Unit 56: Electrical and Electronic Principles in Engineering

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

Unit introduction

The modern world relies on electrical and electronic devices – from mobile telephones to jet aeroplanes, these devices have had an enormous impact on the way we live today. Without early engineers such as Faraday and Lenz, who studied the then new concept of electricity, many of the inventions we now take for granted would not have been developed.

The unit starts by developing and extending learners ' understanding of fundamental electrical and electronic principles through analysis of simple direct current (DC) circuits. Learners are then taken through the various properties and parameters associated with capacitance and inductance, before finally considering the application of single-phase alternating current (AC) theory. The unit will encourage learners to take an investigative approach through practical construction, measurement and testing of circuits and, where applicable, the use of computer-based circuit analysis and simulation.

For learners wishing to follow an electrical/electronic programme this unit is an essential building block that will provide the underpinning knowledge required for further study of electrical and electronic applications.

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 Be able to use circuit theory to determine voltage, current and resistance in direct current (DC) circuits

2 Be able to apply the concepts of capacitance in DC circuits

3 Know the principles and properties of magnetism

4 Be able to use single-phase alternating current (AC) theory

Unit content

1 Be able to use circuit theory to determine voltage, current and resistance in direct current (DC) circuits

DC circuit theory: voltage e.g. potential difference, electromotive force (emf); resistance e.g. conductors and insulators, resistivity, temperature coefficient, internal resistance of a DC source; circuit components (power source e.g. cell, battery, stabilised power supply; resistors e.g. function, types, values, colour coding; diodes e.g. types, characteristics, forward and reverse bias modes); circuit layout (DC power source, resistors in series, resistors in parallel, series and parallel combinations); Ohm's law, power and energy formulae e.g. $V = IR$, $P = IV$, $W = Pt$, application of Kirchhoff's voltage and current laws

DC networks: networks with one DC power source and at least five components e.g. DC power source with two series resistor and three parallel resistors connected in a series parallel arrangement; diode resistor circuit with DC power source, series resistors and diodes

Measurements in DC circuits: safe use of a multimeter e.g. setting, handling, health and safety; measurements (circuit current, voltage, resistance, internal resistance of a DC power source, testing a diode's forward and reverse bias)

2 Be able to apply the concepts of capacitance and determine in DC circuits

Capacitors: types (electrolytic, mica, plastic, paper, ceramic, fixed and variable capacitors); typical capacitance values and construction (plates, dielectric materials and strength, flux density, permittivity); function e.g. energy stored, circuits (series, parallel, combination); working voltage

Charging and discharging of a capacitor: measurement of voltage, current and time; tabulation of data and graphical representation of results; time constants

DC network that includes a capacitor: e.g. DC power source with two/three capacitors connected in series, DC power source

3 Know the principles and properties of magnetism

Magnetic field: magnetic field patterns e.g. flux, flux density (B), magnetomotive force (mmf) and field strength (H), permeability, B/H curves and loops; ferromagnetic materials; reluctance; magnetic screening; hysteresis

Electromagnetic induction: principles e.g. induced electromotive force (emf), eddy currents, self and mutual inductance; applications (electric motor/generator e.g. series and shunt motor/generator; transformer e.g. primary and secondary current and voltage ratios); application of Faraday's and Lenz's laws

4 Be able to use single-phase alternating current (AC) theory

Single phase AC circuit theory: waveform characteristics e.g. sinusoidal and non-sinusoidal waveforms, amplitude, period time, frequency, instantaneous, peak/peak-to-peak, root mean square (rms), average values, form factor; determination of values using phasor and algebraic representation of alternating quantities e.g. graphical and phasor addition of two sinusoidal voltages, reactance and impedance of pure R, L and C components

AC circuit measurements: safe use of an oscilloscope e.g. setting, handling, health and safety; measurements (periodic time, frequency, amplitude, peak/peak-to-peak, rms and average values); circuits e.g. half and full wave rectifiers

