

Unit 108: Aerospace Electronic Devices and Circuits

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

Modern aircraft rely on an increasingly sophisticated range of electronic components and systems used for actuation, control, instrumentation and monitoring. These systems are often integrated into comprehensive automatic flight control systems (AFCS) that allow an aircraft to fly in difficult situations (such as reduced visibility) without continuous intervention from the crew.

This unit aims to broaden the knowledge that learners will have already gained from their study of *Unit 5: Electrical and Electronic Principles*, which is an essential prerequisite. It also focuses on the specific application of electronics in a variety of avionic systems used for indicating, controlling and regulating aircraft parameters.

The unit will introduce learners to semiconductor theory and the basic operation of diodes and transistors, two of the most important building blocks in electronic circuits.

Filters are used in many avionic applications and the unit introduces the fundamental characteristics and operation of different types of filter including low-pass, band-pass, band-stop and high-pass types.

Learners will be introduced to the fundamental concepts of open- and closed-loop systems and how various functional circuit blocks (transducers, amplifiers, comparators, etc) can be arranged to form a functional closed-loop control system. Such systems are used extensively in aircraft instrumentation and as a means of controlling and regulating aircraft systems generally.

When taken with *Unit 5: Electrical and Electronic Principles* and *Unit 85: Aircraft Electrical Machines*, this unit covers the underpinning knowledge of the European Aviation Safety Agency (EASA) Part 66 *module 3: Electrical Fundamentals*. The unit will also be useful for those seeking employment with the armed forces or the aircraft manufacturing industry.

Learning outcomes

On completion of this unit a learner should:

- 1 Understand semi-conductor theory and the fundamental construction and operation of diodes and transistors
- 2 Understand filter types, characteristics and operation
- 3 Understand the function and operation of open- and closed-loop systems
- 4 Be able to apply electronic theory to the construction and operation of aircraft servomechanisms.

Unit content

1 Understand semi-conductor theory and the fundamental construction and operation of diodes and transistors

Theory: molecular structure of conductors, semiconductors and insulators; doping (trivalent and pentavalent impurities); structure of P-type and N-type semiconductor materials; conduction in semiconductors; majority and minority carriers

Diodes: the P-N junction; symbol and construction of a junction diode; forward and reverse bias and direction of current flow; diode applications (rectification, signal detection, switching); functional testing of diodes (forward and reverse resistance measurement)

Transistors: symbols and constructions of PNP and NPN bipolar junction transistors (BJT); transistor current gain; functional testing of BJT (forward and reverse resistance measurement for each junction)

2 Understand filter types, characteristics and operation

Types: low-pass, high-pass, band-pass and band-stop; single section and multiple section; active and passive types

Characteristics: eg frequency response, cut-off frequency, bandwidth, insertion loss and attenuation

Operation: simple passive filters based on T-section and pi-section R-C, R-L and R-C-L networks

3 Understand the function and operation of open- and closed-loop systems

Function: difference between open and closed-loop systems; block schematic diagrams for typical systems showing functional elements

Operation: terminology used with closed-loop systems (feedback, input or demand, output, error, null, inertia, dead-band, overshoot, undershoot, rise-time, settling time, damping, oscillation); formulae (relationship between output and input given forward gain and feedback ratio); time response of a typical closed-loop system with different amounts of damping applied

4 Be able to apply electronic theory to the construction and operation of aircraft servomechanisms

Construction and operation: transducers and sensors eg potentiometers, tachogenerators, linear variable differential transducers (LVDT), resistive strain gauges, semiconductor strain gauges, piezoelectric sensors, temperature sensors, light sensors, vibration sensors, flow sensors, accelerometers; E-I transformers; inductance transmitters; capacitance transmitters; synchronous transmitters; synchro resolvers and transformers; phase sensitive detectors; synchro defects (reversal of stator or rotor connections, hunting); amplifiers and filters

