeter, oscilloscope, signal generator, logic probe), soldering facilities, library facilities and the internet. A suitable laboratory or technology workshop will facilitate essential aspects of this unit.

Employer engagement and vocational contexts

Wherever possible, visits to electronics manufacturers and materials technology companies should be arranged. Learners may benefit from a work placement in electronics related workshops. At every stage of this unit electronic circuits can be introduced in the context for which they are used.

Indicative reading for learners

Textbooks

Bird J – *Electrical and Electronic Principles and Technology* (Newnes, 2007) ISBN 9780750685566

Bishop O – *Electronics: Circuits and Systems* (Newnes, 2007) ISBN 9780750684989

Duncan T – *Electronics for Today and Tomorrow* (Philip Allan, 1997) ISBN 978071957413 9

Floyd T L – *Electronic Devices: Conventional Flow Version* (Prentice Hall, 2004) ISBN 9780131140806

Fowler P and Horsley M – *Technology* (Collins CDT, 1998) ISBN 9780003220360

Kybett H – *Electronics* (Wiley Press, 1986) ISBN 9780471009160

Malvino A – *Electronic Principles* (Career Education, 1998) ISBN 9780028028330

Mawson D et al – *Design & Make It* (Nelson Thornes, 2001) ISBN 9780748760794

McLaughlin M – *Electronics For You* (Nelson Thornes, 1994) ISBN 9780748717903

Sah C T – *Fundamentals of Solid State Electronics* (McGraw Hill, 2006) ISBN 9780073222776

Journals

IET Circuits, Devices and Systems (Institute of electrical engineers)

International Journal of Component Technology

International Journal of Electronics

Websites

www.kpsec.freeuk.com	The Electronics Club
www.mikroe.com	MikroElektronika
www.science-campus.com	Science Campus resources
www.technologystudent.com	Design and Technology resources for tutors
www.tpub.com/neets	Electrical engineering publications

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	[IE1] carrying out practical activities which produce good quality circuit development and fault finding
Creative thinkers	[CT5] trying out alternatives when assembling circuits
Reflective learners	[RL3] making decisions when selecting test equipment
Team workers	[TW1,2] designing and building circuits; making group decisions on correct testing equipment and fault diagnosis
Self-managers	[SM3] identifying and setting up test equipment, initially, followed by pre-planning of assignment and evidence organisation
Effective participators	[EP3] carrying out planned investigative activities in relation to internet research and circuit development.

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 ...
Independent enquirers	[IE4] analysing complex circuits involving logic and integrated circuits
Creative thinkers	[CT5,6] analysing circuit development and attempting to rectify faults which are related to design; applying electrical relationships to circuit understanding and measurement
Reflective learners	[RL3,5] experimenting with the application of various component values within circuits
Team workers	[TW5,6] researching applications of integrated circuits and developing practical circuits
Self-managers	[SM4] applying health and safety practices routinely
Effective participators	[EP2,3,4] taking part in cross-group circuit analysis.

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	researching information for use of systems in circuit analysis when producing report
Use ICT to effectively plan work and evaluate the effectiveness of the ICT system they have used	investigating electronic components, carrying out practical circuit analysis and reporting on findings
Manage information storage to enable efficient retrieval	reporting practical investigation results
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	adapting information for use in development of analogue and digital circuits
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	researching and assessing information from electronics websites
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	producing relevant graphs, tables, circuit diagrams and suitable circuit software from experimental work
Bring together information to suit content and purpose	producing assignment reports
Present information in ways that are fit for purpose and audience	developing reports and presentations, using appropriate software
Evaluate the selection and use of ICT tools and facilities used to present information	discussing appropriate methods of reporting with tutors and other learners
Select and use ICT to communicate and exchange information safely, responsibly and effectively including storage of messages and contact lists	saving relevant data and research information in correct format and using email messaging, memory software and suitable storage

Skill	When learners are ...
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	calculating expected circuit values and adapting to measured values
Identify the situation or problem and the mathematical methods needed to tackle it	responding to measured quantities in circuit construction and development
Select and apply a range of skills to find solutions	using appropriate data presentation
Use appropriate checking procedures and evaluate their effectiveness at each stage	calculating and using scientific methodology for error
Draw conclusions and provide mathematical justifications	using fault-finding and circuit analysis to provide values for mathematical interpretation
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	presenting investigative work from circuit construction using appropriate software or in group activities
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching from wide range of sources for comparative information and data on electronics principles
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	producing complete reports from practical activity.