Cambridge TECHNICALS

CAMBRIDGE TECHNICALS IN ENGINEERING

LEVEL 3 UNIT 6 - Circuit simulation and manufacture

DELIVERY GUIDE

Version 1

OCR
Oxford Cambridge and RSA

CONTENTS

INTRODUCTION

This Delivery Guide has been developed to provide practitioners with a variety of creative and practical ideas to support the delivery of this qualification. The Guide is a collection of lesson ideas with associated activities, which you may find helpful as you plan your lessons.

OCR has collaborated with current practitioners to ensure that the ideas put forward in this Delivery Guide are practical, realistic and dynamic. The Guide is structured by learning outcome so you can see how each activity helps you cover the requirements of this unit.

We appreciate that practitioners are knowledgeable in relation to what works for them and their learners. Therefore, the resources we have produced should not restrict or impact on practitioners' creativity to deliver excellent learning opportunities.

Whether you are an experienced practitioner or new to the sector, we hope you find something in this guide which will help you to deliver excellent learning opportunities.

If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resourcesfeedback@ocr.org.uk.

Unit aim

For electrical and electronic devices to function, they depend on their circuits operating normally. Circuit simulation and safe, effective manufacture of circuit boards is therefore a key function within electrical engineering companies.

The aim of this unit is for learners to develop the ability to make working printed circuit boards (PCBs).

Learners will develop the ability to use computer aided design (CAD) software to design and simulate electronic circuits, and then to design PCBs. They will go on to be able to safely manufacture and construct PCBs.

Learners will also develop their fault-finding techniques for PCBs, to test and rectify, where possible, faults on circuits. They will also gain knowledge on the commercial manufacture of circuits, including manufacturing process methods and quality assurance techniques.

Unit 6 Circuit simulation and manufacture	
LO1	Be able to use Computer Aided Design (CAD) for circuit design and simulation
LO2	Be able to use Computer Aided Design (CAD) to design printed circuit boards (PCBs)
LO3	Be able to manufacture and construct electronic circuits safely
LO4	Be able to test and perform fault-finding on electronic circuits
LO5	Understand commercial circuit manufacture

Opportunities for English and maths skills development

We believe that being able to make good progress in English and maths is essential to learners in both of these contexts and on a range of learning programmes. To help you enable your learners to progress in these subjects, we have signposted opportunities for English and maths skills practice within this resource. These suggestions are for guidance only. They are not designed to replace your own subject knowledge and expertise in deciding what is most appropriate for your learners.

ABC English

123 Maths

Please note

The timings for the suggested activities in this Delivery Guide **DO NOT** relate to the Guided Learning Hours (GLHs) for each unit.

Assessment guidance can be found within the Unit document available from www.ocr.org.uk.

The latest version of this Delivery Guide can be downloaded from the OCR website.

RELATED ACTIVITIES

The Suggested Activities in this Delivery Guide listed below have also been related to other Cambridge Technicals in Engineering units/Learning Outcomes (LOs). This could help with delivery planning and enable learners to cover multiple parts of units.

This unit (Unit 6)	Title of suggested activity	Other units/LOs	
LO1	Circuit design tasks	Unit 2 Science for engineering	LO3 Understand fundamental scientific principles of electrical and electronic engineering
		Unit 4 Principles of electrical and electronic engineering	LO1 Understand fundamental electrical principles
		Unit 4 Principles of electrical and electronic engineering	LO2 Understand alternating voltage and current
		Unit 4 Principles of electrical and electronic engineering	LO5 Understand analogue electronics
		Unit 4 Principles of electrical and electronic engineering	LO6 Understand digital electronics
LO1	Circuit simulation tasks	Unit 2 Science for engineering	LO3 Understand fundamental scientific principles of electrical and electronic engineering
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		Unit 4 Principles of electrical and electronic engineering	LO5 Understand analogue electronics
		Unit 4 Principles of electrical and electronic engineering	LO6 Understand digital electronics
LO4	Introduction to test and fault finding methods	Unit 2 Science for engineering	LO1 Understand applications of SI units and measurement
LO4	Use of test equipment	Unit 2 Science for engineering	LO1 Understand applications of SI units and measurement
LO4	Test and fault finding activities	Unit 2 Science for engineering	LO1 Understand applications of SI units and measurement
		Unit 2 Science for engineering	LO3 Understand fundamental scientific principles of electrical and electronic engineering
		Unit 4 Principles of electrical and electronic engineering	LO1 Understand fundamental electrical principles
		Unit 4 Principles of electrical and electronic engineering	LO2 Understand alternating voltage and current
		Unit 4 Principles of electrical and electronic engineering	LO5 Understand analogue electronics
		Unit 4 Principles of electrical and electronic engineering	LO6 Understand digital electronics

