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# Edexcel BTEC Level 4 HNC Diploma in General Engineering

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## Contents – Course Specifications

NB: Requirement of 3 compulsory courses, plus additional courses to total 120-155 credits in total, decided by NK College subject to needs of students participating on programme. The units listed below are a selection from a bank of units available for the programme. Should the need arise due to the preferences of either the sponsoring employer or attending student, any of the remaining units from the bank may be used as optional units for the qualification.

Unit	Subject – <a href="#">Select Hyperlink to view</a>	Level	Credits	Pages
Unit 1:	<a href="#">Analytical Methods for Engineers</a>	4	15	2 – 6
Unit 2:	<a href="#">Engineering Science</a>	4	15	7 – 11
Unit 3:	<a href="#">Project Design, Implementation and Evaluation</a>	5	20	12 – 15
Unit 5:	<a href="#">Electrical and Electronic Principles</a>	5	15	16 – 19
Unit 22:	<a href="#">Programmable Logic Controllers</a>	4	15	20 – 23
Unit 35:	<a href="#">Further Analytical Methods for Engineers</a>	5	15	24 – 29
Unit 37:	<a href="#">Management of Projects</a>	4	15	30 – 34
Unit 57:	<a href="#">Mechatronic Systems</a>	4	15	35 – 38
Unit 68:	<a href="#">Applications of Power Electronics</a>	4	15	39 – 42
Unit 71:	<a href="#">Combinational and Sequential Logic</a>	4	15	43 – 46

## Unit 1: Analytical Methods for Engineers

Unit code: A/601/1401

QCF level: 4

Credit value: 15

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- Aim

This unit will provide the analytical knowledge and techniques needed to carry out a range of engineering tasks and will provide a base for further study of engineering mathematics.

- Unit abstract

This unit enables learners to develop previous mathematical knowledge obtained at school or college and use fundamental algebra, trigonometry, calculus, statistics and probability for the analysis, modelling and solution of realistic engineering problems.

Learning outcome 1 looks at algebraic methods, including polynomial division, exponential, trigonometric and hyperbolic functions, arithmetic and geometric progressions in an engineering context and expressing variables as power series.

The second learning outcome will develop learners' understanding of sinusoidal functions in an engineering concept such as AC waveforms, together with the use of trigonometric identities.

The calculus is introduced in learning outcome 3, both differentiation and integration with rules and various applications.

Finally, learning outcome 4 should extend learners' knowledge of statistics and probability by looking at tabular and graphical representation of data; measures of mean, median, mode and standard deviation; the use of linear regression in engineering situations, probability and the Normal distribution.

- Learning outcomes

**On successful completion of this unit a learner will:**

- 1 Be able to analyse and model engineering situations and solve problems using algebraic methods
- 2 Be able to analyse and model engineering situations and solve problems using trigonometric methods
- 3 Be able to analyse and model engineering situations and solve problems using calculus
- 4 Be able to analyse and model engineering situations and solve problems using statistics and probability.

## Unit content

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### 1 Be able to analyse and model engineering situations and solve problems using algebraic methods

*Algebraic methods:* polynomial division; quotients and remainders; use of factor and remainder theorem; rules of order for partial fractions (including linear, repeated and quadratic factors); reduction of algebraic fractions to partial fractions

*Exponential, trigonometric and hyperbolic functions:* the nature of algebraic functions; relationship between exponential and logarithmic functions; reduction of exponential laws to linear form; solution of equations involving exponential and logarithmic expressions; relationship between trigonometric and hyperbolic identities; solution of equations involving hyperbolic functions

*Arithmetic and geometric:* notation for sequences; arithmetic and geometric progressions; the limit of a sequence; sigma notation; the sum of a series; arithmetic and geometric series; Pascal's triangle and the binomial theorem

*Power series:* expressing variables as power series functions and use series to find approximate values eg exponential series, Maclaurin's series, binomial series

### 2 Be able to analyse and model engineering situations and solve problems using trigonometric methods

*Sinusoidal functions:* review of the trigonometric ratios; Cartesian and polar co-ordinate systems; properties of the circle; radian measure; sinusoidal functions

*Applications:* angular velocity, angular acceleration, centripetal force, frequency, amplitude, phase, the production of complex waveforms using sinusoidal graphical synthesis, AC waveforms and phase shift

*Trigonometric identities:* relationship between trigonometric and hyperbolic identities; double angle and compound angle formulae and the conversion of products to sums and differences; use of trigonometric identities to solve trigonometric equations and simplify trigonometric expressions

### 3 Be able to analyse and model engineering situations and solve problems using calculus

*Calculus:* the concept of the limit and continuity; definition of the derivative; derivatives of standard functions; notion of the derivative and rates of change; differentiation of functions using the product, quotient and function of a function rules; integral calculus as the calculation of area and the inverse of differentiation; the indefinite integral and the constant of integration; standard integrals and the application of algebraic and trigonometric functions for their solution; the definite integral and area under curves

*Further differentiation:* second order and higher derivatives; logarithmic differentiation; differentiation of inverse trigonometric functions; differential coefficients of inverse hyperbolic functions

*Further integration:* integration by parts; integration by substitution; integration using partial fractions

*Applications of the calculus:* eg maxima and minima, points of inflexion, rates of change of temperature, distance and time, electrical capacitance, rms values, electrical circuit analysis, AC theory, electromagnetic fields, velocity and acceleration problems, complex stress and strain, engineering structures, simple harmonic motion, centroids, volumes of solids of revolution, second moments of area, moments of inertia, rules of Pappus, radius of gyration, thermodynamic work and heat energy

*Engineering problems:* eg stress and strain, torsion, motion, dynamic systems, oscillating systems, force systems, heat energy and thermodynamic systems, fluid flow, AC theory, electrical signals, information systems, transmission systems, electrical machines, electronics

### 4 Be able to analyse and model engineering situations and solve problems using statistics and probability

*Tabular and graphical form:* data collection methods; histograms; bar charts; line diagrams; cumulative frequency diagrams; scatter plots

*Central tendency and dispersion:* the concept of central tendency and variance measurement; mean; median; mode; standard deviation; variance and interquartile range; application to engineering production

*Regression, linear correlation:* determine linear correlation coefficients and regression lines and apply linear regression and product moment correlation to a variety of engineering situations

*Probability:* interpretation of probability; probabilistic models; empirical variability; events and sets; mutually exclusive events; independent events; conditional probability; sample space and probability; addition law; product law; Bayes' theorem

*Probability distributions:* discrete and continuous distributions, introduction to the binomial, Poisson and normal distributions; use of the normal distribution to estimate confidence intervals and use of these confidence intervals to estimate the reliability and quality of appropriate engineering components and systems

## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Be able to analyse and model engineering situations and solve problems using algebraic methods	1.1 determine the quotient and remainder for algebraic fractions and reduce algebraic fractions to partial fractions 1.2 solve engineering problems that involve the use and solution of exponential, trigonometric and hyperbolic functions and equations 1.3 solve scientific problems that involve arithmetic and geometric series 1.4 use power series methods to determine estimates of engineering variables expressed in power series form
LO2 Be able to analyse and model engineering situations and solve problems using trigonometric methods	2.1 use trigonometric functions to solve engineering problems 2.2 use sinusoidal functions and radian measure to solve engineering problems 2.3 use trigonometric and hyperbolic identities to solve trigonometric equations and to simplify trigonometric expressions
LO3 Be able to analyse and model engineering situations and solve problems using calculus	3.1 differentiate algebraic and trigonometric functions using the product, quotient and function of function rules 3.2 determine higher order derivatives for algebraic, logarithmic, inverse trigonometric and inverse hyperbolic functions 3.3 integrate functions using the rules, by parts, by substitution and partial fractions 3.4 analyse engineering situations and solve engineering problems using calculus
LO4 Be able to analyse and model engineering situations and solve problems using statistics and probability	4.1 represent engineering data in tabular and graphical form 4.2 determine measures of central tendency and dispersion 4.3 apply linear regression and product moment correlation to a variety of engineering situations 4.4 use the normal distribution and confidence intervals for estimating reliability and quality of engineering components and systems.

