Unit 75: Aircraft Electronic Devices and Circuits

Unit code: T/600/7217

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit focuses on the specific application of electronics in a variety of avionic systems used for indicating, controlling and regulating aircraft parameters.

Unit introduction

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 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.

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

Diodes: characteristics and properties; the P-N junction; symbol and construction of a junction diode; forward and reverse bias and direction of current flow; types (light emitting diode, photo conductive diode, varistor, rectifier diodes); diode applications (rectification, signal detection, switching); diodes in series and parallel; characteristics and use of silicon controlled rectifiers; thyristors; 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 Understand how electronic theory is applied 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

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 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	**M1** determine the functional state of three junction diodes and three BJTs using a multi-range meter	**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
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	**M2** determine the current gain of a BJT using simple a power supply and a multi-range meter	**D2** diagnose and correct three different fault conditions present in a closed-loop servo system.
P3 describe and explain the construction, properties, operation, and circuit symbols for PNP and NPN bipolar junction transistors (BJTs)	**M3** determine the pass-band loss, cut-off frequencies and bandwidth of a passive filter using a signal generator and basic test instruments	
P4 explain the functional testing of diodes (using forward and reverse resistance measurement) and transistors (using forward and reverse resistance measurement for each junction) [IE1]	**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.	
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		

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	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		
P7	explain the construction and operation of a typical aircraft servomechanism with reference to the function of the individual components used in the system.		

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

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 encourage 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.

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 content, scheme of work and method of assessment • explain the molecular structure of conductors, semi-conductors and insulators • explain P-type and N-type semi-conductors and conduction in semi-conductors • explain the characteristics, properties and applications of diodes and describe and demonstrate functional testing • explain the construction of bipolar junction transistors and describe and demonstrate functional testing of BJTs. *Practical workshop activities:* • practical investigation and functional testing of junction diodes and bipolar junction transistors.
Prepare for and carry out **Assignment 1: Construction and Operation of Semiconductors** (P1, P2, P3, P4, M1, M2).
Whole-class teaching: • review of properties and characteristics of resistors, capacitors and inductors • describe the different types of filters and explain their characteristics and operation. Practical workshop activities: • investigation of filter circuits to plot frequency response and measure filter characteristics.
Prepare for and carry out **Assignment 2: Operation of Filters** (P5, M3, D1).
Whole-class teaching: • explain the difference between open- and closed-loop systems • explain and demonstrate the use of schematic diagrams for typical systems • describe the terminology used with closed-loop systems • explain the use of equations for closed-loop gain, using positive and negative feedback in terms of open-loop gain and feedback ratio • explain the time response of a typical closed-loop system. *Practical workshop activities:* • investigation of closed-loop systems.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain the construction and operation of transducers and sensors • explain the construction and operation of E-I transformers, inductance transmitters, capacitance transmitters and synchronous transmitters • explain the construction and operation of synchro resolvers and transformers, phase sensitive detectors and amplifiers and filters. *Practical workshop activities:* • practical investigation of aircraft servomechanisms and their components • carrying out measurements on servomechanisms.
Prepare for and carry out **Assignment 3: Construction and Operation of Servomechanisms** (P6, P7, M4, D2).
Feedback on assessment and unit evaluation.

Assessment

Assessment evidence for this unit could be developed through a combination of written assignments, practical investigations and conventional 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.

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, P2, P3, P4, M1, M2	Construction and Operation of Semiconductors	A technician needs to produce a report on the construction and operation of semi-conductors, diodes and transistors.	Written assignment.
P5, M3, D1	Operation of Filters	A technician has been asked to produce a report on the operation of filters.	Written assignment.
P6, P7, M4, D2	Construction and Operation of Servomechanisms	A technician has been asked to produce a report on the function of open- and closed-loop systems and the operation of aircraft servomechanisms.	Written assignment.

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
		Aircraft Electrical Machines

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.

This unit also support the underpinning knowledge and understanding for the Level 3 NVQ in Aeronautical Engineering, particularly *Unit 120: Carrying Out Fault Diagnosis on Aircraft Avionics Components or Systems.*

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.

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

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

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 explaining the use of functional testing of diodes and transistors.

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 ...
Reflective learners	Setting goals with success criteria for their development and work.

Functional Skills – Level 2

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	explaining the construction, operation and function of aircraft electronic devices and circuits
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	investigating and researching aircraft electronic devices and circuits
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining the construction, operation and function of aircraft electronic devices and circuits.