Unit 35: Principles and Applications of Electronic Devices and Circuits

Unit code: K/600/0300

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to give learners an understanding of electronic devices and the skills needed to simulate, construct and test a variety of electronic circuits.

Unit introduction

Electronics and electronic devices are used in a huge variety of manufactured products. From everyday popular items such as cameras and thermometers to the robotic welding machines used in industry, the use of electronics is continually growing.

This unit provides a practical introduction to basic electronic devices and analogue and digital electronic principles. It provides learners with an opportunity to investigate the operation of diodes and transistors, two of the most important building blocks in electronic circuits. Learners will then go on to build and test circuits that make use of these devices and will consider the operation of integrated circuits such as the operational amplifier. Logic gates and flip-flops are also investigated both in practice and by using simple electronic principles, such as voltage gain or truth tables.

Finally, the unit will introduce learners to computer-based circuit design and simulation software packages that will allow them to build and test analogue and digital circuits. This will enable learners to recognise the importance of simulation software in the design of electronic circuits.

The overall aim of this unit is to build learners' confidence in their ability to construct and test simple electronic circuits. The emphasis is on prototyping, constructing and measuring. The unit treats systems in terms of their functionality and their input/output relationships.

Learning outcomes

On completion of this unit a learner should:

1 Understand the function and operation of diodes, transistors and logic gates

2 Be able to build and test operational amplifier-based analogue circuits

3 Be able to build and test combinational and sequential logic circuits

4 Be able to use computer-based simulation software packages to construct and test the operation of analogue and digital circuits.

Unit content

1 Understand the function and operation of diodes, transistors and logic gates

Diodes: types eg Zener, light emitting diode (LED), PN-junction; circuit applications eg voltage stabiliser, indicator light, half-wave rectifier

Transistors: types eg NPN, PNP or field-effect transistor (FET); analogue circuit (single-stage amplifier); digital circuit eg comparator, transistor as a switch (automatic night light); operation eg analogue (voltage gain, phase inversion), digital (set-point of operation); function of components in circuits

Logic gates: types of gates eg AND, OR, NOT, NAND, NOR, XOR; gate symbols eg British Standards (BS), International Electrotechnical Commission (IEC), American National Standards Institute (ANSI); truth tables; Boolean expressions eg $A+B$, $\bar{A}$, $A \bullet B$

2 Be able to build and test operational amplifier based analogue circuits

Building analogue circuits: method of construction eg prototype/bread-board, printed circuit, strip-board; types of circuits eg oscillator, filter circuit, comparator circuit, inverting and/or non-inverting amplifier

Testing analogue circuits: performance against given design requirement; recording actual input and output voltages (tabulating data, plotting graph of results); circuit measurements eg measurement of resonant frequency, cut-off frequency, switching point, gain at mid-frequency, bandwidth

3 Be able to build and test combinational and sequential logic circuits

Building combinational and sequential logic circuits: types of combinational circuit eg at least three gates and three input variables; types of sequential circuit eg R-S bi-stables, JK bi-stable, 3-stage counter, 3-stage shift-register based on JK or D-type bi-stables; types of logic family eg transistor-transistor logic (TTL) and complementary metal oxide semiconductor (CMOS); characteristics of chips eg supply voltage, input and output operating voltages, input and output impedance, propagation delay, power

Testing of logic circuits: records of performance against given design requirement; input and output states; use of truth tables; use of test equipment eg logic probe, signature analyser

Minimisation of logic circuits: eg use of De-Morgan's theorem; Karnaugh maps

4 Be able to use computer-based simulation software packages to construct and test the operation of analogue and digital circuits

Simulation of analogue circuit: types of circuits eg transistor amplifier, op-amp, active filter, rectifier; types of components eg resistor, capacitor, transistor, diode; instrument simulation eg voltmeter, ammeter, oscilloscope; records of performance against given design requirement eg screen print, input/output waveforms (with scales), gain-frequency response

Simulation of digital circuit: types of circuit eg three input combinational circuit, counter, shift register; types of gates/sequential circuit eg R-S bi-stables, JK bi-stable, 3-stage counter, 3-stage shift-register based on JK or D-type bi-stables; instrument simulation eg on/off indicator, logic probe, word generator, logic analyser; records of performance against given design requirement eg screen print, digital input/output waveforms (with scales)