KEY TERMS

UNIT 6 - CIRCUIT SIMULATION AND MANUFACTURE

Explanations of the key terms used within this unit, in the context of this unit

Key term	Explanation
Auto component placement (for PCB)	The PCB design part of the software will take a schematic diagram and convert this into a PCB design layout ready for manufacture. Many software packages will automatically place components on the PCB design layout, and automatically route tracks between these. This may or may not be done efficiently. The user often has the option of moving components around if required, or manually placing tracks.
Automatic test equipment (ATE)	Automatic test equipment (ATE) is often used to test PCBs during commercial manufacture. It includes computer-controlled equipment testing voltages (test point voltages) on the PCB and also visual inspection – sometimes using computer-controlled image recognition.
Bill of Material (BOM)	Many software packages have the capability to produce a list of components required to manufacture the circuit (a Bill of Material) and this might also include manufacturer's part codes and order numbers. Some programmes even have the capability to automatically place an order for components with a supplier.
Circuit diagram / schematic diagram	A circuit diagram (electrical diagram, elementary diagram, schematic diagram) is a graphical representation of an electrical circuit.
Component library	Software will contain a library of electrical components (e.g. resistors, capacitors, semiconductors etc) which are used in schematic circuit design. The components will usually have: a circuit symbol; simulation parameters; PCB layout part. New components can often be created or imported.
Connection or Interconnection	Connections (or wires) are used to connect components to produce a circuit diagram.
Continuity testing	Continuity testing is used to determine if an electrical path exists between two points in a circuit.
Design checking, design rule checking	Most software packages will perform a check to make sure that components are placed correctly and that there are no broken or missing connections. Missing or unconnected wires might be shown with a different colour.
Engraving (PCB)	Does not involve producing a printed design, or the use of etching chemicals. Data is taken straight from PCB design software and used to control a computer-controlled milling or engraving machine. The PCB is produced by the milling machine removing copper from the blank PCB, leaving copper where required.
Etch resists method	PCB is not light sensitive, but design is transferred directly to PCB. Design might be printed directly to blank PCB copper surface using etch-resistant ink. PCB is etched using chemicals leaving copper where design is, but removing excess copper.
Export file	Data can usually be exported from design and simulation software such as with the schematic diagram, for printing, results of simulations for analysis and PCB layouts for manufacture. Files might also be sent to computer-controlled machines that can automatically produce a PCB.
Flow solder process	Flow (or wave) soldering is a technique used in commercial manufacture for soldering components to a PCB. It involves moving the PCB over a flowing wave of molten solder in a solder bath. It is usually carried out by computer-controlled machines.
Grid	A layout grid is used to ensure the accurate placement of circuit symbols and interconnecting wires. Components and wires snap to set grid points. The grid spacing can sometimes be changed.

