Unit 57: Principles and Applications of Analogue Electronics

Unit code: K/600/6744

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will provide learners with an understanding of analogue electronics and the skills needed to design, test and build analogue circuits.

Unit introduction

Although digital circuits have become predominant in electronics, most of the fundamental components in a digital system, particularly the transistor, are based on analogue devices. Advances in technology mean that, as transistors get smaller, it becomes more important when designing digital circuits to account for effects usually present in analogue circuits. This unit will give learners an understanding of the key principles and function of analogue electronics.

Analogue electronics are still widely used in radio and audio equipment and in many applications where signals are derived from analogue sensors and transducers prior to conversion to digital signals for subsequent storage and processing.

This unit will introduce learners to the basic analogue principles used in electronics, such as gain, loss and noise and the principles of a range of classes of amplifier. The unit will also cover the operation of analogue electronic circuit systems and their components, such as integrated circuits (ICs) and the sensors required in analogue (and some digital) circuits.

Learners will be able to apply their understanding of principles and operation in the design and testing of analogue electronic circuits for specified functions using electronic computer-based methods.

Finally, learners will build and test circuits such as a filter, amplifier, oscillator, transmitter/receiver, power control, or circuits/systems with telecommunication applications. This will include the use of circuit assembly and testing methods, such as circuit diagrams, interpreting/recording measurements, analysis of performance and the use of a range of test equipment.

Learning outcomes

On completion of this unit a learner should:

1 Understand the principles of gain and loss and the function of amplifiers in analogue circuits

2 Understand the operation of analogue electronic circuit systems and their components

3 Be able to use computer-based techniques to design and test analogue electronic circuits for specified functions

4 Be able to build and test an analogue electronic circuit.

Unit content

1 Understand the principles of gain and loss and the function of amplifiers in analogue circuits

Gain and loss: definition and use of the decibel (dB), benefits of using the logarithmic unit for voltage/power gain; decibel reference to one milliwatt (dBm)

Noise: types of noise eg thermal, cross-talk, shot; effects of noise on typical circuits/components; signal-to-noise ratio

Transistor amplifier: classes of amplifier such as A, B, AB and C; feedback and its effects on gain, bandwidth, input and output impedance, noise and distortion

2 Understand the operation of analogue electronic circuit systems and their components

Analogue integrated circuit (IC): use of and interpretation of manufacturers' data; IC operation eg gain, frequency, power consumption; typical IC systems eg 555 oscillators/timers, amplifiers (operational, power, instrumentation), voltage regulators (linear or switch mode), filters (switched capacitor), phase locked loop (PLL), power control (smart devices, MOSFET bridge driver), sensors (thermal, opto, magnetic), analogue switches

3 Be able to use computer-based techniques to design and test analogue electronic circuits for specified functions

Propose design solutions: use of integrated circuits; use of simulation program with integrated circuit emphasis (SPICE)/electronic computer aided design (ECAD) techniques to analyse and develop circuits

Circuits and systems: eg filters (anti-aliasing, mains, notch), amplifiers (specified gain/frequency response, power), oscillators (voltage controlled oscillator (VCO) for frequency shift keying (FSK) or frequency modulation (FM)), PLL for FSK or FM demodulator, opto-transmitter/receiver (fibre link, remote control), power supplies (DC/AC converter, non-interruptible), sensors (environmental), power control (stepper motor driver), circuits and systems with telecommunication applications

Circuit simulation and testing: functional testing using a supplied test specification to determine circuit design inputs and outputs eg test-point voltages, output signals

4 Be able to build and test an analogue electronic circuit

Circuit assembly: use of prototyping methods eg breadboard, stripboard, printed circuit board (PCB); typical circuits eg filter, amplifier, oscillator, transmitter/receiver, power control, circuits/systems with telecommunication applications

Circuit testing: use circuit diagrams; interpret/record measurements eg voltage, frequency, noise, gain; analysis of performance; use of test equipment eg oscilloscope, signal generator, digital multimeters, frequency meter/spectrum analyser, virtual (computer-based) instruments, data capture

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 decibel as a measure of gain and noise	**M1** compare the practical performance of two different classes of amplifier	**D1** analyse the results of a designed electronic circuit with reference to measured signals in terms of both voltage and frequency
P2 describe two different classes of amplifier	**M2** justify the selection of specific analogue integrated circuit devices to meet a given design specification	**D2** evaluate computer-based and practical methods used to analyse the behaviour of analogue circuits with respect to their effectiveness in the design process.
P3 explain four different effects of feedback on the function of an amplifier	**M3** evaluate the performance of an analogue circuit by interpreting measured results.	
P4 explain the operation of three common analogue integrated circuit devices		
P5 describe two system applications for each of three common analogue integrated circuit devices		
P6 use computer-based simulation methods to produce a possible design solution for three different analogue circuit systems [IE1, CT1]		
P7 use computer-based simulation methods to simulate and test the performance of a given analogue electronic circuit [IE1]		
P8 build and test an electronic circuit to a given analogue circuit specification [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 can be delivered as a stand-alone unit or with *Unit 58: Construction and Applications of Digital Systems*.