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 explain the purpose of two different types of diode, each in a different electronic circuit application	**M1** modify an existing analogue circuit to achieve a given revised specification by selecting and changing the value of one of the components	**D1** using a simulation package, analyse the effects of changing the values of circuit parameters on the performance of an analogue circuit containing an operational amplifier or transistors
P2 explain the operation of two different types of transistor, one in an analogue and one in a digital circuit	**M2** modify a digital circuit to achieve a given revised specification by selecting and changing up to two logic gates	**D2** compare and contrast two different types of logic family with reference to five characteristics.
P3 explain the operation of three different logic gates with appropriate gate symbols, truth tables and Boolean expressions	**M3** evaluate and minimise a three input combinational logic circuit containing three gates.	
P4 build and test two different types of analogue circuit using operational amplifiers [IE1, CT1, CT5]		
P5 build and test a combinational logic circuit that has three input variables [IE1, CT1, CT5, SM3]		
P6 build and test a sequential circuit using integrated circuit(s) [IE1, CT1, CT5, SM3]		
P7 use a computer software package to simulate the construction and testing of an analogue circuit with three different types of components [IE1, CT1, CT5, SM3]		

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:**
P8 use a computer software package to simulate the construction and testing of a digital logic circuit with three gates. [IE1, CT1, CT5, SM3]		

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 will require a predominantly practical approach to delivery. Emphasis should be placed on well-planned practical activities that complement and reinforce theory. The correct selection and use of equipment and measuring instruments is essential and should be encouraged at every opportunity.

It is suggested that, wherever possible, delivery of learning outcome 1 is integrated into the practical activities used for learning outcomes 2 and 3. The work on diodes and transistors requires only very basic semiconductor theory, for instance giving the main difference between p type and n type. Only superficial coverage should be given to introduce the p-n junction, ie that this is an insulating layer which can be removed by approximately 0.7 V forward bias. The depth of treatment should be that of a low-level introductory topic, with emphasis on practical application. The diode characteristic, forward and reverse bias modes and simple calculations of current flow and voltage drops in a simple circuit should be included. The treatment of the transistor should similarly be limited to basic coverage. It should include simple biasing of a bipolar transistor and its use as an electronic switch and amplifier in simple circuits.

The delivery of the unit could include the following examples of practical activities:

- a Zener diode-series resistor stabiliser, with records of input and output voltages
- calculation of the series resistor needed for a high-brightness LED
- a field-effect transistor (FET) amplifier (measure DC voltages and voltage gain at 1 kHz)
- a NPN transistor used as a switch, eg automatic alarm/night light
- an inverting and then a non-inverting operational amplifier (op-amp), measuring their voltage gains
- building any type of logic circuit with three or more inputs and gates, recording the output in a truth table to show it is working
- building a circuit such as a three-bit counter made from JKs and recording the inputs and outputs.

The use of computer-based software packages is essential and it is assumed that centres will use simulation techniques as part of the delivery and learning process of this unit.

Activities, case studies and project work used for the delivery of this unit should, where appropriate, focus on present industrial electronic engineering or communication applications. Industrial visits or work experience, where appropriate, would be of value in supporting the learning activities.

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 methods • explain the different types and applications of diodes • explain the different types and operation of transistors in analogue and digital circuits • explain the different types of logic gates and the symbols used to identify them • explain and demonstrate the use of truth tables and Boolean expression.
Whole-class teaching/demonstration: • explain and demonstrate methods of construction and types of analogue circuits • explain and demonstrate testing of circuit performance against design requirements • explain and demonstrate recording of voltages and use of circuit measurements. *Practical learner activities:* • research and practise construction of different types of analogue circuit • research and practise testing of analogue circuits.
Prepare for and carry out **Assignment 1: Construction and Operation of Analogue Circuits** (P1, P2, P4, M1)
Whole-class teaching/demonstration: • explain and demonstrate construction of different types of combinational and sequential circuits • explain types of logic family and the function and characteristics of chips • demonstrate testing of performance against design requirements • demonstrate the use of truth tables and test equipment • explain the minimisation of logic circuits. *Practical learner activities:* • research and practise construction of different types of combinational and sequential logic circuits • research and practise testing of logic circuits.
Prepare for and carry out **Assignment 2: Construction and Operation of Logic Circuits** (P3, P5, P6, M2, D2)
Whole-class teaching/demonstration: • explain and demonstrate the use software for simulation of different types of analogue circuit, components and instrument • explain and demonstrate the use software for simulation of different types of digital circuit, gates/sequential circuits and instruments. *Practical learner activities:* • practise use of simulation software for analogue and digital circuits.
Prepare for and carry out **Assignment 3: Using Simulation Software to Construct and Test Circuits** (P7, P8 and D1)
Unit evaluation, feedback and close.

Assessment

The learning outcomes and related criteria can be assessed in any order. The criteria P1, P2 and P4 are related and it would make sense to build a practical assignment or project around them. The focus would be to build two different types of analogue circuit (P4) that would allow learners to explain the purpose of two different types of diodes (P1) and the operation of one of the two different types of transistor (P2). Learners would then need to work on another circuit or simply explain the operation of a transistor in a digital circuit.

A second assignment could be used to cover the practical work required for P5 and P6. This could be linked to the explanation of theory that is necessary to achieve P3.

The last two pass criteria, P7 and P8, could be covered either before the build and test exercise to prove the circuits, or afterwards, to simulate the circuit performance and testing that learners have already experienced.

