

Unit 61: Construction and Applications of Digital Systems

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

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 make use of 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 are useful devices that offer the ability to 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 (ADC) 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 logics (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

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 describes 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 how two different types of small energy sources are used to support two different digital electronic systems	M1 explain the benefits of combining a small energy source together 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 describe 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		

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:
<p>P7 build two different digital electronic circuits to be used in different digital systems</p> <p>P8 carry out circuit testing of the two constructed circuits to check system performance against specification.</p>		

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.

The importance of standards bodies for local and international markets is 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.

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 describe 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 operational environment in which it operates and the expected energy levels required by the system in order to maintain effective operation.

P2 considers similar aspects to that of 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. The explanation learners provide needs to consider 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 also 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 consider and 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 make use of 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 describe 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 the reasons 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 together so that the two circuits that are built are the same circuits that are tested.

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, demultiplexer 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 should actually 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 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 will need to 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 through the comparison of two different circuits provided by the tutor. The comparison should be based upon 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. D1 allows learners to 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.

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

This unit can be linked with *Unit 25: Selection and Applications of Programmable Logic Controllers*. The unit builds upon *Unit 34: Electronic Circuit Manufacture* and *Unit 54: Electronic Measurement and Testing* and assumes learners are able to build circuits, use test equipment and carry out circuit measurements before starting this unit.

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.

Indicative reading for learners

Textbooks

Ifeachor E and Jervis B – *Digital Signal Processing: A Practical Approach* (Prentice Hall, 2001) ISBN 0201596199

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

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. Tutors 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:
<ul style="list-style-type: none"> carrying out practical measurements and laboratory work. 	<p>N3.1 Plan an activity and get relevant information from relevant sources.</p> <p>N3.2 Use this information to carry out multi-stage calculations to do with:</p> <ul style="list-style-type: none"> a amounts or sizes b scales or proportion c handling statistics d using formulae. <p>N3.3 Interpret the results of your calculations, present your findings and justify your methods.</p>
Communication Level 3	
When learners are:	They should be able to develop the following key skills evidence:
<ul style="list-style-type: none"> investigating digital electronic systems and devices preparing technical reports on systems and devices eg energy sources, legacy systems, and logic device families. 	<p>C3.2 Read and synthesise information from at least two documents about the same subject.</p> <p>Each document must be a minimum of 1000 words long.</p> <p>C3.3 Write two different types of documents, each one giving different information about complex subjects.</p> <p>One document must be at least 1000 words long.</p>