Explanations of the key terms used within this unit, in the context of this unit	
Key term	**Explanation**
Half-split method	The half-split method is a technique used in fault-finding to locate defects with a few measurements. Essentially the technique involves splitting the circuit path into halves and troubleshooting from the middle of the first half, then the second half and so on.
Logic probe	A logic probe is a hand-held pen-like test probe used for analyzing and troubleshooting the logical states (Boolean 0 or 1) of a digital circuit. While most are powered by the circuit under test, some devices use batteries.
Multi-meter	A multi-meter is an instrument designed to measure electric current, voltage, and usually resistance, typically over several ranges of value.
Multiple layer PCB	PCBs can be single-sided (one copper layer), double-sided (two copper layers) or multi-layer. Multi-layer PCBs are used where the design is complex, and where miniaturisation is required (e.g. in a mobile telephone). They are also often used where the circuit operation is fast or susceptible to interference.
Netlist/node list	The netlist is a file that describes the components and connections for the circuit. It is often produced automatically by the schematic design part of the software and the file that SPICE uses to simulate the circuit.
Oscilloscope	An oscilloscope is a test instrument commonly used to display and analyze the waveform of electronic signals.
PCB	Printed Circuit Board - an electronic circuit consisting of thin strips of a conducting material such as copper, which have been etched from a layer fixed to a flat insulating sheet called a printed circuit board, and to which integrated circuits and other components are attached.
Photoresist method	Perhaps the most common method of PCB manufacture. Design is applied to photo-sensitive PCB which is then exposed to ultraviolet light. PCB is then developed and etched with chemicals leaving copper where image of design was.
Pick and place robot	A pick and place robot is often used in commercial PCB manufacture to pick components and to place them onto the PCB. This process is often extremely rapid.
Power supply	A power supply converts one type of electrical power to another – and supplies at least one electrical load. Typically a power supply will convert AC mains electricity to a regulated DC supply (e.g. 5V or 12V). It will also usually include some form of overcurrent or overvoltage protection.
Schematic capture / schematic design	Schematic design is a term used for the process of entering (drawing) a circuit diagram into CAD software. Sometimes it is called schematic capture. This is the part of the software where the circuit diagram is drawn visually.
Signal generator	A signal generator is a piece of test equipment that generates electrical waveforms (e.g. sine wave, square wave and triangular wave). The output voltage and frequency of the signal generator can be changed. It is often used to produce test inputs to a circuit.
Signal tracing: input to output/output to input	Signal tracing involves tracing an electrical signal from the input terminals of a circuit to the output terminal (or vice versa) to locate where the signal is lost or where it deteriorates. The point at which the signal is lost or deteriorates indicates the location of a fault.
Soldering	Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal (solder) into the joint, the filler metal having a lower melting point than the adjoining metal.

Explanations of the key terms used within this unit, in the context of this unit	
Key term	**Explanation**
SPICE (Simulation Program with Integrated Circuit Emphasis) simulation	SPICE is the name given to the circuit simulation part of schematic design software. It is a program that is used to check and predict circuit behaviour. Sometimes it is built into schematic design software, or is an external software program.
Surface mount component	Surface mount technology (SMT) is a method for producing electronic circuits in which the components are mounted or placed directly onto the surface of printed circuit boards (PCBs). An electronic device made in this way is called a surface mount device (SMD). SMT components do not have long connecting leads but are soldered directly to the PCB.
Test-point voltage	A test point voltage is a point (node) in a circuit where there is an expected value of voltage. This might be determined by calculation or simulation, and then measured as a part of circuit testing.
Virtual instruments (VIs)	Virtual instruments are the equivalent of physical test equipment used within the simulation part of the software. These will include DC and AC power sources, meters to read voltage and current, signal generators and oscilloscopes. They are virtual (not real) instruments that are used in the software when simulating and testing circuit operation.
Visual inspection	Visual inspection means inspection of equipment using any of the basic human senses such as vision, hearing, touch and smell and/or any non-specialized inspection equipment.

MISCONCEPTIONS/AREAS OF DIFFICULTY

Some common misconceptions and guidance on how they could be overcome		
What is the misconception/area of difficulty?	**How can this be overcome?**	**Resources which could help**
Circuit simulation – adding a ground wire and stray connections	Most circuit simulation software packages require the connection of a 'ground' terminal in order for the simulation to run. They also require all wires to be connected to a node in the circuit (i.e. no stray or unconnected wires). Design rule error checking may detect errors if the simulation fails to run. Learners may need to be reminded of the requirements of the particular software being used in order for their simulations to run correctly.	Practice activities using circuit simulation software
Appreciation of tolerances in real components	Learners may need to be reminded that physical components have value tolerances which are sometimes not present in 'ideal' components used in simulation. Resistors typically have a tolerance of +/- 10% and capacitors of +/- 20%. Component tolerances may result in differences in simulation results and tests on physical circuits.	Practice activities comparing results of simulation with measurements from physical circuits
Correct range setting and use of measuring instruments	Learners often misread measurements taken with measuring instruments (e.g. multi-meter or oscilloscope). Multi-meters often have an auto-range function which scales voltage, current and resistance measurement readings. Learners may misread this value. Teachers might reinforce the importance of checking the setting or range selection on measuring instruments	Practice activities using a range of measuring instruments

