Unit 58: Construction and Applications of Digital Systems

Unit code: A/600/6747

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to give learners an understanding of modern digital systems and technology and the skills needed to build and test a range of digital electronic circuits.

Unit introduction

Digital electronics play an integral part in modern society. Their wide application, from washing machines and car management systems to street furniture devices (eg turning street lighting on and off), means that there is an increased need for safe, low maintenance, energy-efficient systems. These new systems also frequently use alternative energy sources and have their eventual disposal (e-waste) taken into account from their conception.

This unit will give learners an understanding of recent advances in digital electronics and the new technologies that often replace older electrical and electronic systems (legacy systems). Learners will also develop an understanding of how the components of an electronic system are connected together (interfaced) to enable analogue signals to be transmitted digitally. For example, interface circuit devices such as optocouplers can transfer an electrical signal from one circuit to another while electrically isolating the two.

Learners will also have the opportunity to build and test different digital systems, enabling them to understand circuit life cycles, circuit costs and build and test methods.

Learning outcomes

On completion of this unit a learner should:

1 Understand energy efficient use of modern digital electronics technology

2 Understand the transmission of analogue data in a digital system

3 Understand the selection and use of interface devices and logic devices for digital circuits

4 Be able to build and test digital systems

Unit content

1 Understand energy efficient use of modern digital electronics technology

Small energy sources: source types eg solar (photovoltaic), batteries (lead-acid, nickel-cadmium (NiCad), nickel-iron (NiFe)), alternative sources (small-scale wind/water turbines); maintenance, handling and care eg recharging, testing, replacement techniques, disposal

Extended system life: legacy systems and modern applications eg historical technologies, impact of required energy levels, load evaluation and usage, alternative systems, consideration of e-waste, use of 'fuzzy logic' techniques; applications eg street furniture, charge regulators, thermostats, load diverting controllers, calculators; lifetime costs, efficiencies, reliability, maintenance

2 Understand the transmission of analogue data in a digital system

Data transmission: digital-to-analogue converters (DACs) eg digital-ramp, summing amplifier, current switches, R-2R ladder; analogue-to-digital converters (ADCs) eg counter, successive approximation, flash; integrated circuits eg slope, dual slope; code converters and function generators (look-up tables); optoelectronic display devices eg 7-segment, 14-segment (starburst), dot-matrix, liquid crystal display (LCD), light-emitting diode (LED), organic light-emitting diode (OLED), plasma, vacuum fluorescent display (VFD)

Tri-state devices: tri-state buffers and line drivers; control of data access to bus or transmission channel; random bus arbitration access; ordered time division multiplexed access

3 Understand the selection and use of interface devices and logic devices for digital circuits

Standard data interface: industry standards eg general applications (International Standards Organisation (ISO), American National Standards Institute (ANSI), British Standards Institute (BSI)), telecommunication applications (Telecommunications Industry Association (TIA), International Telecommunication Union (ITU), European Telecommunications Standards Institute (ETSI), Office of Communications (Ofcom)), electronic applications (Joint Electronic Device Engineering Council (JEDEC)); standard interfaces eg RS232, RS422, RS562, V24, V28, V10, V11; electrical current sourcing and heat sinking requirements; voltage level adjusting; optocouplers/optoisolator; tri-state/bi-directional line driver device in a multiplexed data bus transmission system

Logic devices families: characteristics eg power consumption and interfacing (emitter-coupled logic (ECL), transistor-transistor logic (TTL), low-power Schottky transistor-transistor logic (LSTTL), complementary metal-oxide semiconductor (CMOS), high-speed CMOS (HCMOS)); levels of integration and benefits eg small/medium/large/very large/ultra large scale integration (SSI/MSI/LSI/VLSI/ULSI), system-on-chip (SOC)