## Guidance

### Links

This unit can be linked with the core units and other principles and applications units within the programme. It will also form the underpinning knowledge for the study of further mathematical units such as *Unit 35: Further Analytical Methods for Engineers*, *Unit 59: Advanced Mathematics for Engineering*.

Entry requirements for this unit are at the discretion of the centre. However, it is strongly advised that learners should have completed the BTEC National unit *Mathematics for Engineering Technicians* or equivalent. Learners who have not attained this standard will require appropriate bridging studies.

**Essential requirements** - There are no essential resources for this unit.

### Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study material

ISBN Number (for printed material)	Author	Date	Title	Publisher
ISBN 0-7506-3608-4	Mike Tooley & Lloyd Dingle	2014	Higher National Engineering (2 <sup>nd</sup> Edition)	Newnes
ISBN 0-582-41371-0	JO Bird & AJC May	2014	Algebra and Calculus for Technicians	Longman
ISBN 0-7506-3621-1	W. Bolton	2014	Essential Mathematics for Engineers	Butterworth Heinemann

Scheduled contact hours: Note: include in scheduled time: project supervision, demonstrations, practical classes and workshops, supervised time in studio or workshop, scheduled lab work, fieldwork, external visits, work-based learning where integrated into a structured academic programme	lectures	36
	seminars	0
	supervised practical sessions	0
	tutorials	0
	formative assessment	16
	other scheduled time	0
	Guided independent study Note: include in guided independent study preparation for scheduled sessions, follow up work, wider reading or practice, revision	Independent coursework
	Independent laboratory work	0
	other non-scheduled time	
Placements (including work placement and year abroad)		
<b>Total hours ('Should be equal to credit x 10')</b>		<b>150Hrs</b>

## Unit 2: Engineering Science

Unit code: L/601/1404

QCF level: 4

Credit value: 15

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- Aim

This unit aims to provide learners with an understanding of the mechanical and electrical principles that underpin mechanical and electrically focused engineering systems.

- Unit abstract

Engineers, no matter from what discipline, need to acquire a fundamental understanding of the mechanical and electrical principles that underpin the design and operation of a large range of engineering equipment and systems.

This unit will develop learners' understanding of the key mechanical and electrical concepts that relate to all aspects of engineering.

In particular, learners will study elements of engineering statics including the analysis of beams, columns and shafts. They will then be introduced to elements of engineering dynamics, including the behavioural analysis of mechanical systems subject to uniform acceleration, the effects of energy transfer in systems and to natural and forced oscillatory motion.

The electrical system principles in learning outcome 3 begin by refreshing learners' understanding of resistors connected in series/parallel and then developing the use of Ohm's law and Kirchhoff's law to solve problems involving at least two power sources. Circuit theorems are also considered for resistive networks only together with a study of the characteristics of growth and decay of current/voltage in series C-R and L-R circuits.

The final learning outcome develops learners' understanding of the characteristics of various AC circuits and finishes by considering an important application – the transformer.

- Learning outcomes

**On successful completion of this unit a learner will:**

- 1 Be able to determine the behavioural characteristics of elements of static engineering systems
- 2 Be able to determine the behavioural characteristics of elements of dynamic engineering systems
- 3 Be able to apply DC theory to solve electrical and electronic engineering problems
- 4 Be able to apply single phase AC theory to solve electrical and electronic engineering problems.

## Unit content

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### 1 Be able to determine the behavioural characteristics of elements of static engineering systems

*Simply supported beams:* determination of shear force; bending moment and stress due to bending; radius of curvature in simply supported beams subjected to concentrated and uniformly distributed loads; eccentric loading of columns; stress distribution; middle third rule

*Beams and columns:* elastic section modulus for beams; standard section tables for rolled steel beams; selection of standard sections eg slenderness ratio for compression members, standard section and allowable stress tables for rolled steel columns, selection of standard sections

*Torsion in circular shafts:* theory of torsion and its assumptions eg determination of shear stress, shear strain, shear modulus; distribution of shear stress and angle of twist in solid and hollow circular section shafts

### 2 Be able to determine the behavioural characteristics of elements of dynamic engineering systems

*Uniform acceleration:* linear and angular acceleration; Newton's laws of motion; mass moment of inertia and radius of gyration of rotating components; combined linear and angular motion; effects of friction

*Energy transfer:* gravitational potential energy; linear and angular kinetic energy; strain energy; principle of conservation of energy; work-energy transfer in systems with combine linear and angular motion; effects of impact loading

*Oscillating mechanical systems:* simple harmonic motion; linear and transverse systems; qualitative description of the effects of forcing and damping

### 3 Be able to apply DC theory to solve electrical and electronic engineering problems

*DC electrical principles:* refresh idea of resistors in series and parallel; use of Ohm's and Kirchhoff's laws; voltage and current dividers; review of motor and generator principles eg series, shunt; circuit theorems eg superposition, Thevenin, Norton and maximum power transfer for resistive circuits only; fundamental relationships eg resistance, inductance, capacitance, series C-R circuit, time constant, charge and discharge curves of capacitors, L-R circuits



**4 Be able to apply single phase AC theory to solve electrical and electronic engineering problems**

*AC electrical principles:* features of AC sinusoidal wave form for voltages and currents; explanation of how other more complex wave forms are produced from sinusoidal wave forms; R, L, C circuits eg reactance of R, L and C components, equivalent impedance and admittance for R-L and R-C circuits; high or low pass filters; power factor; true and apparent power; resonance for circuits containing a coil and capacitor connected either in series or parallel; resonant frequency; Q-factor of resonant circuit; transformer fundamentals: construction eg double wound; transformation ratio; equivalent circuit; unloaded transformer; resistance (impedance) matching; transformer losses; applications eg current transformers, voltage transformers

## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Be able to determine the behavioural characteristics of elements of static engineering systems	1.1 determine distribution of shear force, bending moment and stress due to bending in simply supported beams 1.2 select standard rolled steel sections for beams and columns to satisfy given specifications 1.3 determine the distribution of shear stress and the angular deflection due to torsion in circular shafts
LO2 Be able to determine the behavioural characteristics of elements of dynamic engineering systems	2.1 determine the behaviour of dynamic mechanical systems in which uniform acceleration is present 2.2 determine the effects of energy transfer in mechanical systems 2.3 determine the behaviour of oscillating mechanical systems
LO3 Be able to apply DC theory to solve electrical and electronic engineering problems	3.1 solve problems using Kirchhoff's laws to calculate currents and voltages in circuits 3.2 solve problems using circuit theorems to calculate currents and voltages in circuits 3.3 solve problems involving current growth/decay in an L-R circuit and voltage growth/decay in a C-R circuit
LO4 Be able to apply single phase AC theory to solve electrical and electronic engineering problems	4.1 recognise a variety of complex waveforms and explain how they are produced from sinusoidal waveforms 4.2 apply AC theory to solve problems on R, L, C circuits and components 4.3 apply AC theory to solve problems involving transformers.

## Guidance

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### Links

This unit may be linked with *Unit 1: Analytical Methods for Engineers*.

Successful completion of this unit would enable learners to meet, in part, the Incorporated Engineer (IEng) requirements laid down in the UK Engineering Council Standard for Professional Engineering Competence (UK-SPEC) Competence A2, 'Use appropriate scientific, technical or engineering principles'.

### Essential requirements

Learners will need access to suitable mechanical and electrical laboratory equipment.

### Employer engagement and vocational contexts

Liaison with employers would prove of benefit to centres, especially if they are able to offer help with the provision of suitable mechanical or electrical systems/equipment that demonstrate applications of the principles.