Opportunities for the achievement of the merit criteria can be set within the assignments suggested above. For example, a task could be set for M1 that requires learners to modify a circuit to produce a different voltage gain to the one used in P4, or for a different resonant frequency for an oscillator. M2 could be obtained through a task additional to that used for P5, such as to modify the circuit given for P5. M3 simply requires a minimisation (for example using a Karnaugh map).

D1 requires an analysis, using a simulation package, of the effects on the performance of an analogue circuit containing an operational amplifier or transistors of changing the values of circuit parameters (for example components or component values, input/output voltages or signals). This could be a computer-based investigation of how the feedback resistor in an operational amplifier changes not only the gain but also the bandwidth. To meet the criterion it would require at least one other parameter to be changed – possibly the supply voltage, or input voltage – and noting how 'clipping' can occur. Part of the analysis could be to use calculations to show how the theoretical results align with those actually obtained through simulation.

Again, careful selection of the circuits used for the pass/merit assignment could enable this final step to be a natural development from the work already carried out. Establishing firm links between the pass, merit and distinction criteria in this way will encourage learners to work towards higher levels of achievement and will improve the relevance and coherence of the assessment activities.

To achieve D2, learners need to compare and contrast two different types of logic family with reference to at least five characteristics. The comparison, which can be partly but not wholly achieved using a table, should consider common logic families such as TTL and CMOS. Where a table is used for comparison it is expected that the meaning of any terms used (for example sink current) should be clearly explained. The comparison as a whole (table, written explanations, diagrams etc) must make it clear how one logic family can be differentiated from another.

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, P4, M1	Construction and Operation of Analogue Circuits	Learners have been asked by their employer to build and test analogue circuits to meet a new design requirement.	A practical assignment accompanied by written tasks/oral questioning in which learners construct and test two different analogue circuits, each circuit containing a diode and one containing a transistor. One of the circuits could then be modified to meet a revised specification. Additional tasks would then require the learner to explain the purpose/operation of the diodes and transistor, plus an additional transistor from a further digital circuit.
P3, P5, P6, M2, D2	Construction and Operation of Logic Circuits	Learners have been asked by their employer to build and test logic circuits to meet a new design requirement.	A practical assignment accompanied by written tasks/oral questioning, in which learners construct and test combinational and sequential circuits. Additional tasks would then require the learner to explain the operation of logic gates and compare and contrast different types of logic family.
P7, P8, D1	Using Simulation Software to Construct and Test Circuits	Learners have been asked by their employer to use software to simulate the construction and testing of circuits to meet a new design requirement.	A practical assignment in which learners construct and test analogue and digital circuits using simulation software. They should also be given the opportunity to analyse the effect of changing circuit parameter values.

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 Construction	Electrical and Electronic Principles
		Electronic Circuit Design and Manufacture

The unit also contributes towards the knowledge and understanding for the SEMTA Level 3 NVQ in Engineering Maintenance, particularly Unit 17: Testing Electronic Equipment and Circuits.

It also supports the following units within the SEMTA Level 3 NVQ in Electrical and Electronic Engineering:

- Unit 10: Selecting and Preparing Materials and Components for Manufacturing
- Unit 12: Monitoring and Analysing Data from Electronic Circuit Manufacturing Processes
- Unit 18: Testing Post-Production Electronic Components and Circuits.

Essential resources

Centres will need to provide access to an appropriate electronics laboratory with a range of measuring and test equipment, as listed in the unit content. For example, facilities for circuit construction and proto-typing, a range of components, logic-tutor boards, hardware and software to support computer-based analogue and digital schematic capture and circuit simulation will be needed. Learners will also need access to publications, reference data and manufacturers' product information to enable them to consider the different types of components listed within the unit.

Employer engagement and vocational contexts

Much of the practical work for this unit could be set in the context of learners' work placements or be based on the relevant activities of local employers.

There are a range of organisations that may be able help centres engage and involve local employers in the delivery of this unit, for example:

- 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

Bell D – *Fundamentals of Electronic Devices and Circuits* (Oxford University Press, 2009) ISBN

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

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 preparing to construct and test electronic circuits
Creative thinkers	generating ideas, exploring possibilities and trying out alternatives or new solutions when constructing and testing electronic circuits
Self-managers	organising time and resources and prioritising actions when constructing and testing electronic circuits.

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 ...
Reflective learners	setting goals with success criteria for their development and work reviewing progress, acting on the outcomes
Team workers	collaborating with others when working in small groups on 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 computer software to simulate the construction and testing of electronic circuits
Mathematics	
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	checking test data against theoretical values and preparing data for presentation interpreting and presenting the results of circuit tests
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	presenting results of build and test practical work and explaining the types and operation of electronic devices
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	presenting results of build and test practical work and explaining the types and operation of electronic devices producing results and reports on practical work undertaken.