4 Be able to build and test digital systems

Circuits and systems: combinational circuit eg logic encoder, decoder, multiplexer, demultiplexer, code converter, function generator; asynchronous/synchronous circuit eg counter, frequency divider, ring counter, clock waveform generator, register, shift register, converters (serial-to-parallel, parallel-to-serial); systems eg security (access control, intruder alarms, fire, nurse call), safety (weight levels, proximity, sensor technologies), monitoring (level indicators, flow rates, temperature), embedded (dedicated computers, RAM/Flash memory)

Circuit testing: aids eg data sheets, test instruments, specialised tools; built-in self-tests, in-circuit emulators; glitches eg electronic pulse of short duration cross-talk, amplitude noise margins; race conditions eg input condition conflicts, floating inputs; hazards (static, timing); test patterns; precautions when testing components, datalines and systems

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 how two different types of small energy sources are used to support two different digital electronic systems	**M1** discuss the benefits of combining a small energy source with modern digital technologies	**D1** evaluate a digital system to consider how a modern energy source and/or energy reducing components might improve the system's future life cycle
P2 explain how modern technologies can be used to extend the life of an existing electronic system	**M2** compare the operation of two different types of data transmission device	**D2** evaluate and suggest improvements to the circuit operation of a digital system with respect to the method of data acquisition and human interface employed.
P3 describe how analogue data is transmitted by a digital electronic circuit	**M3** compare the operation of a combinational logic device and a sequential logic device.	
P4 explain the role and operation of a tri-state device in analogue data transmission		
P5 explain the selection and use of two different types of standard data interfaces within working systems		
P6 identify a logic device family, its current levels of integration and the benefits of using it		
P7 build two different digital electronic circuits to be used in different digital systems [SM3]		
P8 carry out circuit testing of the two constructed circuits to check system performance against specification [IE1, SM3].		

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

Delivery of this unit should focus on practical investigation of digital electronic systems and components.

Tutors should ensure that learners understand how growth in new technologies and the phasing out of legacy systems tends to increase efficiency and reliability of operation. Industrial visits, employer support and use of the internet can help learners obtain knowledge of the latest developments and trends.

The practical aspects of unit delivery should be used to enable learners to recognise different components, circuits and complete systems. This will allow them to appreciate how the various aspects fit together to produce an efficient, reliable and safe device/system that can be used in a range of environments.

Standards bodies for local and international markets are essential in a global economy. Learners will need access to standards and related materials and their importance should be highlighted when looking at existing devices/systems and considering the development of new ones.

Learning outcome 4 requires learners to build a digital electronic circuit and test it to ensure that it functions as expected. During delivery of these practical tasks attention must be given to health and safety arrangements.

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 methods of assessment • explain the application and use of the different types of energy sources • explain the maintenance requirements for different energy sources and correct methods of handling and care • explain and investigate legacy systems and modern applications • explain levels of efficiency and reliability, maintenance requirements and the related costs over the lifetime of the system. *Individual learner research:* • using case studies, learners investigate possible modern applications of legacy systems.
Prepare for and completion of **Assignment 1: Efficient Use of Digital Electronics** (P1, P2, M1, D1, D2).
Whole-class teaching: • explain the function and operation of digital-to-analogue and analogue-to-digital converters • explain data transmission in integrated circuits and the use of code converters and function generators • explain the function and operation of a range of optoelectronic display devices • explain tri-state devices and the control of access.
Prepare for and completion of **Assignment 2: Transmission of Analogue Data in a Digital System** (P3, P4, M2).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain the purpose, selection and use of a range of industry standards • explain standard interfaces and interface characteristics • explain current, heat sinking requirements and adjustment of voltage level • explain use of opto-isolators • explain the use of tri-state/bi-directional line driver devices. *Learner investigation:* • learners to research a range of standard interfaces.
Prepare for and completion of **Assignment 3: Interface Devices** (P5).
Whole-class teaching: • define the characteristics of different logic device families, their levels of integration and related benefits.
Prepare for and completion of **Assignment 4: Logic Devices** (P6).
Whole-class teaching: • explain the function of a range of circuits including combinational and asynchronous/synchronous circuits • explain the function of a range of digital systems. *Practical workshop session:* • explain and demonstrate construction of digital electronic circuits for use in different systems • explain and demonstrate testing of circuits against specification. *Small group activity:* • practise construction and testing of different digital electronic circuits.
Prepare for and completion of **Assignment 5: Building and Testing Digital Systems** (P7, P8, M3).
Feedback on assessment and unit evaluation.