ISBN Number (for printed material)	Author	Date	Title	Publisher
ISBN 0-7506-3608-4	Mike Tooley & Lloyd Dingle	2014	Higher National Engineering (2 <sup>nd</sup> Edition)	Newnes
ISBN 0-7506-51466	C.R.Robertson	2013	Fundamental Electrical & Electronic Principles	Newnes

Scheduled contact hours: Note: include in scheduled time: project supervision, demonstrations, practical classes and workshops, supervised time in studio or workshop, scheduled lab work, fieldwork, external visits, work-based learning where integrated into a structured academic programme	lectures	36
	seminars	0
	supervised practical sessions	0
	tutorials	0
	formative assessment	16
	other scheduled time	0
Guided independent study Note: include in guided independent study preparation for scheduled sessions, follow up work, wider reading or practice, revision	Independent coursework	98
	Independent laboratory work	0
	other non-scheduled time	
Placements (including work placement and year abroad)		
<b>Total hours ('Should be equal to credit x 10')</b>		<b>150Hrs</b>

## Unit 3: Project Design, Implementation and Evaluation

Unit code: L/601/0995

QCF level: 5

Credit value: 20

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- Aim

To develop learners' skills of independent enquiry by undertaking a sustained investigation of direct relevance to their vocational, academic and professional development.

- Unit abstract

This unit provides opportunities for learners to develop skills in decision making, problem solving and communication, integrated with the skills and knowledge developed in many of the other units within the programme to complete a realistic project.

It requires learners to select, plan, implement and evaluate a project and finally present the outcomes, in terms of the process and the product of the project. It also allows learners to develop the ability to work individually and/or with others, within a defined timescale and given constraints, to produce an acceptable and viable solution to an agreed brief.

If this is a group project, each member of the team must be clear about their responsibilities at the start of the project and supervisors must ensure that everyone is accountable for each aspect of the work and makes a contribution to the end result.

Learners must work under the supervision of programme tutors or work-based managers.

- Learning outcomes

**On successful completion of this unit a learner will:**

- 1 Be able to formulate a project
- 2 Be able to implement the project within agreed procedures and to specification
- 3 Be able to evaluate the project outcomes
- 4 Be able to present the project outcomes.

## Unit content

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### 1 Be able to formulate a project

*Project selection:* researching and reviewing areas of interest; literature review; methods of evaluating feasibility of projects, initial critical analysis of the outline specification, selection of project option, initiating a project logbook/diary, estimating costs and resource implications, identifying goals and limitations, value of project, rationale for selection, agree roles and allocate responsibilities (individually with tutor/supervisor and within project group if appropriate)

*Project specifications:* developing and structuring a list of requirements relevant to project specifications eg costs, timescales, scale of operation, standards, legislation, ethics, sustainability, quality, fitness-for-purpose, business data, resource implications

*Procedures:* planning and monitoring methods, operating methods, lines of communication, risk analysis, structure of groups and collaborative working eg learner groups or roles and responsibilities within a work-based project, targets and aims

*Project plan:* production of a plan for the project including timescales, deliverables, milestones, quality assurance systems and quality plans, and monitoring progress

### 2 Be able to implement the project within agreed procedures and to specification

*Implement:* proper use of resources, working within agreed timescale, use of appropriate techniques for generating solutions, monitoring development against the agreed project plan, maintaining and adapting project plan where appropriate

*Record:* systematic recording of relevant outcomes of all aspects and stages of the project to agreed standards

### 3 Be able to evaluate the project outcomes

*Evaluation techniques:* detailed analysis of results, conclusions and recommendations, critical analysis against the project specification and planned procedures, use of appropriate evaluation techniques, application of project evaluation and review techniques (PERT), opportunities for further studies and developments

*Interpretation:* use of appropriate techniques to justify project progress and outcomes in relation to the original agreed project specification

*Further consideration:* significance of project; application of project results; implications; limitations of the project; improvements; recommendations for further consideration

### 4 Be able to present the project outcomes

*Record of procedures and results:* relevant documentation of all aspects and stages of the project

*Format:* professional delivery format appropriate to the audience; use of appropriate media

## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Be able to formulate a project	1.1 formulate and record possible outline project specifications 1.2 identify the factors that contribute to the process of project selection 1.3 produce a specification for the agreed project 1.4 produce an appropriate project plan for the agreed project
LO2 Be able to implement the project within agreed procedures and to specification	2.1 match resources efficiently to the project 2.2 undertake the proposed project in accordance with the agreed specification. 2.3 organise, analyse and interpret relevant outcomes
LO3 Be able to evaluate the project outcomes	3.1 use appropriate project evaluation techniques 3.2 interpret and analyse the results in terms of the original project specification 3.3 make recommendations and justify areas for further consideration
LO4 Be able to present the project outcomes	4.1 produce a record of all project procedures used 4.2 use an agreed format and appropriate media to present the outcomes of the project to an audience.

## Guidance

### Links

This unit is suitable for use by all sectors and should utilise the full range of skills developed through study of other units in the programme. These include planning, practical work, data handling and processing, analysis and presentation.

The knowledge applied may link to one particular unit or to a number of other units.

### Essential requirements

The required resources will vary significantly with the nature of the project. The identification of the equipment and materials required, and the establishment of their availability, is a vital part of the planning phase. Learners should therefore have access to a wide variety of physical resources and data sources relevant to the project. Tutors should ensure that learners do not embark on work that cannot succeed because of lack of access to the required resources.

### Employer engagement and vocational contexts

Centres should try to establish relationships with appropriate organisations in order to bring realism and relevance to the project.

ISBN Number (for printed material)	Author	Date	Title	Publisher
ISBN 0-7506-3608-4	Mike Tooley & Lloyd Dingle	2014	Higher National Engineering (2 <sup>nd</sup> Edition)	Newnes
ISBN: 9780071471602	David L. Cleland, Lewis R. Ireland	2013	PROJECT MANAGEMENT: STRATEGIC DESIGN AND IMPLEMENTATION	McGraw Hill

Scheduled contact hours: Note: include in scheduled time: project supervision, demonstrations, practical classes and workshops, supervised time in studio or workshop, scheduled lab work, fieldwork, external visits, work-based learning where integrated into a structured academic programme	lectures	46
	seminars	0
	supervised practical sessions	0
	tutorials	0
	formative assessment	4
	other scheduled time	0
Guided independent study Note: include in guided independent study preparation for scheduled sessions, follow up work, wider reading or practice, revision	Independent coursework	100
	Independent laboratory work	50
	other non-scheduled time	
Placements (including work placement and year abroad)		
<b>Total hours ('Should be equal to credit x 10')</b>		<b>200Hrs</b>

## Unit 5: Electrical and Electronic Principles

Unit code: R/601/1453

QCF level: 5

Credit value: 15

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- Aim

This unit provides an understanding of electrical and electronic principles used in a range of engineering careers and provides the basis for further study of more specialist areas of electrical/electronic engineering.

- Unit abstract

Circuits and their characteristics are fundamental to any study of electrical and electronic engineering and therefore a good understanding is important to any engineer.

The engineer must be able to take complex electrical circuit problems, break them down into acceptable elements and apply techniques to solve or analyse the characteristics. Additionally, fine tuning of the circuits can be performed to obtain required output dynamics.

This unit draws together a logical appreciation of the topic and offers a structured approach to the development of the broad learning required at this level. Learners will begin by investigating circuit theory and the related theorems to develop solutions to electrical networks.

In learning outcome 2 the concept of an attenuator is introduced by considering a symmetrical two-port network and its characteristics. The design and testing of both T and  $\pi$  networks is also covered.

Learning outcome 3 considers the properties of complex waveforms and Fourier analysis is used to evaluate the Fourier coefficients of a complex periodic waveform.

Finally, learning outcome 4 introduces the use of Laplace transforms as a means of solving first order differential equations used to model RL and RC networks, together with the evaluation of circuit responses to a step input in practical situations.

- Learning outcomes

**On successful completion of this unit a learner will:**

- 1 Be able to apply electrical and electronic circuit theory
- 2 Be able to apply two-port network models
- 3 Understand the use of complex waves
- 4 Be able to apply transients in R-L-C circuits.