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 use DC circuit theory to calculate current, voltage and resistance in DC networks	M1 use Kirchhoff's laws to determine the current in various parts of a network having four nodes and the power dissipated in a load resistor containing two voltage sources	
P2 use a multimeter to carry out circuit measurements in a DC network		
P3 Describe the forward and reverse characteristics of two different types of semiconductor diode		
P4 describe the types and function of capacitors		
P5 carry out an experiment to determine the relationship between the voltage and current for a charging and discharging capacitor		
P6 calculate the charge, voltage and energy values in a DC network for both	M2 explain capacitance, charge, voltage and energy in a network containing a series-	

three capacitors in series and three capacitors in parallel	parallel combination of three capacitors	
P7 describe the characteristics of a magnetic field		
P8 describe the relationship between flux density (B) and field strength (H)		
P9 describe the principles and applications of electromagnetic induction	M3 explain the application of electromagnetic induction in motors and generators	D1 evaluate the performance of a motor and a generator by reference to electrical theory.
P10 use single phase AC circuit theory to determine the characteristics of a sinusoidal AC waveform	M4 compare the results of adding and subtracting two sinusoidal AC waveforms graphically and by phasor diagram.	D2 analyse the operation and the effects of varying component parameters of a power supply circuit that includes a transformer, diodes and capacitors
P11 use an oscilloscope to measure and determine the inputs and outputs of a single phase AC circuit.		

Essential guidance for tutors

Assessment

Much of the evidence for the pass criteria can be achieved by practical experimentation with real components and circuits and computer-based software packages, where appropriate.

It is likely that at least five assessment instruments will be required for this unit. If practical work 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 high assessment burden on learners or the tutor.

Wherever possible, practical work should lead to a final product that can be handed in for assessment at the end of the session without further need for report writing. This will help control authenticity of evidence and also keep the assessment activities short, sharp and relevant.

Clearly, the ability to safely use a multimeter (P2) will require process evidence, i.e, it will need to be observed by the tutor during relevant practical activities. Tutors could capture this evidence by using an appropriate record of observation and oral questioning of each learner during the practical activities used for delivery.

The assessment of the use of circuit theory to calculate current, voltage and resistance in DC networks (P1) could be achieved by using a paper-based or computer-based method. However, it is essential that centres combine any testing of this sort with practical hands-on experience of real circuits and components. This could be achieved by prototyping circuits using simulation software to establish theoretical circuit values, followed by learners building the circuit and physically checking theory against actual results by measurement. Whichever method is used, centres need to ensure that sufficient product evidence is available of the circuit being used/developed and the formulae selected/used to determine the required current, voltage or resistance values. This is particularly important where computer software is used that does not have a facility to print results or where print-outs do not show sufficient detail to meet the criteria.

The description of the forward and reverse characteristics of two types of semi-conductor diode (P3) will require the use of a multimeter, power supply, ammeter with shunt, and a switch resistor box.

For P4, learners will need to describe the full range of types of capacitors (electrolytic, mica, plastic, and paper, ceramic, fixed and variable) including typical capacitance values, construction (plates, dielectric materials and strength, flux density, permittivity), their function and working voltages.

P5 requires learners to carry out a laboratory experiment to investigate the charging and discharging of a capacitor through a resistor. A simple but effective way of doing this is to use a power supply unit, a 500μF electrolytic capacitor, a stopwatch or clock and an AVO type multimeter, using the internal resistance of the meter as the resistor. Learners could then be asked to plot the graph of the growth of capacitor voltage against time and evaluate the time constant by comparing the results with standard theory.

P6 involves the calculation of charge, voltage and energy values for DC networks that include a DC power source with two/three capacitors connected in series and a DC power source with two/three capacitors connected in parallel.

The characteristics of magnetic fields for P7 could be demonstrated on an OHP by using magnets and iron filings. Learners could sketch the results and then make appropriate comparisons with expected theoretical results. For P8, learners need to explain the relationship between flux density (B) and field strength (H) with particular emphasis on BH curves and the use of different materials such as silicon iron and mild steel.

The evidence for P9 will be descriptive and requires learners to provide basic explanations of the principles and concepts of electromagnetic induction such as the movement of a conductor within a magnetic field.

P10 and P11 could link AC theory and practice with learners observing and measuring some of the fundamental characteristics of a single wave AC circuit. This will require the use of a multimeter and an oscilloscope to make appropriate comparisons of frequency, maximum and rms values.

M1 relates to the use of Kirchhoff's laws and here again learners should be encouraged to check their results by using a computer software package and/or practical experiment. This criterion naturally follows on from the work on resistors in series and parallel in DC circuits and, as such, could perhaps be incorporated into an assignment covering P1, P2 and M1. For M2, learners need to explain capacitance, charge, voltage and energy for specific capacitors in a series parallel combination. This extends the understanding from the pass grade criterion and could naturally form a next step in an assignment/assessment activity devised for P6. M3 is an extension of P9 requiring an explanation of the application of electromagnetic induction in motors and generators. M4 is intended as an exercise in the graphical addition of two sinusoidal voltages or currents, checking the values theoretically by calculation and also by practical means. This criterion could be linked to *Unit 3: Mathematics for Engineering Technicians* and, once learners had been taught the sine and cosine rules, could be used to provide evidence for both units.