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:
<p>P1 explain the structure of conductors, semiconductors and insulators and the production of P-type and N-type semiconductor materials by doping with trivalent and pentavalent impurities respectively</p> <p>P2 explain the principle of conduction in semiconductors in relation to majority and minority carriers and the action of a P-N junction when forward and reverse biased</p> <p>P3 describe and explain the construction, properties, operation, and circuit symbols for PNP and NPN bipolar junction transistors (BJTs)</p> <p>P4 explain the functional testing of diodes (using forward and reverse resistance measurement) and transistors (using forward and reverse resistance measurement for each junction)</p>	<p>M1 determine the functional state of three junction diodes and three BJTs using a multi-range meter</p> <p>M2 determine the current gain of a BJT using simple a power supply and a multi-range meter</p> <p>M3 determine the pass-band loss, cut-off frequencies and bandwidth of a passive filter using a signal generator and basic test instruments</p> <p>M4 determine the rise-time, settling time and overshoot/undershoot of a simple closed-loop servo system under various conditions of demand, load and damping.</p>	<p>D1 design and construct simple low-pass and high-pass filters for a given cut-off frequency and analyse their performance using laboratory test equipment</p> <p>D2 diagnose and correct three different fault conditions present in a closed-loop servo system.</p>

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:
<p>P5 explain the operation of low-pass, high-pass, band-pass and band-stop filters in relation to frequency response, cut-off frequency and bandwidth and describe simple passive filters based on T-section and pi-section R-C, R-L and R-C-L networks</p> <p>P6 explain, with the use of block schematic diagrams, the functions of open-loop and closed-loop systems and the terminology used to describe their operation</p> <p>P7 explain the construction and operation of a typical aircraft servomechanism with reference to the function of the individual components used in the system.</p>		

Essential guidance for tutors

Delivery

All four learning outcomes are linked and the delivery strategy used should ensure that these links are maintained. Learning outcome 1 is the most likely starting point for delivery, as it will establish much of the underpinning knowledge and skills required for the rest of the unit content.

The unit could be delivered through a combination of theory lessons, demonstrations and practical investigations carried out in an avionics workshop or electronics laboratory.

Delivery of learning outcome 1 should include practical investigations of junction diodes and bipolar junction transistors (BJTs). During these investigations, learners should be encouraged to carry out forward and reverse resistance measurements of the semiconductor junctions, relating the measured values to what would be expected from previous theory. Learners should also be shown how to identify a semiconductor device that has an open-circuit or short-circuit junction. In order to demonstrate the concept of current gain and amplification, a simple investigation can be carried out in which learners measure the input (base) and output (collector) current in a junction transistor.

Learning outcome 2 should begin with a reminder of the basic properties and characteristics of resistors, capacitors and inductors. Learners should recall how capacitive and inductive reactance varies with frequency and should be encouraged to perform simple calculations of reactance at different frequencies (for example, 100 Hz and 10 kHz) for capacitors and inductors of given values.

Learners should be introduced to the different types of filter (low-pass, high-pass, band-pass and band-stop) and the frequency response for each type. Practical investigations of ready-made filter circuits will provide learners with an opportunity to plot frequency response and measure filter characteristics.

The delivery of learning outcome 3 should be based on introductory theory but should be treated in a descriptive rather than mathematical way. However learners should be introduced to the basic equations for the closed-loop gain, using positive and negative feedback in terms of open-loop gain and feedback ratio. Learners should also be introduced to the time response of closed-loop systems and this can be done through demonstrations or practical investigations in which learners make measurements on model closed-loop systems (eg position controllers, speed controllers, temperature controllers).

Learning outcome 4 could be delivered through an investigation of the construction and operation of aircraft servomechanisms. Learners should be given the opportunity to familiarise themselves with the components used in servomechanisms (such as transducers, amplifiers, rectifiers, resolvers, etc) and to investigate a complete servo system on which measurements can be made and faults can be placed.

Wherever possible, centres should enable learners to experience a range of electronic test equipment (specifically multimeters and oscilloscopes) that reflect typical and current use in the aerospace industry. Tutors should ensure that learners are aware of the safe use of test equipment (and the need for routine inspection and calibration) in an aircraft workshop and industry setting.

