Unit 34: Electronic Circuit Manufacture

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

A diverse range of techniques is used in the manufacture of electronic circuits. The techniques used for manufacturing prototype electronic circuits are often significantly different from those used in high volume production. This unit provides an introduction to prototype manufacture, as well as the techniques used for the mass production of electronic circuits.

Large-scale electronic manufacture generally involves fully automated assembly techniques using equipment that can produce complex circuits quickly, accurately, at very low cost and with minimal human intervention. Alternatively, if only one circuit is to be built (perhaps for evaluation or testing purposes) then a hand-built prototype is much more appropriate.

Computer aided design (CAD) and computer aided manufacture (CAM) are now widely used in the production of electronic circuits. This unit will introduce learners to the use of modern production methods including printed circuit board (PCB) layout and computer numerical control (CNC) drilling and mask production.

When an electronic circuit is developed for a commercial application it is usually tested and proved using computer simulation prior to manufacture. This unit will give learners an opportunity to develop and test circuits using SPICE (simulation program with integrated circuit emphasis) software.

The unit will also enable learners to experience the full cycle of design, manufacture and testing of an electronic circuit assembled on a simple single-layer printed circuit board.

Learning outcomes

On completion of this unit a learner should:

1 Understand the design processes and production methods used in the manufacture of a printed circuit board

2 Understand the use of software techniques and thermal analysis techniques in the design, simulation and manufacture of an electronic circuit

3 Understand the use and application of surface mount technology in the manufacture of an electronic circuit

4 Be able to design and manufacture a prototype printed circuit board and use it to assemble and test an electronic circuit.

Unit content

1 **Understand the design processes and production methods used in the manufacture of a printed circuit board**

Printed circuit board (PCB) design: design strategy eg methodology and techniques used in its realisation (build type, number of layers, net rules, track and gap, via size); design tools eg PCB design software, schematic design and capture, creating and modifying component geometries; creating and modifying schematic diagrams; design verification and design rule checking for both tracking and component layout; auto-routing tools; related documents eg parts lists, bills of materials, machine files, component geometries

PCB production methods: artwork generation; board production eg etching, masking, drilling, silk screening, cutting; automated production techniques eg robotics and automated assembly, CNC drilling and mask production; soldering methods eg wave soldering, automated wave soldering; fabrication and assembly requirements eg placement on one side, placement on both sides, combination of surface mount technology (SMT) and through-hole technology (THC); test strategy eg electromagnetic compatibility (EMC), signal integrity, high frequency requirements; manufacturability analysis

Types of PCB: laminates eg single and double sided, plated through-hole, fibreglass-resin laminate; solder mask over bare copper (SMOBC); tinned; conventional component and surface mount; single, double and multi-layer boards; gold plated contacts, flexible and membrane PCB, chip-on-board (COB)

2 **Understand the use of software techniques and thermal analysis techniques in the design, simulation and manufacture of an electronic circuit**

Computer aided design (CAD) software: simulation program with integrated circuit emphasis (SPICE) software; direct current (DC) analysis, alternating current (AC) small-signal analysis; more complex analysis methods eg mixed-mode analysis, transient analysis, pole-zero analysis, distortion analysis, sensitivity analysis, noise analysis, thermal analysis; software integration methods eg export and import data, links with companion software for circuit layout and PCB manufacture

Thermal analysis: heat dissipation methods; thermal ratings of semiconductor devices; thermal calculations eg total power dissipation, thermal resistance, $\theta_T = \theta_{JC} + \theta_{CS} + \theta_{SA}$, junction temperature, $T_J = (P_T \times \theta_T) + T_A$, temperature rise above ambient, $\Delta_T = P_T \times \theta_T = T_J - T_A$, de-rating, correct rating for thermal dissipator/heatsink

3 **Understand the use and application of surface mount technology in the manufacture of an electronic circuit**

Surface mount technology (SMT): types of SMT device eg passive components (resistors, capacitors, inductors and transformers), active components (transistors, diodes and integrated circuits), connectors and sockets; surface mount device (SMD) outlines, packaging and storage; manufacturers' markings and supporting data; hybrid circuits and multi-chip modules (MCM)

SMT circuit manufacturing: manufacturing methods eg use of solder pastes, flow and wave soldering equipment; SMT quality assurance methods eg batch testing, statistical methods; SMT component reliability and testing of finished SMT assemblies; assembly-level packaging and interconnection

4 **Be able to design and manufacture a prototype printed circuit board and use it to assemble and test an electronic circuit**

PCB design: single-sided printed circuit board for a given electronic circuit design that includes no more than four active devices eg transistors, diodes and conventional dual in-line (DIL) packaged integrated circuits; associated passive components eg PCB mounted resistors, capacitors, inductors, transformers; means of connection eg external controls, connectors, power sources; layout techniques based on the use of electronic CAD to generate PCB master artwork