SUGGESTED ACTIVITIES

LO No:	**1**		
LO Title:	**Be able to use Computer Aided Design (CAD) for circuit design and simulation**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
Introduction to circuit schematics and design using CAD	Learners could begin by investigating how circuits can be designed using CAD software, including the key features of different types of software available. Teachers might introduce learners to the concepts of schematic capture and design, use of component libraries, interconnection between components and the use of a grid to aid layout. Learners could research the range of free and licensed software available, including comparing key features. The following is a review of circuit design software: http://www.circuitstoday.com/circuit-design-and-simulation-softwares	2 Hours	
Circuit design tasks	Learners might, with teacher guidance, spend a significant amount of time using free or licensed software to design or reproduce circuit schematic diagrams for a range of circuits. Free software includes Designspark (http://www.rs-online.com/designspark/electronics/eng/page/designspark-pcb-home-page) and Circuit Lab (http://www.circuitlab.com/). Licensed software includes NI MultiSim (http://www.ni.com/multisim/) and OrCAD (http://www.orcad.com/). There are many other free and licensed software packages. Learners might use software to produce or reproduce schematic circuit diagrams for a range of circuits including simple resistor combinations, transistor and diode circuits, op amp and flip flop circuits, digital logic circuits. Circuits might be prepared ready for computer simulation.	6 Hours	Unit 2, LO3 Unit 4, LO1 Unit 4, LO2 Unit 4, LO5 Unit 4, LO6
Introduction to circuit simulation using CAD	Circuit simulation tools are frequently included as part of circuit schematic design software. The teacher might begin by explaining the purpose and benefits of circuit simulation, compared with immediately building a physical circuit. Learners could investigate terminology involved with circuit simulation including: design rule checking, SPICE (Simulation Program with Integrated Circuit Emphasis) simulation, adjustment of component parameters and values, production of netlists and the use of virtual instruments (VIs).	2 Hours	
Circuit simulation tasks	With teacher guidance, learners might utilise existing circuit design schematics to run as a computer-based simulation. Concepts such as the use of virtual power sources, virtual measuring points and virtual test instruments could be part of this process. Learners might also be able to relate previously learnt electrical and electronic theory in order to predict the outcomes of simulation. Learners might compare and document the operation of virtual circuits with physical circuits once built and tested.	6 Hours	Unit 2, LO3 Unit 4, LO1 Unit 4, LO2 Unit 4, LO5 Unit 4, LO6

SUGGESTED ACTIVITIES

LO No:	**2**		
LO Title:	**Be able to use Computer Aided Design (CAD) to design printed circuit boards (PCBs)**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
Introduction to PCB design using CAD	Learners could begin by researching the advantages and disadvantages of producing a PCB for a circuit design compared with using stripboard, breadboard or other types of experimental manufacture. PCB design tools are frequently an extension of circuit schematic design and simulation software. Learners might explore the PCB design features of particular software adopted by the centre. The following gives some guidance on good PCB design techniques: http://electronicdesign.com/embedded/engineer-s-guide-high-quality-pcb-design	2 Hours	
PCB design tasks	Learners might spend a significant amount of time producing PCB layouts using CAD. With teacher guidance, learners might take a schematic circuit design, and using CAD software convert this to a PCB layout ready for manufacture. The use of component libraries and good layout techniques will be part of this process. Learners might export a design, or produce suitable artwork ready for manufacture.	8 Hours	

SUGGESTED ACTIVITIES

LO No:	3		
LO Title:	**Be able to manufacture and construct electronic circuits safely**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
Introduction to PCB manufacture	Learners might begin be researching the different techniques that are available for small-scale circuit board manufacture (i.e. photo-resist, etch resist and engraving/milling). Advantages and disadvantages of each technique could be compared. Internet videos might be used to explore these (e.g. PCB milling and construction: http://www.youtube.com/watch?v=na9-USi_hZQ and photo-resist method: http://www.youtube.com/watch?v=tWnfnt2rNO0). Teachers could discuss health and safety with learners before guiding them with safely producing a PCB. Learners might be encouraged to undertake a risk assessment activity of their selected technique. It is expected that, as an outcome, learners will take their CAD-based PCB design and manufacture this using an appropriate method ready for construction. See Lesson Element Introduction to PCB manufacture.	2 Hours	
PCB manufacturing task	Learners could use a chosen method to manufacture PCBs ready for population. This might include applying artwork to a blank PCB, or creating a suitable computer-aided manufacture file. Learners might prepare the completed PCB (e.g. by cleaning and drilling component holes) ready for population.	4 Hours	
Introduction to safe construction methods	Before learners begin to construct and populate their PCB, the teacher might introduce them to appropriate construction techniques. Practical activities could include the use of hand-tools (e.g. pliers, side cutters, screwdriver) and soldering. The correct use of PPE should also be included. Safety will be a key feature of any practical activity, and so learners might be encouraged to undertake a risk assessment activity. Learners might be given the opportunity, with teacher guidance, to practice using hand-tools and soldering before moving on to constructing their PCB for real. Internet videos could be used to support these activities (e.g. soldering: http://www.youtube.com/watch?v=fYz5nIHH0iY)	2 Hours	
Safe construction activities	Construction of the learners' PCB will build upon techniques that may have already been developed and practiced. The teacher might begin by encouraging learners to identify the tools and PPE required, and to undertake a risk assessment. Teachers might provide guidance while learners populate their PCB with components. Care and attention to detail will be important for learners to achieve a satisfactory result. Others techniques that the teacher might guide the learner with include: heat sinks to protect sensitive components; desoldering incorrectly placed components; joining wires and connections to the PCB; fitting the PCB to a case.	7 Hours	