## Unit content

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### 1 Be able to apply electrical and electronic circuit theory

*Transformation theorems:* energy sources as constant-voltage and constant-current generators; Thévenin's and Norton's theorems; delta-star and star-delta transformation

*Circuit theory:* maximum power transfer conditions for resistive and complex circuits; mesh and nodal analysis; the principle of superposition

*Magnetically coupled circuits:* mutual inductance; the use of dot notation; equivalent circuits for transformers including the effects of resistive and reactive features

*R-L-C tuned circuits:* series and parallel resonant circuits; impedance; phase angle; dynamic resistance; Q-factor; bandwidth; selectivity and resonant frequency; the effects of loading on tuned circuit performance

### 2 Be able to apply two-port network models

*Network models:* symmetrical two-port network model; characteristic impedance,  $Z_0$ ; propagation coefficient (expressed in terms of attenuation,  $\alpha$ , and phase change  $\beta$ ); input impedance for various load conditions including  $Z_L = Z_0$ ; relationship between the neper and the dB; insertion loss

*Symmetrical attenuators:* T and  $\pi$  attenuators; the expressions for  $R_0$  and  $\alpha$  in terms of component values

### 3 Understand the use of complex waves

*Properties:* power factor; rms value of complex periodic waveforms

*Analyse:* Fourier coefficients of a complex periodic voltage waveform eg Fourier series for rectangular, triangular or half-wave rectified waveform, use of a tabular method for determining the Fourier series for a complex periodic waveform; use of a waveform analyser; use of an appropriate software package

### 4 Be able to apply transients in R-L-C circuits

*Laplace transforms:* definition of the Laplace transform of a function; use of a table of Laplace transforms

*Transient analysis:* expressions for component and circuit impedance in the s-plane; first order systems must be solved by Laplace (ie RL and RC networks); second order systems could be solved by Laplace or computer-based packages

*Circuit responses:* over, under, zero and critically damped response following a step input; zero initial conditions being assumed

## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Be able to apply electrical and electronic circuit theory	1.1 calculate the parameters of AC equivalent circuits using transformation theorems 1.2 apply circuit theory techniques to the solution of AC circuit problems 1.3 analyse the operation of magnetically coupled circuits 1.4 use circuit theory to solve problems relating to series and parallel R-L-C tuned circuits
LO2 Be able to apply two-port network models	2.1 apply two-port network model to the solution of practical problems 2.2 design and test symmetrical attenuators against computer models
LO3 Understand the use of complex waves	3.1 calculate the properties of complex periodic waves 3.2 analyse complex periodic waves
LO4 Be able to apply transients in R-L-C circuits	4.1 use Laplace transforms for the transient analysis of networks 4.2 calculate circuit responses to a step input in practical situations.

## Guidance

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### Links

This unit relies heavily on the use of mathematical analysis to support the underlying theory and practical work. Consequently it is assumed that *Unit 1: Analytical Methods for Engineers* has been taught previously or is being delivered in parallel. It may also be linked with *Unit 2: Engineering Science*.

### Essential requirements

Learners will require access to a range of electronic test equipment, eg oscilloscopes, signal generators, etc.

### Employer engagement and vocational contexts

Delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

ISBN Number (for printed material)	Author	Date	Title	Publisher
ISBN 0-7506-3608-4	Mike Tooley & Lloyd Dingle	2014	Higher National Engineering (2 <sup>nd</sup> Edition)	Newnes
ISBN 0-7506-51466	C.R.Robertson	2012	Fundamental Electrical & Electronic Principles	Newnes
ISBN 0-675-20883-1	Thomas L Floyd	2012	Electronic Devices	(Merrill)

Scheduled contact hours: Note: include in scheduled time: project supervision, demonstrations, practical classes and workshops, supervised time in studio or workshop, scheduled lab work, fieldwork, external visits, work-based learning where integrated into a structured academic programme	lectures	36
	seminars	0
	supervised practical	0
	tutorials	0
	formative assessment	16
	other scheduled time	0
Guided independent study Note: include in guided independent study preparation for scheduled sessions, follow up work, wider reading or practice, revision	Independent coursework	98
	Independent laboratory	0
	other non-scheduled time	
Placements (including work placement and year abroad)		
<b>Total hours ('Should be equal to credit x 10')</b>		<b>150Hrs</b>

## Unit 22: Programmable Logic Controllers

Unit code: A/601/1625

QCF level: 4

Credit value: 15

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- Aim

The aim of this unit is to investigate programmable logic controller (PLC) concepts and their applications in engineering.

- Unit abstract

The unit focuses on the design and operational characteristics and internal architecture of programmable logic control systems. It examines the signals used and the programming techniques that can be applied. The unit also provides learners with the opportunity to produce and demonstrate a program for a programmable logic controller device (for example produce a programme for an engineering application, store, evaluate and justify approaches taken).

- Learning outcomes

**On successful completion of this unit a learner will:**

- 1 Understand the design and operational characteristics of a PLC system
- 2 Understand PLC information and communication techniques
- 3 Be able to apply programmable logic programming techniques
- 4 Understand alternative implementations of programmable control.

## Unit content

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### 1 Understand the design and operational characteristics of a PLC system

*Design characteristics:* unitary; modular; rack-mounted

*Input and output devices:* mechanical switches; non-mechanical digital sources; transducers; relays

*Communication links:* twisted pair; coaxial; fibre-optic; networks

*Internal architecture:* central processor unit (CPU); arithmetic logic unit (ALU); storage devices; memory; opto-isolators; input and output units; flags; shift; registers

*Operational characteristics:* scanning; performing logic operations; continuous updating; mass input/output (I/O) copying

### 2 Understand PLC information and communication techniques

*Forms of signal:* analogue (0-10 v dc, 4-20mA); digital

*Digital resolution and relationships:* 9-bit; 10-bit; 12-bit

*Number systems:* decimal; binary; octal; hexadecimal; Binary-Coded Decimal (BCD)

*Evaluate communication standards:* comparison of typical protocols used in signal communication

*Evaluate networking methods and standards:* master to slave; peer to peer; ISO; IEE; MAP

*Logic functions:* writing programmes using logic functions based on relay ladder logic (AND; OR; EXCLUSIVE OR; NAND; NOR)

### 3 Be able to apply programmable logic programming techniques

*Write programs:* use of ladder and logic diagrams; statement lists; Boolean algebra; function diagrams; graphical programming languages; production of a PLC

*Advanced functions:* less than; greater than; binary to BCD conversion; proportional feedback control

*Producing and storing text:* contact labels; rung labels; programming lists; cross-referencing

*Test and debug programs:* forcing inputs, forcing outputs; changing data; comparing files (tapes, EPROM, disc); displayed error analysis

*Associated elements:* contacts; coils; timers; counters; override facilities; flip-flops; shift registers; sequencers

### 4 Understand alternative implementations of programmable control

*PICs and other programmable devices:* specification and use of PICs and other programmable devices; embedded controllers

*PLC simulators:* compare operation and functionality; advantages and limitations

## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Understand the design and operational characteristics of a PLC system	1.1 evaluate the design characteristics of typical programmable logic devices 1.2 describe different types of input and output device 1.3 evaluate the different types of communication link used in programmable logic control systems 1.4 describe the internal architecture and operational characteristics of the CPU of a typical programmable logic device
LO2 Understand PLC information and communication techniques	2.1 evaluate the different forms of signal used in programmable logic control 2.2 describe the resolution and relationship between analogue inputs and outputs and word length 2.3 express numbers using different number systems 2.4 describe typical protocols used in signal communication and evaluate networking methods and networking standards
LO3 Be able to apply programmable logic programming techniques	3.1 identify elements associated with the preparation of a programmable logic controller program 3.2 write programs using logic functions based on relay ladder logic 3.3 evaluate the range and type of advanced functions of programmable logic controllers 3.4 use and justify methods of testing and debugging hardware and software
LO4 Understand alternative implementations of programmable control	4.1 evaluate PICs and other programmable devices as programmable devices and embedded controllers 4.2 compare the operation, functionality, advantages and limitations of PLC simulators.

## Guidance

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### Links

This unit may be linked to *Unit 46: Plant and Process Control*, *Unit 49: Computer Control of Plant*, *Unit 58: Microprocessor Systems* and *Unit 71: Combinational and Sequential Logic*.