Centres are encouraged to relate theory to real aircraft and aerospace applications wherever possible. Industrial visits or work experience could be used to support delivery and to give learners an appreciation of the use of electrical components and system within the aerospace industry and in aircraft maintenance in particular. Wherever possible, learners should be encouraged to refer to relevant aircraft maintenance manuals for recommended procedures and information on the operation of components and systems.

Assessment

Assessment evidence for this unit could be developed through a combination of assignments, investigations and conventional written examinations with short- and long-answer questions.

The method of assessment preferred by national legislative bodies relative to the aerospace industry involves the use of multiple choice questions. Many centres may have existing banks of multiple choice questions designed to prepare and test learners for Module 3 of EASA Part 66. Where learners are aiming to achieve recognised licensed status, this method of assessment could be adopted as a means of supporting and checking learning. Multiple-choice questions should not, however, be used as assessment instruments for the purposes of this unit.

It is likely that at least three assessment instruments will be required for this unit. If practical investigations and tests are also used then the total number of pieces of assessed work could be even more than this. This should be carefully considered so that it does not place an unduly heavy assessment burden on learners or the tutor.

Wherever possible, the evidence should be handed in at the end of an assignment. This will help control authenticity of evidence and also keep the assessment activities short, sharp and relevant. Clearly, the ability to work safely in an aircraft environment should be paramount and centres should ensure that learners are adequately briefed concerning the hazards that exist.

The three assessment instruments could be based on:

- semiconductors (providing evidence that will contribute to P1, P2, P3, P4, M1 and M2)
- filters (providing evidence that will contribute to P5, M3 and D1)
- servomechanisms (providing evidence that will contribute to P6, P7, M4 and D2).

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*. It also has links with *Unit 85: Aircraft Electrical Machines*.

The unit also contributes towards the knowledge and understanding for the SEMTA Level 3 NVQ in Engineering Maintenance, including:

- Unit 4: Designing Electronic Circuit Board Layouts Using CAD Tools
- Unit 10: Selecting and Preparing Materials and Components for Manufacturing
- Unit 12: Monitoring and Analysing Data from Electronic Circuit Manufacturing Processes
- Unit 13: Adjusting and Sustaining Electronic Circuit Manufacturing Processes
- Unit 15: Checking the Compliance of Electronic Components Against the Specification
- Unit 17: Assembling and Wiring Electronic Equipment and Systems
- Unit 18: Testing Post-Production electronic components and Circuits.

The unit also covers the underpinning knowledge of the European Aviation Safety Agency (EASA) Part 66 module 3: Electrical Fundamentals.

Essential resources

It is essential that learners have access to a well equipped electronic/avionic workshop or electronic laboratory with up to date electrical test instruments such as digital and analogue multimeters, waveform and function generators and oscilloscopes. Centres will also need to provide a range of typical electronic components used in aircraft and aerospace applications generally. Learners will also benefit from access to 'live' aircraft, spare parts and maintenance information found in a typical aviation technical library.

In order to deliver learning outcome 2, a selection of different pre-built filters should be available for learners to examine and investigate. For learning outcome 3, one or more model control systems should be available for learners to use in conjunction with their investigation of closed-loop control systems. Finally, in order to deliver learning outcome 4, a model of a typical aircraft servomechanism should be available on which faults can be introduced and diagnosed by learners.

Indicative reading for learners

Dingle L and Tooley M – *Aircraft Engineering Principles* (Elsevier, 2005) ISBN 075065015X

Eismin T – *Aircraft Electricity and Electronics* (McGraw-Hill, 1994) ISBN 0711382864

Tooley M – *Electronic Circuits: Fundamentals and Applications* (Third Edition, 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.

Communication Level 3	
When learners are:	They should be able to develop the following key skills evidence:
<ul style="list-style-type: none"> • explaining the structure of conductors, semiconductors and insulators • explaining the principle of conduction in semiconductors • explaining the functional testing of diodes • describing and explaining the construction and operation of bipolar junction transistors • explaining the operation of filters • explaining open-loop and closed-loop systems • explaining the operation of an aircraft servomechanism. 	<p>C3.3 Write two different types of documents each one giving different information about complex subjects.</p> <p>One document must be at least 1000 words long.</p>