Unit 35: Principles and Applications of Electronic Devices and Circuits

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

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 • 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)

Grading grid

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

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 P2 explain the operation of two different types of transistor, one in an analogue and one in a digital circuit P3 explain the operation of three different logic gates with appropriate gate symbols, truth tables and Boolean expressions P4 build and test two different types of analogue circuit using operational amplifiers P5 build and test a combinational logic circuit that has three input variables P6 build and test a sequential circuit using integrated circuit(s)	M1 modify an existing analogue circuit to achieve a given revised specification by selecting and changing the value of one of the components M2 modify a digital circuit to achieve a given revised specification by selecting and changing up to two logic gates M3 evaluate and minimise a three input combinational logic circuit containing three gates.	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 D2 compare and contrast two different types of logic family with reference to five characteristics.

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 computer software package to simulate the construction and testing of an analogue circuit with three different types of components P8 use a computer software package to simulate the construction and testing of a digital logic circuit with three gates.		

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.

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 (eg 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 (eg 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 then it is expected that the meaning of any terms used (eg 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.

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

This unit has links with *Unit 5: Electrical and Electronic Principles* and *Unit 34: Electronic Circuit 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.

Indicative reading for learners

Beasley J, Rico G and Bogart T — *Electronic Devices and Circuits* (Prentice Hall, 2003) ISBN 0131219901

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

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of level 3 key skill evidence are given here. Staff should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Application of number Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• gathering information and preparing to collect circuit test data • checking test data against theoretical values and preparing data for presentation • interpreting and presenting the results of circuit tests.	N3.1 Plan an activity and get relevant information from relevant sources. N3.2 Use this information to carry out multi-stage calculations to do with: a amounts or sizes b scales or proportion c handling statistics d using formulae. N3.3 Interpret the results of your calculations, present your findings and justify your methods.
Communication Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• 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.	C3.1b Make a formal presentation of at least eight minutes using an image or other support material. C3.3 Write **two** different types of documents each one giving different information about complex subjects. One document must be at least 1000 words long.

Information technology Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• searching the internet, CD ROMs and manufacturers' literature for electronic product information • preparing results and reports of practical work and combining data that has been captured from circuit simulation packages.	ICT3.1 Search for information, using different sources, and multiple search criteria in at least one case. ICT3.2 Enter and develop the information and derive new information. ICT3.3 Present combined information such as text with image, text with number, image with number.