### Essential requirements

Centres delivering this unit must be equipped with, or have access to, industrial-standard programmable logic control units and development software.

### Employer engagement and vocational contexts

Visits to industrial PLC installations will be of value to supplement the learning activities.

ISBN Number (for printed material)	Author	Date	Title	Publisher
ISBN 0-7506-6432-0	W.Bolton	2012	Instrumentation and Control Systems	Newnes
ISBN 0750681128, 9780750681124	W.Bolton	2012	Programmable Logic Controller	Newnes

Scheduled contact hours: Note: include in scheduled time: project supervision, demonstrations, practical classes and workshops, supervised time in studio or workshop, scheduled lab work, fieldwork, external visits, work-based learning where integrated into a structured academic programme	lectures	37
	seminars	0
	supervised practical	6
	tutorials	0
	formative assessment	9
	other scheduled time	0
Guided independent study Note: include in guided independent study preparation for scheduled sessions, follow up work, wider reading or practice, revision	Independent coursework	98
	Independent laboratory	0
	other non-scheduled time	
Placements (including work placement and year abroad)		
<b>Total hours ('Should be equal to credit x 10')</b>		<b>150Hrs</b>

## Unit 35: Further Analytical Methods for Engineers

Unit code: J/601/1465

QCF level: 5

Credit value: 15

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- Aim

This unit aims to further develop the analytical knowledge and techniques necessary to analyse and solve a variety of engineering situations and problems.

- Unit abstract

This unit has been designed to enable learners to use number systems, graphical and numerical methods, vectors, matrices and ordinary differential equations to analyse, model and solve realistic engineering problems.

Learners will use estimation techniques and error arithmetic to establish realistic results from experiments and general laboratory work. They will then consider the conversion of number systems from one base to another and the application of the binary number system to logic circuits. Complex numbers and their application to the solution of engineering problems are also studied.

Learners will look at the use of graphical techniques together with various methods of numerical integration (for example Simpson's rules) and estimation (for example Newton-Raphson). They will then go on to analyse and model engineering situations using vector geometry and matrix methods.

Finally, learners will study both first and second order differential equations and their application to a variety of engineering situations dependant upon the learner's chosen discipline.

- Learning outcomes

**On successful completion of this unit a learner will:**

- 1 Be able to analyse and model engineering situations and solve problems using number systems
- 2 Be able to analyse and model engineering situations and solve problems using graphical and numerical methods
- 3 Be able to analyse and model engineering situations and solve problems using vector geometry and matrix methods
- 4 Be able to analyse and model engineering situations and solve problems using ordinary differential equations.



## Unit content

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### 1 Be able to analyse and model engineering situations and solve problems using number systems

*Error arithmetic:* significant figures and estimation techniques; error arithmetic operations; systematic and random errors; application to experimentation and general laboratory work

*Number systems:* natural, integer, rational, reals, dinary, binary, octal and hexadecimal number systems; conversion from dinary to numbers of other bases and vice versa; two-state logic systems, binary numbers and logic gates, logic gate tables, application to logic circuits

*Complex numbers:* real and imaginary parts of complex numbers, complex number notation; Cartesian and polar forms; modulus, argument and complex conjugate; addition, subtraction, multiplication and division of Cartesian and polar forms; use of Argand diagrams; powers and roots and the use of de Moivre's theorem

*Engineering applications:* applications eg electric circuit analysis, phasors, transmission lines, information and energy control systems

### 2 Be able to analyse and model engineering situations and solve problems using graphical and numerical methods

*Graphical techniques:* Cartesian and polar co-ordinate systems and representation of complex number operations; vector representation; standard curves; asymptotes; systematic curve sketching; curve fitting; irregular areas and mean values of wave forms; use of phasor and Argand diagrams; application to engineering situations

*Numerical integral:* determine the integral of functions using mid-ordinate; trapezoidal and Simpson's rules

*Numerical estimation methods:* method of bisection; Newton-Raphson iteration method; estimates of scientific functions

### 3 Be able to analyse and model engineering situations and solve problems using vector geometry and matrix methods

*Vector notation and operations:* Cartesian co-ordinates and unit vectors; types of vector and vector representation; addition and subtraction; multiplication by a scalar; graphical methods

*Matrix operations and vectors:* carry out a range of matrix operations eg vectors in matrix form, square and rectangular matrices, row and column vectors, significance of the determinant, determinant for 2x2 matrix, the inverse of a 2x2 matrix; use Gaussian elimination to solve systems of linear equations (up to 3x3)

*Vector geometry:* determine scalar product, vector product, angle between two vectors, equation of a line, norm of a vector, dot and cross products; apply vector geometry to the solution of engineering problems eg velocity vector and mechanisms, acceleration vector and mechanisms, forces in static frameworks and structures, evaluation of static joint structures using dot product, phasors

**4 Be able to analyse and model engineering situations and solve problems using ordinary differential equations**

*First order differential equations:* engineering use; separation of variables; integrating factor method, complementary function and particular integral

*Numerical methods for first order differential equations:* need for numerical solution; Euler's method; improved Euler method; Taylor series method

*Application of first order differential equations:* applications eg RC and RL electric circuits, time constants, motion with constant and variable acceleration, Fourier equation for heat transfer, Newton's laws of cooling, charge and discharge of electrical capacitors, complex stress and strain, metrology problems

*Second order differential equations:* engineering use; arbitrary constants; homogeneous and non-homogeneous linear second order equations

*Application of second order differential equations:* applications eg RLC series and parallel circuits, undamped and damped mechanical oscillations, fluid systems, flight control laws, mass-spring-damper systems, translational and rotational motion systems, thermodynamic systems, information and energy control systems, heat transfer, automatic control systems, stress and strain, torsion, shells, beam theory

*Engineering situations:* applications eg heat transfer, Newton's laws, growth and decay, mechanical systems, electrical systems, electronics, design, fluid systems, thermodynamics, control, statics, dynamics, energy systems, aerodynamics, vehicle systems, transmission and communication systems

## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Be able to analyse and model engineering situations and solve problems using number systems	1.1 use estimation techniques and error arithmetic to establish realistic results from experiment 1.2 convert number systems from one base to another, and apply the binary number system to logic circuits 1.3 perform arithmetic operations using complex numbers in Cartesian and polar form 1.4 determine the powers and roots of complex numbers using de Moivre's theorem 1.5 apply complex number theory to the solution of engineering problems when appropriate
LO2 Be able to analyse and model engineering situations and solve problems using graphical and numerical methods	2.1 draw graphs involving algebraic, trigonometric and logarithmic data from a variety of scientific and engineering sources, and determine realistic estimates for variables using graphical estimation techniques 2.2 make estimates and determine engineering parameters from graphs, diagrams, charts and data tables 2.3 determine the numerical integral of scientific and engineering functions 2.4 estimate values for scientific and engineering functions using iterative techniques
LO3 Be able to analyse and model engineering situations and solve problems using vector geometry and matrix methods	3.1 represent force systems, motion parameters and waveforms as vectors and determine required engineering parameters using analytical and graphical methods 3.2 represent linear vector equations in matrix form and solve the system of linear equations using Gaussian elimination 3.3 use vector geometry to model and solve appropriate engineering problems

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO4 Be able to analyse and model engineering situations and solve problems using ordinary differential equations	4.1 analyse engineering problems and formulate mathematical models using first order differential equations 4.2 solve first order differential equations using analytical and numerical methods 4.3 analyse engineering problems and formulate mathematical models using second order differential equations 4.4 solve second order homogeneous and non-homogenous differential equations 4.5 apply first and second order differential equations to the solution of engineering situations.

## Guidance

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### Links

This unit builds on and can be linked to *Unit 1: Analytical Methods for Engineers* and can provide a foundation for *Unit 59: Advanced Mathematics for Engineering*.

### Essential requirements

There are no essential requirements for this unit.