PCB manufacture: developing, etching, drilling

Electronic circuit assembly: component mounting, soldering

PCB and circuit testing: functional testing using a supplied test specification to determine circuit design inputs and outputs eg test-point voltages, output signals

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:**
P1 describe typical processes used in the design of both a single and a multi-layer PCB for electronic circuits of different complexity P2 describe typical production methods used in the manufacture of both a single and a multi-layer PCB for electronic circuits of different complexity P3 explain how computer aided design software can be used in the analysis of an electronic circuit prior to manufacture P4 explain the need for thermal analysis and the need for effective heat dissipation for an electronic circuit	M1 explain the benefits of using automated techniques for the manufacture of an electronic circuit M2 use SPICE software to carry out DC and small-signal AC analysis of a simple electronic circuit M3 explain the use of typical quality assurance methods in the manufacture of electronic circuits using SMT.	D1 apply thermal analysis techniques in order to determine the heat dissipation requirements for an electronic circuit D2 evaluate the design and manufacture of the prototype PCB and circuit and make appropriate recommendations for mass production.

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:**
P5 explain the use of SMT in the manufacture of an electronic circuit and give two different examples of the outlines and packages used for surface mounted devices P6 describe the methods used for the manufacture of an electronic circuit using SMT P7 design, manufacture, assemble and test a prototype printed circuit board for a given electronic circuit.		

Essential guidance for tutors

Delivery

This unit can be delivered as a stand-alone unit or can be co-delivered with *Unit 54: Electronic Measurement and Testing*.

A major feature of this unit is its concentration on the design and manufacture of electronic circuits. In this context, 'design' should be taken as referring to the realisation of an electronic circuit from a given circuit diagram, rather than the more theoretical aspects of designing an electronic circuit to achieve desired circuit parameters eg the design of an active filter.

For learning outcomes 2 and 4, learners should be introduced to the use of appropriate software packages for PCB layout and manufacture and simulation of electronic circuits prior to manufacture using SPICE software.

In relation to learning outcomes 1 and 3, learners should be given the opportunity to experience production methods used in large-scale manufacturing of electronic circuits (including extensive use of integrated CAD/CAM and the use of wave and flow soldering techniques). Emphasis should be placed on the processes most relevant to local industrial requirements. Where possible, centres should arrange visits to industrial sites so that learners can see current manufacturing techniques such as wave soldering.

All CAD activities and SPICE tests carried out by learners should be recorded in an appropriate logbook (with the capacity to include relevant printed output and screen-dumps).

Due to the hazardous nature of some of the processes, materials and chemicals used, appropriate attention must be given to health, safety and welfare arrangements.

Note that the use of 'eg' 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 'eg' needs to be taught or assessed.

Assessment

P1 and P2 are closely related and evidence could be gathered from either an extended case study or from research and investigation. Case studies and investigations should ideally be based on production techniques and manufacturing processes that are used locally. Learners would benefit from visits to local industry to view the processes in action. An alternative to an extended case study or investigation might be the use of one or more written essay-type questions. However, this approach is likely to be less effective in bringing the topic to life.

To achieve P1, evidence should focus on design strategy, design tools (for example, schematic capture and auto-routing PCB CAD), creating and modifying schematic diagrams (for example, exchanging logic functions), design verification and design rule checking for both tracking and component layout.

It is important that learners demonstrate that they understand the additional processes required to produce multi-layer boards and that they appreciate the need for this type of board in conjunction with more complex electronic circuits. For example, circuits where microprocessor bus systems are realised on different layers or where power and ground connections are separated from signal tracks.

For P2, learners should be able to describe typical production methods used in the manufacture of both single and multi-layer types of printed circuit board for electronic circuits of different complexity.

The explanation of the use of computer aided design software required for P3 should normally be based on the use of a SPICE package to verify a circuit design before it is manufactured.

For P4, learners should explain the need for thermal analysis and effective heat dissipation in terms of the total power dissipated and the maximum junction temperature ratings for the semiconductor device(s) present. They should explain that the requirements are satisfied by means of appropriately designed heat dissipators on which the semiconductor devices are mounted.

To satisfy P5, learners should provide a written or verbal presentation of the use of surface mount technology (SMT) in the manufacture of electronic circuits. Learners should be able to state the advantages and disadvantages of SMT and surface mounted devices (SMD) and should be able to describe the typical outlines and packages used for SMD.

For P6, learners should describe the typical methods used for the manufacture of electronic circuits using SMDs. Note that learners are not expected to know how SMDs themselves are manufactured.