Assessment

Assessment evidence for this unit could be collected from a mixture of written technical reports and practical activities, supported by tutor observation records.

To achieve P1, learners need to consider two different given or chosen digital electronic systems, each with a different small energy source. Learners are expected to explain the type of energy source being used and the requirements of that system in terms of the source's maintenance, handling and care. When describing the type of small energy source being used learners should also consider the environment in which it operates and the expected energy levels required by the system to maintain effective operation.

For P2 learners must consider similar aspects to those required for P1 but from the perspective of a legacy system. Once again, the system can be chosen by the learner or be given by the tutor. Learners need to explain how current technologies might be used to enhance the efficiency of operation and maintenance of the existing system. This may draw from some or most of the examples given in the unit content such as historical technologies, impact of required energy levels, load evaluation and usage etc. Typical applications that may be considered are listed in the unit content although others may equally apply. The learner's explanation must cover aspects of lifetime costs, efficiencies, reliability and maintenance.

The work carried out for P1 and P2 will naturally prepare learners for achievement of M1, when they are required to explain the benefits of combining a small energy source together with modern digital technologies.

To achieve P3 and P4, learners need to consider the transmission aspects of data that many systems require in order to effectively process data. P3 requires learners to demonstrate their knowledge and understanding of how analogue and digital signals can be transposed. P4 requires them to show how the data transmitted around the system is controlled. Learners should consider at least one large complete circuit or a series of smaller ones. The written explanations/descriptions should use correct circuit/logic symbols that are based on an appropriate standard. Appropriate standards should be used at all times and learners should provide a key/suitable reference to indicate the standard to which they are working.

The work carried out for P3 and P4 can be extended to M2, when learners compare the operation of two different types of data transmission device.

P5 requires learners to explain the selection and use of two different types of standard data interfaces within working systems. They will need to look at two different and currently operational devices/systems and describe why they are the most appropriate for that situation.

P6 requires learners to identify a logic device family, the available levels of integration and the benefits of that family. This could be achieved by learners taking a digital image of a device/system and making a leaflet to identify the characteristics of the device family and relevant levels of integration that can be achieved.

P7 and P8 should be linked so that learners test the two circuits they have built. P7 requires learners to build two different digital electronic circuits that are to be used within different digital systems. It is expected that one of these would be a combinational circuit, eg logic encoder, decoder, multiplexer, de-multiplexer etc. The other digital electronic circuits should be either an asynchronous or synchronous circuit, eg counter, frequency divider, ring counter etc. These circuits may be given by the tutor or selected by the learner, with tutor guidance to ensure coverage of unit content. Typically, these circuits will be part of a digital electronic system such as a security system, a safety system, a monitoring system or an embedded system. It is not expected that the constructed circuit be used within the system but learners need to show they understand how it could be integrated within the working system.

The focus of this unit is not on circuit building or testing and it is assumed that learners have gained sufficient knowledge of these elsewhere, eg in *Unit 34: Electronic Circuit Design and Manufacture*. Assessment of P7 should therefore concentrate on learners' use of modern digital electronics, their understanding of analogue data transmission and the selection and use of interface devices and logic devices.

P8 requires learners to carry out circuit testing of the two constructed circuits to check system performance against specification. Between the two tests there should be sufficient evidence to meet all the requirements of the unit content. This must include a range of aids to testing, built-in self-tests, in-circuit emulators and identification of circuit glitches, race conditions, hazards, test patterns and precautions.