### Employer engagement and vocational contexts

This unit will benefit from centres establishing strong links with employers who can contribute to the delivery of teaching, work-based placements and/or detailed case study material

ISBN Number (for printed material)	Author	Date	Title	Publisher
ISBN 0-7506-3608-4	Mike Tooley & Lloyd Dingle	2014	Higher National Engineering (2 <sup>nd</sup> Edition)	Newnes
ISBN 0-582-41371-0	JO Bird & AJC May	2014	Algebra and Calculus for Technicians	Longman
ISBN 0-7506-3621-1	W.Bolton	2014	Essential Mathematics for Engineers	Butterworth Heinemann

Scheduled contact hours: Note: include in scheduled time: project supervision, demonstrations, practical classes and workshops, supervised time in studio or workshop, scheduled lab work , fieldwork, external visits, work-based learning where integrated into a structured academic programme	lectures	36
	seminars	0
	supervised practical sessions	0
	tutorials	0
	formative assessment	16
	other scheduled time	0
	Guided independent study Note: include in guided independent study preparation for scheduled sessions, follow up work, wider reading or practice, revision	Independent coursework
	Independent laboratory work	0
	other non-scheduled time	
Placements (including work placement and year abroad)		
<b>Total hours ('Should be equal to credit x 10')</b>		<b>150Hrs</b>

## Unit 37: Management of Projects

Unit code: J/601/0302

QCF level: 4

Credit value: 15

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- Aim

This unit provides an understanding and experience of project management principles, methodologies, tools and techniques that may be used in industry and the public sector.

- Unit abstract

The management of projects is a key element for successful scientific investigation of activities related to academic research, company research and development or consultancy.

Through this unit learners will develop an understanding of what constitutes a project and the role of a project manager. They will examine the criteria for the success or failure of a project, evaluate project management systems and review the elements involved in project termination and appraisal.

Learners will also understand the need for structured organisation within the project team, effective control and coordination and good leadership qualities in the project manager. They will be able to analyse and plan the activities needed to carry out the project, including how to set up a project, how to control and execute a project, and how to carry out project reviews using a specialist software package for project management. They will also appreciate how the project fits into the strategy or business plan of an organisation.

- Learning outcomes

**On completion of this unit a learner should:**

- 1 Understand the principles of project management
- 2 Be able to plan a project in terms of organisation and people
- 3 Be able to manage project processes and procedures.

## Unit content

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### 1 Understand the principles of project management

*Project management:* project management and the role of the project manager eg management of change, understanding of project management system elements and their integration, management of multiple projects, project environment and the impact of external influences on projects; identification of the major project phases and why they are required; an understanding of the work in each phase; the nature of work in the lifecycles of projects in various industries

*Success/failure criteria:* the need to meet operational, time and cost criteria; define and measure success eg develop the project scope, product breakdown structure (PBS), work breakdown structure (WBS), project execution strategy and the role of the project team; consideration of investment appraisal eg use of discount cash flow (DCF) and net present value (NPV); benefit analysis and viability of projects; determine success/failure criteria; preparation of project definition report; acceptance tests

*Project management systems:* procedures and processes; knowledge of project information support (IS) systems; how to integrate human and material resources to achieve successful projects

*Terminating the project:* audit trails; punch lists; close-out reports

*Post-project appraisals:* comparison of project outcome with business objectives

### 2 Be able to plan a project in terms of organisation and people

*Organisational structure:* functional, project and matrix organisational structures eg consideration of cultural and environmental influences, organisational evolution during the project lifecycle; job descriptions and key roles eg the project sponsor, champion, manager, integrators; other participants eg the project owner, user, supporters, stakeholders

*Roles and responsibilities:* the need for monitoring and control eg preparation of project plans, planning, scheduling and resourcing techniques,

*Control and co-ordination:* use of work breakdown structures to develop monitoring and control systems, monitoring performance and progress measurement against established targets and plans; project reporting; change control procedures; the importance of cascading, communications briefing, instilling trust and confidence in others

*Leadership requirements:* stages of team development e.g. Belbin's team roles, motivation and the need for team building, project leadership styles and attributes; delegation of work and responsibility; techniques for dealing with conflict; negotiation skills; chair meetings

*Human resources and requirements:* calculation; specification; optimisation of human resource requirements; job descriptions

### 3 Be able to manage project processes and procedures

*Project organisation:* the product breakdown structure (PBS) and the work breakdown structure (WBS); project execution strategy and the organisation breakdown structure (OBS) eg preparation of organisation charts, task responsibility matrix, statement of work (SOW) for project tasks

*Project management plans:* the why, what, how, when, where and by whom of project management eg contract terms, document distribution schedules, procurement, establishing the baseline for the project

*Scheduling techniques:* relationship between schedules, OBS and WBS; bar charts; milestone schedules; network techniques; resourcing techniques; computer-based scheduling and resourcing packages; project progress measurement and reporting techniques; staff-hours earned value and progress 'S' curves; critical path analysis and reporting; milestone trending

*Cost control techniques:* cost breakdown structure eg types of project estimate, resources needed, estimating techniques, estimating accuracy, contingency and estimation, bid estimates, whole-life cost estimates, sources of information, cost information sensitivity, computer-based estimating; allocation of budgets to packages of work; committed costs; actual costs; cash flow; contingency management

*Performance:* cost performance analysis eg budgeted cost for work scheduled (BCWS) budgeted cost for work performed (BCWP); concept of earned value; actual cost of work performed (ACWP); cost performance indicators

*Change control procedures:* the need for formal control of changes e.g. project impact of changes, principles of change control and configuration management; changes to scope, specification, cost or schedule; change reviews and authorisation; the formation of project teams; project initiation and start-up procedures



## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Understand the principles of project management	1.1 explain the principles of project management 1.2 discuss viability of projects with particular emphasis on the criteria for success/failure 1.3 explore principles behind project management systems and procedures 1.4 explain key elements involved in terminating projects and conducting post-project appraisals
LO2 Be able to plan a project in terms of organisation and people	2.1 plan the most appropriate organisational structure 2.2 discuss roles and responsibilities of participants within a project 2.3 carry out the control and co-ordination of a project 2.4 document project leadership requirements and qualities 2.5 plan specific human resources and requirements for a project
LO3 Be able to manage project processes and procedures	3.1 design the project organisation with reference to prepared project management plans 3.2 use project scheduling and cost control techniques 3.3 report the methods used to measure project performance 3.4 report project change control procedures 3.5 discuss the outcomes of the project and make recommendations.

## Guidance

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### Links

This unit could be studied in parallel with, and complement, *Unit 3: Project Design, Implementation and Evaluation*, which could provide many of the skills necessary for the successful completion of this unit. This unit is also supported by *Unit 7: Business Management Techniques*.

### Essential resources

Appropriate software packages will be needed to demonstrate project control and reporting techniques. Packages might include time and cost scheduling packages, documentation and procurement control packages, spreadsheet packages, graphic presentation packages.

### Employer engagement and vocational contexts

Learners will benefit from visits to organisations that are engaged in project work as a part of academic research, investigations and research for public bodies, company research and development or consultancy activities. An ideal context would be for the learner to manage a project that was of interest to a particular organisation.

ISBN Number (for printed material)	Author	Date	Title	Publisher
ISBN 0-7506-3608-4	Mike Tooley & Lloyd Dingle	2014	Higher National Engineering (2 <sup>nd</sup> Edition)	Newnes
ISBN: 9780071471602	David L. Cleland, Lewis R. Ireland	2013	PROJECT MANAGEMENT: STRATEGIC DESIGN AND IMPLEMENTATION	McGraw Hill

Scheduled contact hours: Note: include in scheduled time: project supervision, demonstrations, practical classes and workshops, supervised time in studio or workshop, scheduled lab work, fieldwork, external visits, work-based learning where integrated into a structured academic programme	lectures	36
	seminars	0
	supervised practical	0
	tutorials	0
	formative assessment	16
	other scheduled time	0
Guided independent study Note: include in guided independent study preparation for scheduled sessions, follow up work, wider reading or practice, revision	Independent coursework	98
	Independent laboratory	0
	other non-scheduled time	
Placements (including work placement and year abroad)		
<b>Total hours ('Should be equal to credit x 10')</b>		<b>150Hrs</b>

## Unit 57: Mechatronic Systems

Unit code: F/601/1416

QCF level: 4

Credit value: 15

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- Aim

This unit will develop learners' understanding of a range of mechatronic systems that are used in industrial and domestic environments and enable them to produce specifications for mechatronic products.