D1 requires learners to evaluate the performance of motors and generators by reference to electrical theory. This can be achieved practically using appropriate experimental rigs that allow learners to compare their results with known characteristics for specific machines.

For D2, a basic power supply could be simulated to allow all the respective properties to be investigated without the hazards of high voltages or currents present. This could be achieved using a function generator as a source of sinusoidal alternating voltage, along with a small isolating transformer, diode rectifiers (half wave and bridge) smoothing capacitors and load resistors.

As suggested earlier, and illustrated in the assignment grid, it would be appropriate to use a five-assessment model to assess this unit.

The first is a theoretical assignment under controlled conditions could assess P1 and M1.

A second practical assignment could be used to assess P2 and P3, again possibly under controlled conditions.

Assignment 3 is to assess P4, P5, P6 and M2 and could be a mixed assignment, preferable not done under controlled conditions.

The fourth assignment could again be a mixed assignment to assess P7, P8, P9, M3 and D1.

Finally, assignment 5 assesses P10, P11, M4 and D2 and could be of a practical nature carried out under controlled conditions.

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, M1	DC Circuit Theory/Resistor Networks and Kirchhoff's Laws	An activity requiring learners to complete two tasks, one for each criterion. Task 1 involves learners evaluating current, voltage and resistance in a DC network and task 2 using Kirchhoff's laws to determine the current and power dissipated in a load resistor.	A report containing the results of calculations to evaluate current, voltage, resistance and power for a DC network using DC circuit theory and Kirchhoff's laws. Carried out under controlled conditions.
P2, P3	DC Circuit Theory/Measurement and Diodes	A practical activity requiring learners to complete measurements using a multimeter in a DC network for task 1 and compare the forward and reverse characteristics of two different types of semi-conductor diode for task 2	For both tasks learners will be required to complete pre-prepared response sheets with their measurements and make required responses together with a brief conclusion. Carried out under controlled conditions
P4, P5, P6, M2	Capacitors	A mixed activity comprising of four tasks. The first being of a descriptive nature to describe the types and function of capacitors	A written report containing written responses to the descriptive task, tabulated results and graphs for the practical, together with calculations for the DC networks

		Second, an experiment to determine the relationship between voltage and current for a charging and discharging capacitor. The third and fourth involve the learner carrying out calculations to evaluate capacitance, charge voltage and energy in DC networks	
P7, P8, P9, M3, D1	Magnetism, Transformers and Motor/Generators	A mixed activity comprising four tasks. The first three are to describe the characteristics of a magnetic field, explain the relationship between flux density and field strength, and describe the principles and applications of electromagnetic induction. The final task is to evaluate the performance of a motor and generator	A written report containing labelled diagrams illustrating magnetic fields, graphical plots of BH curves and diagrams with descriptions to illustrate principles and applications of electromagnetic induction For the distinction criteria it would be envisaged that comprehensive answers to pre-prepared response sheets together with diagrams, graphs and calculations need to be submitted
P10, P11, M4, D2	Single Phase AC	A practical activity requiring learners to complete four tasks. First, using single-phase AC theory to consider the characteristics of a sinusoidal AC waveform and	A written report using pre-prepared response sheets and graph paper carried out under controlled conditions.

		second, use an oscilloscope to evaluate the inputs and outputs of a single phase AC circuit. Third, to compare the results of the addition and subtraction of two sinusoidal AC waveforms. Fourth, to analyse the operation of a power supply.	

Essential resources

It is essential that learners have access to a well-equipped electrical and electronics laboratory with up-to-date electrical/electronic instruments such as digital and analogue multimeters, function generators and oscilloscopes. Centres will also need to provide appropriate circuit components, as identified in the unit content, together with the means to physically construct circuits.

With the increased use of computer-based methods for circuit design and simulation, centres are strongly advised to consider the provision of suitable hardware and software.

Indicative reading for learners

Textbooks

Boyce A, Cooke E, Jones R and Weatherill B – *BTEC Level 3 National Engineering Student Book* (Pearson, 2010) ISBN 9781846907241

Boyce A, Cooke E, Jones R and Weatherill B – *BTEC Level 3 National Engineering Teaching Resource Pack* (Pearson, 2010) ISBN 9781846907265

Bird J O – *Electrical and Electronic Principles and Technology* (Routledge, 2013) ISBN 9780415662857

Bird J O – *Electrical Circuit Theory and Technology* (Routledge, 2013) ISBN 9781466501096

Robertson C R – *Fundamental Electrical and Electronic Principles* (Routledge, 2008) ISBN 9780750687379