The need to fully meet the unit content requirements will inevitably influence the choice of suitable circuits for P7 and P8. Where centres wish to allow learner choice/employer involvement, it will be important to maintain sufficient tutor guidance on the circuits chosen to ensure full unit content coverage.

Assessment evidence for P7 and P8 is likely to be in the form of learner notes and records of circuit construction and testing plus tutor observation records of the build and test procedures. Annotated photographic records could also be used.

Achievement of M3 will build on the knowledge and understanding gained from P7 and P8. The two circuits to be compared could be the same as those built and tested for P7 and P8, although this is not essential. Centres may decide that learners would gain a wider understanding by comparing two different circuits provided by the tutor. The comparison should be based on the unit content as a whole, eg energy source used, consideration of extended system life, data transmission methods, data interfacing, application of a specific logic family, method of circuit/system construction and how circuits have been/could be tested.

For D1 and D2, learners will need to demonstrate a deeper understanding of working systems and the application of current and future technologies. For D1, learners should focus on small energy sources and energy-reducing aspects of a system. There is a natural link between this criterion and the work undertaken for P1, P2, M1 and M2. Learners should consider and review an existing digital system to establish how the system works and how energy reducing components could potentially improve the future life cycle of the system.

D2 is intended to allow learners to work in a way that may meet their own interests or local needs with either employer or centre guidance. Learners should be directed to consider the various aspects of circuit operation related to input and output for a system, including a good range of circuit level considerations.

Centres that do not wish to leave the delivery and assessment of the distinction criteria to the later part of the unit may wish to guide learners towards a suitable system at an early stage and build upon it as the unit progresses.

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, M1, D1, D2	Efficient Use of Digital Electronics	Learners have been asked to investigate small energy sources and how current technologies might be used to enhance the efficiency of operation and maintenance of an electronic system.	A written report.
P3, P4, M2	Transmission of Analogue Data in a Digital System	Learners need to explain data transmission in electronic systems to a new apprentice.	A written report.
P5	Interface Devices	Learners have been asked to compare the selection and use of different types of data device for specific situations.	A written report.
P6	Logic Devices	Learners have been asked to produce an information leaflet detailing the levels of integration and the benefits of a logic device family.	A written report and/or information leaflet/poster.
P7, P8, M3	Building and Testing Digital Systems	Learners must build and test a variety of digital electronic circuits for a new customer.	A written report/portfolio based on practical activities supported by annotated photos and observation records.

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
		Selecting and Using Programmable Controllers
		Electronic Circuit Design and Manufacture
		Electronic Measurement and Testing

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

- Unit 15: Checking the Compliance of Electronic Components Against the Specification
- Unit 16: Assembling and Checking Printed and Allied Electronic Circuits
- Unit 17: Assembling and Wiring Electronic Equipment and Systems
- Unit 18: Testing Post-Production Electronic Components and Circuits.

Essential resources

Centres should have sufficient facilities to carry out practical investigations of legacy systems, working devices/systems and equipment and components for building and testing digital electronic circuits. Relevant software packages should also be available to permit simulation of device and circuit performance.

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

Agarwal A and Lang, J – *Foundations of Analogue and Digital Electronic Circuits* (Morgan Kaufmann, 2005) ISBN 9781558607354

Wakerly J – *Digital Design: Principles and Practices* (Prentice Hall, 2006) ISBN 0131733494

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 building and testing digital electronic circuits
Self-managers	organising time and resources and prioritising actions when building and testing digital electronic circuits.

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 ...
Independent enquirers	analysing and evaluating information when investigating and researching digital electronic circuits and systems, judging its relevance and value
Team workers	collaborating with others when working as part of a group to build and test a range of digital electronic circuits.

Functional Skills – Level 2

Skill	When learners are ...
Mathematics	
Select and apply a range of skills to find solutions	carrying out practical measurements and laboratory work and interpreting results
Draw conclusions and provide mathematical justifications	carrying out practical measurements and laboratory work and interpreting results
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating digital electronic circuits and systems
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing and explaining the use of a range of digital systems.