- Unit abstract

The material and topics covered in this unit will be broad-based to reflect the fact that mechatronics is, by its nature, multi-disciplinary and not confined to a single specialised area. The unit will encompass small, single component systems as well as larger systems integrating components from different engineering disciplines. It will develop a methodology that will allow learners to apply mechatronic design philosophy throughout the development cycle of a systems and products. The intention is to encourage the learner to recognise a system not as an interconnection of different parts but as an integrated module.

Learners will investigate the applications of mechatronics, considering the need for integration and the nature of mechatronic systems and products. Typical mechatronics components are examined by before learners look at the design steps and processes for mechatronic systems and mechatronic products.

- Learning outcomes

**On successful completion of this unit a learner will:**

- 1 Understand the applications of a range of mechatronic systems and products
- 2 Understand electro-mechanical models and components in mechatronic systems and products
- 3 Be able to produce a specification for a mechatronic system or mechatronic product
- 4 Be able to apply mechatronic design philosophies to carry out a design analysis.

## Unit content

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### 1 Understand the applications of a range of mechatronic systems and products

*Discipline integration:* need for systems to be designed in an integrated way rather than as a collection of unrelated yet interconnected constituent parts eg constraints in size and cost of components, reduction in cost of computing power, required reduction in process delays, compatibility of connection systems

*Mechatronics systems:* differentiate between systems that are mechatronics in nature and those that incorporate a number of different disciplines

*Industrial and consumer examples of mechatronics systems:* applications eg industrial robots, computer-based production and manufacture (CNC/CAM) machines, ATMs, transportation systems, 'fly by wire' aircraft, suspension control on road vehicles, brake- and steer-by-wire; auto-exposure, auto-focus cameras, vending machines, domestic appliances

### 2 Understand electro-mechanical models and components in mechatronic systems and products

*Simple mathematical models:* mechanical system building blocks; electrical system building blocks; electrical-mechanical analogies; fluid and thermal systems

*Sensor technologies:* sensor and actuator technologies for mechatronic system eg resistive, inductive, capacitive, optical/fibre-optic, wireless, ultrasonic, piezoelectric

*Actuator technologies:* electric motors; stepper motors; motor control; fluid power; integrated actuators and sensors; embedded systems

### 3 Be able to produce a specification for a mechatronic system or mechatronic product

*Standards:* standards eg appropriate British, European and international standards

*Required sensor attributes:* phenomena being sensed; interaction of variables and removal of undesired changes; proximity of sensor to measurand; invasiveness of the measurement and measurand; signal form; ergonomic and economic factors

*Actuator and sensor technologies:* selection of suitable sensor and actuator technologies for mechatronic systems and mechatronic products

*Controllers:* selection of appropriate computer control hardware for mechatronic systems and mechatronic products eg microprocessor, PLC, PC-based, PIC, embedded controllers

### 4 Be able to apply mechatronic design philosophies to carry out a design analysis

*Designing:* the steps in a design process; comparison between traditional design methods and those designs which are mechatronics driven

## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Understand the applications of a range of mechatronic systems and products	1.1 identify mechatronic systems by their discipline integration 1.2 explain the need for system development in an integrated way 1.3 investigate mechatronic applications in consumer products and industrial processes
LO2 Understand electro-mechanical models and components in mechatronic systems and products	2.1 derive a mathematical model for 1st and 2nd order electrical and mechanical system 2.2 analyse analogies between the models of physically different systems 2.3 describe typical sensors and actuators for mechatronic systems and products
LO3 Be able to produce a specification for a mechatronic system or mechatronic product	3.1 produce a specification for a mechatronic system to meet current British Standards 3.2 select suitable sensor and actuator technologies for a mechatronic system 3.3 specify appropriate computer control hardware for a mechatronic system
LO4 Be able to apply mechatronic design philosophies to carry out a design analysis	4.1 carry out a design analysis on a system or product using mechatronic design philosophies 4.2 compare a system or product which has been designed employing traditional methods with one employing mechatronic methods.

## Guidance

### Links

This unit can be linked to *Unit 5: Electrical and Electronic Principles* and *Unit 32: Industrial Robot Technology*.

### Essential requirements

Centres will need to provide access to a range of case studies, highlighting the use of mechatronic design philosophies.

### Employer engagement and vocational contexts

Learners should be encouraged to review processes in their workplace in order to demonstrate the efficacy of adopting a mechatronics approach.

ISBN Number (for printed material)	Author	Date	Title	Publisher
ISBN 0-85380-182-7	K.J.Bohlman	2012	Electronics Servicing Vol3 Control Systems Technology	Newnes
ISBN 0-7506-51466	C.R.Robertson	2012	Fundamental Electrical & Electronic Principles	Newnes
ISBN 0-675-20883-1	Thomas L Floyd	2012	Electronic Devices	(Merrill)

Scheduled contact hours: Note: include in scheduled time: project supervision, demonstrations, practical classes and workshops, supervised time in studio or workshop, scheduled lab work , fieldwork, external visits, work-based learning where integrated into a structured academic programme	lectures	37
	seminars	0
	supervised practical	6
	tutorials	0
	formative assessment	9
	other scheduled time	0
Guided independent study Note: include in guided independent study preparation for scheduled sessions, follow up work, wider reading or practice, revision	Independent coursework	98
	Independent laboratory	0
	other non-scheduled time	
Placements (including work placement and year abroad)		
<b>Total hours ('Should be equal to credit x 10')</b>		<b>150Hrs</b>

## Unit 68: Applications of Power Electronics

Unit code: D/601/1391

QCF level: 4

Credit value: 15

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- Aim

This unit will develop a technical understanding of power electronics and their application to variable speed drives.

- Unit abstract

Power electronics involves the use of semiconductor devices to control a range of applications in rectification, DC and AC motor control and controlled power supplies. To meet the challenges expected of a modern 'heavy current' engineer the unit carries an emphasis on the application of power electronics to variable speed controllers. The focus is on the power aspects rather than the associated detail of the electronic control and firing circuitry.

In every aspect of engineering variability exists and therefore acceptable tolerances are specified to define close limits of output. Testing and measurement must make use of safe techniques and in this case are conducted via the use of isolating probes and transducers in systems operating from earthed power systems.

The unit involves practical investigations of common configurations of controlled rectifier and inverter systems, as applied to alternating and direct current motor control. The use of commercial/industrial variable speed drives provides a relevant and convenient method of investigation. To broaden the scope of the subject, non-drive applications of power electronics are investigated and developed to meet local industrial requirements.

No matter in which sector he/she is involved, the modern engineer needs to be energy conscious and therefore must seek and implement ways of conserving valuable resources.

- Learning outcomes

**On successful completion of this unit a learner will:**

- 1 Understand common configurations for controlled and uncontrolled rectification
- 2 Understand the methods used for AC motor control
- 3 Understand the methods used for DC motor control
- 4 Understand other applications of power electronics.