For P7, learners should design, manufacture, assemble and test a prototype printed circuit board for a given electronic circuit. The electronic circuit should be supplied, complete with a full component list and component supplier's references. Learners will be able to use these to determine physical constraints such as lead diameter, pin spacing and package outlines as well as any specialised mounting requirements such as the fitting of a heat dissipator. The circuits chosen should use no more than four active devices (eg transistors, diodes and conventional dual in-line (DIL) packaged integrated circuits) and associated passive components (eg PCB mounted resistors, capacitors, inductors, and transformers). The circuit should have an identifiable function and should be capable of functional testing without specialised equipment. In order to carry out this task, learners should be supplied with a simple test specification based on test-point voltages, output signal levels etc. Centres are encouraged to provide learners with a standard test-jig in order to carry out these functional checks.

Typical examples of circuits that learners might develop include:

- a variable pulse generator (based on two 555 timers)
- a function generator (based on a single integrated circuit waveform generator)
- an audio amplifier (based on a complementary symmetrical output stage with driver and pre-amplifier stage)
- a regulated power supply (based on a bridge rectifier and a three-terminal fixed voltage regulator).

Note that these last two examples could require learners to undertake some thermal analysis and incorporate appropriate arrangements for heat dissipation (extending the work required for P4 and providing a basis for developing evidence for D1).

Evidence for M1 could be gathered through a written assignment or formal written test. M2 could be assessed through appropriately designed practical activities and M3 by means of an assignment in which learners investigate modern industrial processes used for the high-volume manufacture of electronic circuits.

Learners can achieve D1 by means of an extended assignment involving thermal analysis and the design of a heat dissipator (for example, a heatsink for fitting to a three-terminal integrated circuit voltage regulator).

For D2, the exercise carried out to satisfy P7 could be developed further as learners evaluate their designs and make appropriate recommendations for mass production (based on the understanding that they have evidenced in relation to P1 and P2). These recommendations will typically include size reduction (including the use of miniaturised or equivalent surface mounted components), the use of multi-layer boards and the use of appropriate interconnecting technologies (for example the use of multi-pole insulation displacement connectors (IDCs) fitted with PCB headers).

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

This unit covers some of the knowledge and understanding associated with the SEMTA Level 3 National Occupational Standards in Electrical and Electronic Engineering, particularly:

- Unit 4: Designing Electronic Circuit Board Layouts Using CAD Tools
- Unit 10: Selecting and Preparing Materials and Components for Manufacturing
- Unit 11: Preparing Manufacturing Systems Equipment for Operations
- Unit 12: Monitoring and Analysing Data from Electronic Circuit Manufacturing Processes
- Unit 13: Adjusting and Sustaining Electronic Circuit Manufacturing Processes.

The unit can also be successfully delivered alongside *Unit 54: Electronic Measurement and Testing*. It also links with *Unit 35: Principles and Applications of Electronic Devices and Circuits*, *Unit 60: Analogue Electronics* and *Unit 61: Construction and Applications of Digital Systems*.

Essential resources

Learners will need access to an electronics workshop with a range of electronic manufacturing equipment sufficient to meet the needs of the grading criteria (eg developing tanks, heated etching baths, PCB drilling equipment, soldering and wiring equipment). Centres will need to provide sufficient electronic test equipment to confirm the functionality of printed circuit boards and provide access to PCs equipped with PCB CAD and SPICE simulation packages.

Learners will also need to be provided with relevant personal protective equipment (eg goggles, gloves, protective clothing) when manufacturing circuit boards, handling chemicals, soldering etc.

Indicative reading for learners

Sinclair I — *Practical Electronics Handbook, Fifth edition* (Newnes, 2000) ISBN 0750645857

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.

Application of number Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• applying thermal analysis techniques in order to determine the heat dissipation requirements for an electronic circuit • using appropriate production methods to assemble and test a prototype electronic circuit.	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 proportion c handling statistics 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:**
• describing processes used in the design and manufacture of a typical printed circuit board for an electronic circuit • explaining the use of and methods of manufacture for surface mount technology in electronic circuits • describing each of the stages in the design and manufacture of a printed circuit board for a prototype electronic circuit.	C3.1a Take part in a group discussion. C3.1b Make a formal presentation of at least eight minutes using an image or other support material. 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.

Improving own learning and performance Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• using appropriate methods to design and produce master artwork for a simple single-sided printed circuit board for a prototype electronic circuit • using appropriate production methods to produce a simple single-sided printed circuit board for a prototype electronic circuit • using appropriate production methods to assemble and test a prototype electronic circuit using a simple single-sided printed board.	LP3.1 Set targets using information from appropriate people and plan how these will be met. LP3.2 Take responsibility for your learning, using your plan to help meet targets and improve your performance. LP3.3 Review progress and establish evidence of your achievements.
Problem solving Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• using SPICE to carry out analysis of an electronic circuit • applying thermal analysis techniques in order to determine the heat dissipation requirements for an electronic circuit.	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.