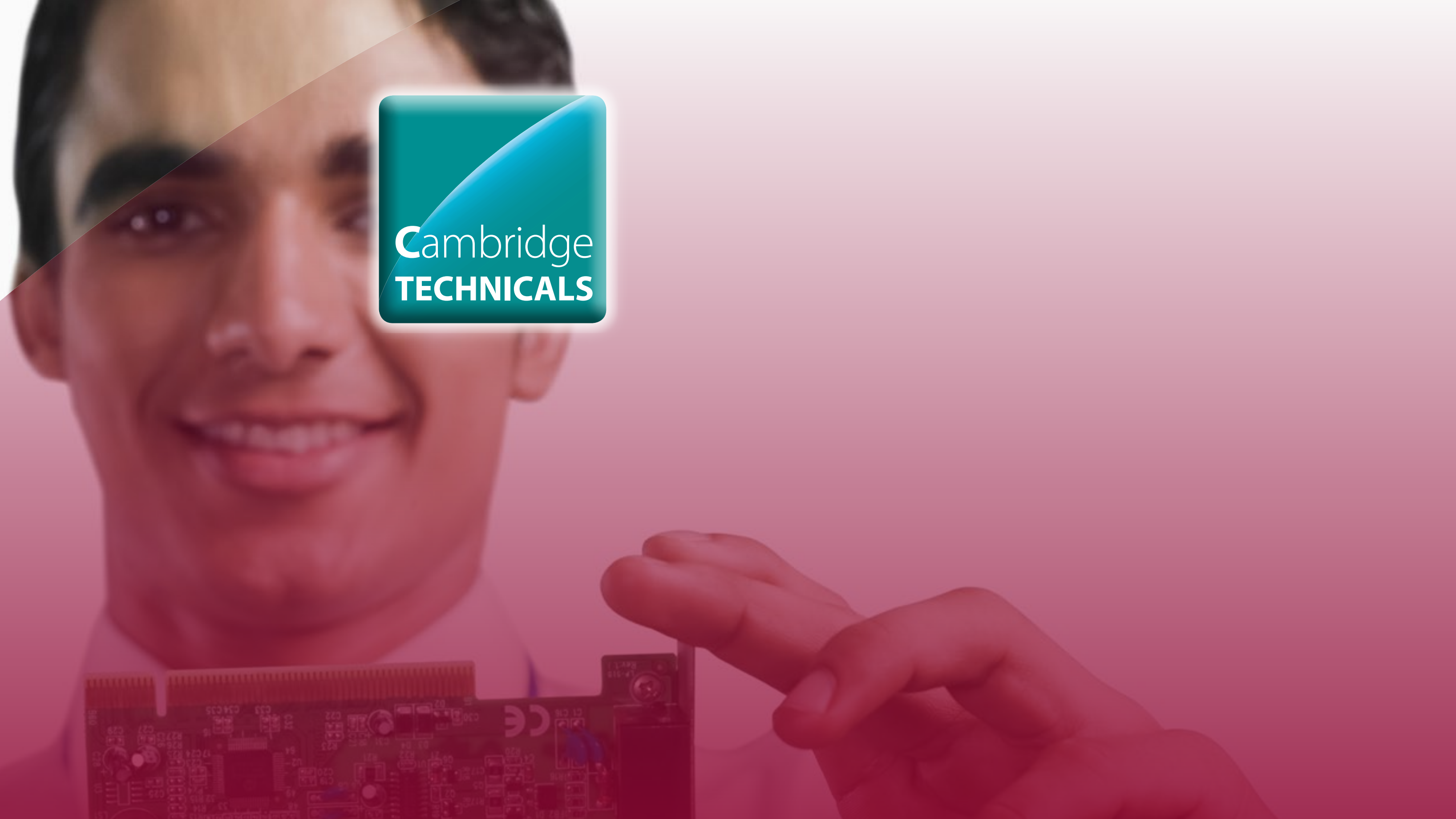
SUGGESTED ACTIVITIES

LO No:	**4**		
LO Title:	**Be able to test and perform fault-finding on electronic circuits**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
Introduction to test and fault finding methods	The teacher might begin by introducing learners to a range of faults that can be identified by visual inspection of PCBs. These could include: checking for correct fitting of components, misplaced components, dry joints and bridged tracks. The teacher could develop a picture worksheet for learners to identify faults from, or use suitable internet videos (e.g. dry solder joint: http://www.youtube.com/watch?v=9VYA9ufb4Jc) With guidance, learners could visually inspect their own PCB before moving onto applying power and testing.	3 Hours	Unit 2, LO1
Use of test equipment	Learners might research test equipment available for testing circuit operation. This could include: power supplies, multi-meter, logic probe, signal generator and oscilloscope. The teacher might explain the application and function of a range of appropriate test equipment that is available for learners to practically test their own circuit board. Safe use of test equipment will also be important in order to avoid injury or circuit damage and so learners might undertake a risk assessment activity. Internet videos might prove useful with introducing test instrument (e.g. multimeter: http://www.youtube.com/watch?v=arKUmGaRvIM and oscilloscope: http://www.youtube.com/watch?v=qIfo_-d82Co) Learners might be guided to practice using test equipment on simple circuits prior to testing their circuit and PCB. See Lesson Element Use of test equipment	2 Hours	Unit 2, LO1
Test and fault finding activities	Testing and fault finding of the learners' PCB may build upon techniques that have already been developed through visual inspection and using test equipment. Teachers might begin by asking learners to consider how they will test their PCB, and to justify the techniques and test equipment they will use. With teacher guidance, learners could test their circuit for correct operation against expected parameters. Test and fault-finding techniques might include, but are not limited to: continuity testing, test point voltage measurement, current measurement, signal tracing and half-split method. The following video tutorial explains the half-split method: http://www.allaboutcircuits.com/videos/28.html	5 Hours	Unit 2, LO1 Unit 2, LO3 Unit 4, LO1 Unit 4, LO2 Unit 4, LO5 Unit 4, LO6

Title of suggested activity	Suggested activities	Suggested timings	Also related to