## Unit content

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### 1 Understand common configurations for controlled and uncontrolled rectification

*Standard configurations:* half wave and full wave bridge circuits; resistive and inductive loads, flywheel diodes

*Signal parameters:* amplitude; peak-to-peak; waveforms; full and half wave forms; ripple; average and root-mean-square (RMS) values; pulse number; harmonics; resonance calculations of signal parameters of rectified waveforms eg average and root-mean-square (RMS) values, pulse number, waveforms, harmonics

*Device protection:* protection methods for power semiconductors eg over-voltage, over-current, transients

*Measurement techniques:* safety considerations in a heavy current power environment eg in systems where voltages exceed 50V; use of isolated differential voltage attenuator probes; Hall effect current probes; power oscilloscope

### 2 Understand the methods used for AC motor control

*Frequency conversion methods:* inverter switching strategies eg quasi-square-wave, pulse width modulation, cycloconverter, waveforms, harmonics, filters

*AC motor control:* soft starter; speed; torque; reversal; braking; voltage; frequency; voltage/frequency (V/Hz); vector control

*Investigation of an industrial AC motor controller:* preparation and interpretation of circuit and block diagrams; setting of parameters eg min/max speed, ramp up/down time, current/torque limits; applications eg process control, mills, fans, conveyor systems; specification and selection

### 3 Understand the methods used for DC motor control

*Speed control of DC motor:* armature voltage; field weakening; DC choppers; controlled rectifiers; closed loop; tacho-generator; reversal; braking; waveforms

*Torque control of DC motor:* armature current control loops; speed reversal; braking; single quadrant; four quadrant operation; regeneration

*Investigation of an industrial DC motor controller:* preparation and interpretation of circuit and block diagrams; setting of parameters eg min/max speed, ramp up/down time, current/torque limits; applications eg process control, mills, pumps, CNC machinery; specification and selection

### 4 Understand other applications of power electronics

*Principles:* comparison of the principles of operation; control techniques; protection methods; use of block and circuit diagrams

*Other applications:* applications eg uninterruptible power supplies, high voltage DC links, inductive heating, welding machines, compact fluorescent lighting



## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Understand common configurations for controlled and uncontrolled rectification	1.1 compare standard configurations used in single and three-phase systems 1.2 calculate signal parameters of a rectified waveform 1.3 explain methods of device protection 1.4 use safe measurement techniques when measuring current and voltage in earthed systems
LO2 Understand the methods used for AC motor control	2.1 explain methods of frequency conversion 2.2 explain methods of control for an AC motor 2.3 investigate an industrial AC motor controller
LO3 Understand the methods used for DC motor control	3.1 explain methods of speed control for a DC motor 3.2 explain methods of torque control for a DC motor 3.3 examine an industrial DC motor controller
LO4 Understand other applications of power electronics	4.1 compare the principles of three other applications of power electronics 4.2 investigate an area of application for each of the three applications.

## Guidance

### Links

This unit may be linked with *Unit 1: Analytical Methods for Engineers*, *Unit 5: Electrical and Electronic Principles*, *Unit 63: Electrical Power* and *Unit 67: Further Electrical Power*.

### Essential requirements

Centres will need to provide access to sufficient laboratory and test equipment to support a range of practical investigations (eg differential isolated voltage probes, Hall effect current probes, power analyser, DC and AC motors, industrial motor controllers, etc).

### Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

ISBN Number (for printed material)	Author	Date	Title	Publisher
ISBN 0-85380-182-7	K.J.Bohlman	2012	Electronics Servicing Vol3 Control Systems Technology	Newnes
ISBN 0-7506-51466	C.R.Robertson	2012	Fundamental Electrical & Electronic Principles	Newnes
ISBN 0-675-20883-1	Thomas L Floyd	2012	Electronic Devices	(Merrill)

Scheduled contact hours: Note: include in scheduled time: project supervision, demonstrations, practical classes and workshops, supervised time in studio or workshop, scheduled lab work , fieldwork, external visits, work-based learning where integrated into a structured academic programme	lectures	30
	seminars	0
	supervised practical	6
	tutorials	0
	formative assessment	16
	other scheduled time	0
Guided independent study Note: include in guided independent study preparation for scheduled sessions, follow up work, wider reading or practice, revision	Independent coursework	98
	Independent laboratory	0
	other non-scheduled time	
Placements (including work placement and year abroad)		
<b>Total hours ('Should be equal to credit x 10')</b>		<b>150Hrs</b>

## Unit 71: Combinational and Sequential Logic

Unit code: K/601/1362

QCF level: 4

Credit value: 15

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- Aim

This unit aims to provide learners with the skills and understanding required to design and build electronic circuits that use combinational and sequential logic.

- Unit abstract

This unit will develop learners' understanding of digital techniques and the practical applications of both combinational and sequential logic.

Learners will investigate the characteristics and applications of combinational and sequential logic devices. They will then design, construct and test combinational and sequential circuits and will use relevant computer software to simulate and verify circuits.

Learners will then go on to design a digital system that meets a specification and will evaluate the design against given criteria. They will investigate the minimisation of digital circuits and will improve the digital system design through the use of programmable logic devices (PLDs).

- Learning outcomes

**On successful completion of this unit a learner will:**

- 1 Be able to design and build circuits using combinational logic
- 2 Be able to design and build circuits using sequential logic
3. Be able to design and evaluate a digital system.

## Unit content

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### 1 Be able to design and build circuits using combinational logic

*Manufacturers' data sheets:* printed; CD ROM; websites

*Devices:* buffer; line driver; decoder; multiplexer; programmable read-only memory (PROM); programmable logic devices

*Characteristics:* device technology eg transistor-transistor logic (TTL), complementary metal-oxide-semiconductor (CMOS); function; fan-out; propagation delay; power consumption; cost; size; packaging; operating voltage; availability

*Computer simulations:* using a commercial digital electronic circuit analysis package

### 2 Be able to design and build circuits using sequential logic

*Sequential logic devices:* J-K flip-flop; D-type flip-flop; monostable; counter; parallel latch; shift register

*Design sequential circuits:* minimisation; race hazards; clock speeds; power supply decoupling; clock speed/power trade-off for CMOS

*Sequential logic circuits:* clock generator; BCD counter; parallel to serial converter; pseudo random number generator

*Computer simulation:* using a commercial digital electronic circuit analysis package

### 3 Be able to design and evaluate a digital system

*Digital system design:* systems with both combinational and sequential devices; up to 20 components; possibly including programmable devices

*Evaluation criteria:* functionality; chip count; cost

*Reduce chip count:* by replacing logic devices with programmable devices eg erasable programmable logic devices (EPLD), Generic Array Logic (GAL) devices, Programmable Array Logic (PAL) devices, programmable read-only memory (PROM)

## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Be able to design and build circuits using combinational logic	1.1 interpret manufacturers' data sheets to select appropriate combinational logic devices for specific purposes 1.2 compare the characteristics of similar devices using different technologies 1.3 design, construct and test combinational circuits 1.4 use computer software packages to simulate logic circuits
LO2 Be able to design and build circuits using sequential logic	2.1 describe the operation of sequential logic devices 2.2 use formal design techniques to design sequential circuits 2.3 construct and test sequential circuits 2.4 use computer simulation to verify logic designs
LO3 Be able to design and evaluate a digital system	3.1 design a digital system to meet a technical specification 3.2 realise, test and evaluate the design against criteria 3.3 improve the design by reducing the chip count through the use of programmable logic devices.

## Guidance

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### Links

This unit may be linked with *Unit 66: Electrical, Electronic and Digital Principles*.

### Essential requirements

Centres need to provide access to manufacturers' data sheets and computer circuit analysis packages for circuit simulation.

### Employer engagement and vocational contexts

Delivery would benefit from visits to local engineering companies that build a wide range of digital systems and from visits from guest speakers with relevant industrial experience.

ISBN Number (for printed material)	Author	Date	Title	Publisher
ISBN 0-85380-182-7	K.J.Bohlman	2012	Electronics Servicing Vol3 Control Systems Technology	Newnes
ISBN 0-7506-51466	C.R.Robertson	2012	Fundamental Electrical & Electronic Principles	Newnes
ISBN 0-675-20883-1	Thomas L Floyd	2012	Electronic Devices	(Merrill)

Scheduled contact hours: Note: include in scheduled time: project supervision, demonstrations, practical classes and workshops, supervised time in studio or workshop, scheduled lab work , fieldwork, external visits, work-based learning where integrated into a structured academic programme	lectures	30
	seminars	0
	supervised practical	6
	tutorials	0
	formative assessment	16
	other scheduled time	0
Guided independent study Note: include in guided independent study preparation for scheduled sessions, follow up work, wider reading or practice, revision	Independent coursework	98
	Independent laboratory	0
	other non-scheduled time	
Placements (including work placement and year abroad)		
<b>Total hours ('Should be equal to credit x 10')</b>		<b>150Hrs</b>