This unit assumes that learners already have a certain level of related knowledge and are able to build circuits using a range of methods. It also assumes they can use a range of test and measurement instruments. Tutors will need to assess these skills at the beginning of the unit and either adjust their delivery style to incorporate further training or ensure that the appropriate skills are achieved through other units of study.

A practical approach to delivery will be most effective and tutors should reinforce the more theoretical aspects through hands-on activities and practical assignments. Ideally, centres will have strong links with local employers so that learners can apply their knowledge to real work-based applications of the technology. Alternatively, visits to appropriate exhibits, trade fairs and manufacturers can be used to help put the unit into context.

When delivering the benefits of using the decibel (dB) tutors should point out the need to simply add/subtract gains.

The high practical content of this unit means that tutors must give appropriate attention to health and safety. This is of particular importance when relatively large groups may be working in an electronics workshop environment with minimal supervision as would be expected at this level of work.

Learning outcome 4 could provide the focus for delivery with tutors developing a range of mini build and test projects. The content for learning outcome 3 provides a list of example circuits that could be used in small projects. The relevant theory, from learning outcomes 1 and 2 could then be integrated into the projects so that it is taught and applied to reinforce relevance and application.

The use of 'eg' 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 methods of assessment • explain the use of the decibel as a measure of gain and noise. *Practical learner activities:* • determine the voltage gain of a transistor amplifier .
Prepare for and carry out **Assignment 1: Principles of Gain and Loss** (P1).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain the different types of transistor amplifier and effects of feedback. *Practical learner activities:* • investigate and comparing different types of transistor amplifier.
Prepare for and carry out **Assignment 2: Amplifier Types and Functions** (P2, P3, M1).
Whole-class teaching: • explain use of manufacturers' data • explain and demonstrate the operation of integrated circuits • explain operation of typical integrated circuit systems. *Practical learner activities:* • investigate the operation of different integrated circuit devices.
Prepare for and carry out **Assignment 3: Analogue Integrated Circuits** (P4, P5, M2).
Whole-class teaching: • explain and demonstrate the use of computer-based simulation techniques to analyse and develop analogue circuits • explain the applications of different circuits and systems • explain and demonstrate simulation and testing of circuits to determine circuit design inputs and outputs. Practical learner activities: • design and test analogue circuits for a range of different functions.
Prepare for and carry out **Assignment 4: Design and Simulation of Analogue Circuits** (P6, P7, M3, D1).
Whole-class teaching: • explain and demonstrate use of prototyping methods for assembly of a variety of different circuits • explain and demonstrate the use of circuit diagrams and test equipment to interpret and record measurements and to analyse circuit performance. Practical learner activities: • use circuit assembly and testing methods.
Prepare for and carry out A**ssignment 5: Building and Testing Analogue Circuits** (P8, D2).
Feedback on assessment and unit evaluation.

Assessment

This unit could be assessed through a carefully structured series of activities and assignments that link to each other and culminate in the building and testing of an electronic circuit to a given analogue circuit specification.

P1 could be assessed with a short assignment to determine the voltage gain of a transistor amplifier, expressing this first as a ratio and then converting the voltage gain (or loss) into decibels (dB). Learners could also measure the output noise power (in the absence of a signal) and use this to determine the signal to noise ratio for a given input signal voltage.

The assignment should ensure that it includes tasks to cover all the required aspects of content – definition and use of the decibel (dB), benefits of using the logarithmic unit for voltage/power gain and decibel reference to one milliwatt (dBm). The assignment must also provide an opportunity to consider the required aspects of

noise – types of noise, effects of noise on typical circuits/components, signal-to-noise ratio. Setting this within the context of the amplifier investigated by each learner will provide scope for authentic evidence based on individual practical work. Ensuring that each learner is working with a slightly different amplifier could further reinforce this.

Assessment of P2 could build on the learner's work with transistor amplifiers by considering and describing two different classes of amplifier (eg class A and class B). The amplifiers described for P2 could then be used for P3, although the choice of amplifiers must ensure that between them, the learner is able to explain at least four different effects of feedback on the function of an amplifier (eg its effect on gain/bandwidth/input and output impedance/noise and distortion). This assignment could be designed to also provide learners with an opportunity to work towards M1 by comparing the practical performance of the two different classes of amplifier. An alternative to using two separate amplifiers (one of each class) is that of simply switching the bias of the output stage for operation in either class A or class B mode.