Design verification	Learners might gather test data from a manufactured, populated and tested PCB for comparison with expected results from simulation. Learners could compare results from physical tests and compare with simulation results – explaining any differences. Sources of difference are likely to be as a result of tolerances in physical components which may not be present in the simulation (e.g. resistors often have a tolerance of +/- 10% and capacitors a tolerance of +/- 20%). Learners might produce a summary report of their findings.	3 Hours	

SUGGESTED ACTIVITIES

LO No:	5		
LO Title:	**Understand commercial circuit manufacture**		
Title of suggested activity	**Suggested activities**	**Suggested timings**	**Also related to**
Commercial component and PCB types	Teachers might show learners examples of different component types (through-hole and surface mount). By handling real components and circuit boards learners may develop an appreciation of physical component size and construction techniques used in commercial production. Learners might dismantle electronic equipment containing circuit boards in order to investigate the production methods used. Learners could research the benefits and disadvantages of using surface mount components. Learners might also investigate the applications and reasons for using multiple layer PCBs. Suitable videos might be used to demonstrate commercial circuit board manufacture using different component types (e.g. http://www.youtube.com/watch?v=2qk5vxWY46A) See Lesson Element Commercial component and PCB types.	2 Hours	
Commercial PCB manufacturing processes	Teachers may be able to arrange a visit to see circuit board manufacturing and testing in practice. Learners could research commercial circuit board manufacture using the internet – by looking at pick-and place robots, flow soldering and manual component placement.	2 Hours	
Commercial PCB quality assurance	If an industrial visit were arranged then quality assurance would most likely be seen in practice alongside circuit board manufacture. If a visit is not possible, then suitable videos could be shown to learners of automatic testing of circuit boards in action (e.g. http://www.youtube.com/watch?v=YegtDW42peg). Learners could research the different types of circuit board quality assurance used – including visual inspection and automatic test.	2 Hours	



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Contact us

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ISO 9001 UKAS MANAGEMENT SYSTEMS 001

A DIVISION OF CAMBRIDGE ASSESSMENT