

Unit 24: Principles and Applications of Electronic Devices and Circuits

Level:	3
Unit type:	Optional
Assessment type:	Internal
Guided learning:	60

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 along with analogue and digital electronic principles. It gives learners 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.

Note that the use of 'e.g.' 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 'e.g.' needs to be taught or assessed.

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, e.g. Zener, light-emitting diode (LED), PN-junction; circuit applications, e.g. voltage stabiliser, indicator light, half-wave rectifier

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

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

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

Building analogue circuits: method of construction e.g. prototype/bread-board, printed circuit, strip-board; types of circuits, e.g. 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, e.g. 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, e.g. at least three gates and three input variables; types of sequential circuit, e.g. 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, e.g. transistor-transistor logic (TTL) and complementary metal oxide semiconductor (CMOS); characteristics of chips, e.g. 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, e.g. logic probe, signature analyser

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

Simulation of digital circuit: types of circuit, e.g. three input combinational circuit, counter, shift register; types of gates/sequential circuit, e.g. R-S bi-stables, JK bi-stable, 3-stage counter, 3-stage shift-register based on JK or D-type bi-stables; instrument simulation e.g. on/off indicator, logic probe, word generator, logic analyser; records of performance against given design requirement, e.g. 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 function of different types of diodes, transistors and logic gates in different electronic circuit applications		
P2 explain the operation of two different types of transistor, one in an analogue and one in a digital circuit		
P3 build two different types of analogue circuit using operational amplifiers, testing appropriately	M1 modify an existing analogue circuit to achieve a given revised specification by selecting and changing the value of one of the components	
P4 explain the operation of three different logic gates with appropriate gate symbols, truth tables and Boolean expressions		
P5 build a combinational logic circuit that has three input variables, testing appropriately	M2 modify a digital circuit to achieve a given revised specification by selecting and changing up to two logic gates	D1 compare and contrast two different types of logic circuits, referencing five key characteristics

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:
P6 build a sequential circuit using integrated circuit(s), testing its efficiency	M3 minimise a three input variables combinational logic circuit containing three gates	
P7 use a computer software package to simulate the construction and testing of an analogue circuit with three different types of components	M4 explain the benefits and limitations of a computer software package used to simulate the construction and testing of both analogue and digital circuits.	D2 analyse the effects of changing the values of circuit parameters on the performance of an analogue circuit containing transistors.
P8 use a computer software package to simulate the construction and testing of a digital logic circuit with three gates.		

Essential guidance for tutors

Assessment

The learning outcomes and related criteria can be assessed in any order. The criteria P1, P2 and P3 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 (P3) that would allow learners to explain the operation of two different types of diodes, transistors and logic gates (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 P4.

The last two pass criteria, P7 and P8, could be covered by a third assignment, 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 from the one used in P3, 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). M4 could then be completed as this requires an explanation of the benefits and limitations of a computer software package, essentially encompassing P7 and P8.

To achieve D1, 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.

D2 requires an analysis, using a simulation package, of the effects on the performance of an analogue circuit containing transistors of changing the values of circuit parameters (for example components or component values, input/output voltages or signals). 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.

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 Pearson assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, 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.	<p>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.</p> <p>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.</p>

Criteria covered	Assignment title	Scenario	Assessment method
P4, P5, P6, M2, M3, D1	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, M4, D2	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.

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 prototyping, 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

Textbooks

Bell D – *Fundamentals of Electronic Devices and Circuits* (Oxford University Press, 2007) ISBN 9780195425239

Tooley M – *Electronic Circuits: Fundamentals and Applications* (Routledge, 2006) ISBN 9780750669238