The third assignment, to cover P4 and P5, could require learners to explain the operation of three common analogue integrated circuit (IC) devices. One or more of these could then be used in their final circuit for P8. The explanation will need to address the learner's use and interpretation of manufacturers' data and the operation of each IC for typical IC systems. In addition, learners are required to describe two system applications of each IC. Again, one of these could be the focus of the build and test project for P8. A further task could be added to cover M2, requiring learners to justify the selection of specific IC devices to meet a given design specification. Note the use of 'devices' in the criterion. This implies that the system has more than one IC device operational.

Assessment of P6 and P7 could be through a fourth assignment requiring learners to use SPICE/ECAD to produce circuit designs, with annotated printouts of three different circuits, eg filters, amplifiers, oscillators. A more extensive range of examples is given within the unit content section for this criterion. Learners could then simulate and test the performance of one of these in detail (eg for DC levels/gain/frequency/bandwidth), which would give an opportunity to achieve P7. In addition, evidence of learners' ability to evaluate the performance of one of these analogue circuits by interpreting measured results, could lead to achievement of M3. If learners are also able to analyse the results of a designed electronic circuit with reference to measured signal in terms of both voltage and frequency then they could achieve D1. Note that another opportunity exists to achieve M3 and D1 t during the build and test work for P8. However, M3 or D1 only needs to be achieved once and it is not important whether this is through simulated or real circuit evaluation and analysis.

Finally, P8 should bring together all of the learner's experience within one practical build and test of an actual circuit. This could be built using breadboard, stripboard or printed circuit board (PCB) techniques. The circuit could be one of the simulated circuits used for P6 or P7. Learners could reflect on the techniques carried out for P6, P7 and P8 and work towards achievement of D2. For example, the evaluation of the SPICE/ECAD-approach (P6/P7) compared with the practical methods (P8) used to analyse the behaviour of an analogue circuit with respect to their effectiveness in the design process.

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	Principles of Gain and Loss	A technician has been asked to determine the voltage gain of a transistor amplifier.	A practical investigation evidenced through a written report.

Criteria covered	Assignment title	Scenario	Assessment method
P2, P3, M1	Amplifier Types and Functions	A technician needs to compare different types of amplifier to determine the best for an application in the workplace.	A practical investigation evidenced through a written report.
P4, P5, M2	Analogue Integrated Circuits	A technician needs to explain the operation of circuit devices to a new apprentice.	A written description of circuit devices including justification of choice of amplifiers for specific applications.
P6, P7, M3, D1	Design and Simulation of Analogue Circuits	A technician has been asked to design analogue electronic circuits for three different applications.	A practical activity evidenced through annotated printouts, observation records and a written report interpreting measured results.
P8, D2	Building and Testing Analogue Circuits	A technician needs to build and test an analogue electronic circuit.	A practical design and build activity evidenced through observation records and a written report.

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:

Level 1	Level 2	Level 3
		Electrical and Electronic Principles
		Electronic Circuit Design and Manufacture
		Electronic Measurement and Testing
		Construction and Applications of Digital Systems

This unit contributes towards the knowledge and understanding requirements of the SEMTA Level 3 NVQ in Electrical and Electronic Engineering, particularly:

- Unit 15: Checking the Compliance of Electronic Components Against the Specification
- Unit 16: Assembling and Checking Printed and Allied Electronic Circuits
- Unit 17: Assembling and Wiring Electronic Equipment and Systems
- Unit 18: Testing Post-Production Electronic Components and Circuits.

Essential resources

Centres will need to provide access to an electronics workshop including facilities for circuit construction using breadboards/stripboard/PCB methods together with the relevant tools and equipment.

Centres will also need to provide the basic components and appropriate specialised integrated circuits together with relevant catalogues, application notes and data sheets.

Access to SPICE/ECAD facilities that permit circuit simulation and testing is essential. Electronic test equipment will also need to be provided to meet the requirements of the unit content and assessment and grading criteria.

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 case studies of 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

Storey N – *Electronics: A Systems Approach* (Prentice Hall, 2009) ISBN 9780273719182

Tooley M – *Electronics 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 using computer-based simulation methods to produce design solutions for analogue circuits
Creative thinkers	generating ideas and exploring possibilities when using computer-based simulation methods to produce design solutions for analogue circuits
Self-managers	organising time and resources and prioritising actions when building and testing analogue 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 ...
Independent enquirers	planning and carrying out research and analysing and evaluating information relevant to analogue principles and applications

Skill	When learners are ...
Team workers	collaborating with other when working in groups to assemble and test analogue circuits.