Unit 60: Principles and Applications of Analogue Electronics

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

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 is still widely used in radio and audio equipment and in a wide range of 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 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 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

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 describes 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 decibel as a measure of gain and noise P2 describe two different classes of amplifier and explain four different effects of feedback on the function of an amplifier P3 explain the operation of three common analogue integrated circuit devices and describe two system applications of each P4 use computer-based simulation methods to produce a possible design solution for three different analogue circuit systems P5 use computer-based simulation methods to simulate and test the performance of a given analogue electronic circuit P6 build and test an electronic circuit to a given analogue circuit specification.	M1 compare the practical performance of two different classes of amplifier M2 justify the selection of specific analogue integrated circuit devices to meet a given design specification M3 evaluate the performance of an analogue circuit by interpreting measured results.	D1 analyse the results of a designed electronic circuit with reference to measured signal in terms of both voltage and frequency D2 evaluate computer-based and practical methods used to analyse the behaviour of an analogue circuits with respect to their effectiveness in the design process.

Essential guidance for tutors

Delivery

This unit can be delivered as a stand-alone unit or can be co-delivered with *Unit 61*: *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 have the ability to 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) — the need to simply add/subtract gains should be pointed out.

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 by 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 as small projects which can be focused on. 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.

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 upon the learner's work with transistor amplifiers by considering and describing two different classes of amplifier (eg class A and class B). 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 P3 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 P6. 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 P6. 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 P4 and P5 can be through a fourth assignment. This will require 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 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 P5. 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 demonstrate their ability 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 for M3 and D1 to be achieved during the build and test work for P6. 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, P6 should bring all of the learner's experience together 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 well be one of the simulated circuits used for P4 or P5. This could include an opportunity for learners to reflect on the techniques carried out for P4, P5 and P6 and work towards achievement of D2. For example the evaluation of the SPICE/ECAD-approach (P4/P5) compared with the practical methods (P6) used to analyse the behaviour of an analogue circuit with respect to their effectiveness in the design process.

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

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.

The unit can be effectively linked to *Unit 5*: *Electrical and Electronic Principles*, *Unit 61*: *Construction and Applications of Digital Systems*, *Unit 34*: *Electronic Circuit Manufacture* and *Unit 54*: *Electronic Measurement and Testing*.

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. In addition, one or more internet-connected PCs should be available so that learners can locate data and information using the worldwide web.

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.

Indicative reading for learners

Storey N — *Electronics*: *A Systems Approach* (Prentice Hall, 2006) ISBN 0131293966

Tooley M — *Electronics 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. Tutors 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:**
• using an oscilloscope and other test equipment to make and record appropriate measurements • carrying out circuit calculations, interpreting and presenting electronic circuit test results.	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 proportions 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:**
• researching and describing/explaining the decibel as a measure of gain and noise, different classes of amplifier and the operation of analogue integrated circuit devices.	C3.2 Read and synthesise information from at least **two** documents about the same subject. Each document must be a minimum of 1000 words long. 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 and communication technology Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• researching the decibel as a measure of gain and noise, different classes of amplifier and the operation of analogue integrated circuit devices • developing their reports and presenting their findings.	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.
Problem solving Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• using SPICE/ECAD to produce design solutions for analogue circuit systems.	PS3.1 Explore a problem and identify different ways of tackling it. PS3.2 Plan and implement at least one way of solving the problem. PS3.3 Check if the problem has been solved and review your approach to problem solving.