Unit 4064: Analogue and Digital Electronics

Unit Code: **H/650/2944**

Level: **4**

Credits: **15**

Introduction

Analogue and digital electronic systems are widely used for a variety of applications. These systems provide the building blocks for modern living; for example, smart devices/homes, Industry 4.0 and autonomous systems. Digital electronics are used to implement circuits such as the microcontroller-based systems found in mobile phones, computers, televisions, microwaves and many other devices. Analogue electronic circuits are commonly used alongside such systems. A smart speaker uses digital systems to perform ‘smart’ functions and analogue circuits are used to drive the voice interface and speaker response systems. This unit explores some of the specialist applications of these systems.

The overall aim of the unit is to introduce students to the fundamental building blocks of analogue and digital systems. Engineers from the craft technician to the Chartered Engineer should have an understanding and working knowledge of these technologies because they underpin all of our electronic devices, both domestic and industrial. The unit’s learning outcomes promote the development of skills and knowledge in the areas of digital and analogue electronics: digital electronics – developing an understanding of the basic logic components and how they are constructed, tested and used in circuit design; analogue electronics – developing an understanding of common transistors and transistor circuit design. Transistor and operational amplifier systems are another focus of the unit; these types of circuits are essential for signal processing and reproduction.

On successful completion of the unit, students will have developed skills and knowledge in analogue and digital electronics, which are the basis of all electronic systems and device, including the understanding and practice of the theory of logic circuits and how to construct and test such systems, and the understanding and measurement of analogue circuits.

Learning Outcomes

By the end of this unit, a student will be able to:

LO1 Investigate logic functions

LO2 Produce tabular and Karnaugh map designs to implement logic systems

LO3 Examine the use of Class A and Class B amplifiers in modern systems

LO4 Investigate operational amplifier circuits and their application.

Essential Content

LO1 **Investigate logic functions**

Underlying theory:

Logic function implementation: transistor–transistor logic (TTL)

Logic functions: AND, OR, NOT, NAND, NOR and XOR

Complementary metal–oxide–semiconductor (CMOS), emitter-coupled logic (ECL) and current developments

Testing instruments: Pulser, Logic Probe.

Testing digital gates by simulation:

Test logic gates using simulation: AND, OR, NOT, NAND, NOR and XOR

Data sheets and specifications: fan-out, speed, maximum and minimum ratings.

Testing digital gates using TTL and CMOS devices:

Test logic gates in laboratory experiments using TTL and CMOS devices: AND, OR, NOT, NAND, NOR and XOR.

LO2 **Produce tabular and Karnaugh map designs to implement logic systems**

Underlying theory:

Boolean algebra minimisation and reduction techniques

Minimisation using De Morgan's theorems

Minimisation using Karnaugh maps

Minimisation using truth tables.

Logic functions:

Logic functions: AND, OR, NOT and, by extension, NOT AND (NAND), NOT OR (NOR) and Exclusive OR (XOR)

Symbols representation, such as American National Standards Institute (ANSI) and British Standard European Norm (BSEN) Symbols representation using Boolean algebra, Karnaugh maps and truth tables

De Morgan equivalents.

Digital design techniques:

Use of reduction techniques on multivariable circuits, with a maximum of four input variables, to design to a specific requirement: tabular methods, Karnaugh maps, Boolean algebra

Reduction and construction of logic circuits to a given design specification.

LO3 **Examine the use of Class A and Class B amplifiers in modern systems**

Underlying theory:

Input and output impedance of Class A, B and C amplifier circuits using bipolar transistors and metal–oxide–semiconductor field-effect transistors (MOSFETs)

Small-signal and h-parameter models.

Design using bipolar transistors:

Design techniques and requirements of a Class A bipolar transistor amplifier; determine input and output impedance, as well as bandwidth response

Design techniques and requirements of a Class B bipolar transistor amplifier; determine input and output impedance as well as bandwidth response.

Design using MOSFETs:

Design techniques and requirements of a Class A MOSFET amplifier; determine input and output impedance as well as bandwidth response

Design techniques and requirements of a Class B MOSFET amplifier; determine input and output impedance as well as bandwidth response.

LO4 **Investigate operational amplifier circuits and their application.**

Underlying theory:

Operational amplifier design: differential pair, Miller effect, current mirror, long-tailed pair, Class AB amplifier, frequency response, symbol

Operational amplifier parameters: slew rate, offset, common-mode input, gain–bandwidth product, open-loop gain

Use of data sheets to ascertain design data

Negative feedback model; operational amplifier circuit configurations: comparator, summing amplifier, inverting amplifier, non-inverting amplifier, differentiator, integrator, digital-to-analogue converter, oscillators.

Laboratory practice:

Simulate standard circuits using alternating current (AC) signals: comparator, inverting amplifier, non-inverting amplifier, differentiator, integrator

Simulate standard circuits using direct current (DC) signals: comparator, summing amplifier, inverting amplifier, non-inverting amplifier, digital-to-analogue converter (DAC), and analogue-to-digital converters (ADCs): simple-ramp ADC, successive-approximation ADC

Construct trigger circuits using comparator designs for light, and for temperature

Use modern diagnostic tools and equipment including Industry 4.0, cloud-based diagnostics incorporated into network devices and other software tools (e.g., PROFITrace).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate logic functions		
P1 Investigate logic functions; AND, OR, NOT, NAND, NOT and XOR. **P2** Test logic gates by simulation and using TTL and CMOS devices and standard laboratory equipment, and present results.	**M1** Assess device performance in terms of device speed and functionality.	**D1** Analyse results after adapting and testing De Morgan equivalent function against the speed performance of the original device.
LO2 Produce tabular and Karnaugh map designs to implement logic systems		
P3 Produce logic circuits to a given design specification using tabular techniques. **P4** Produce logic circuits to a given design specification using Karnaugh map techniques.	**M2** Analyse non-minimised and equivalent logic circuits to confirm function.	**D2** Evaluate the performance, in terms of speed, cost and manufacturability, of minimised logic circuits to a given design specification.
LO3 Examine the use of Class A and Class B amplifiers in modern systems		
P5 Examine a Class A amplifier operation and functionality. **P6** Examine a Class B amplifier operation and functionality.	**M3** Analyse Class A and Class B amplifiers using small-signal analysis.	**D3** Evaluate amplifier circuits using bipolar and MOSFET devices.
LO4 Investigate operational amplifier circuits and their application.		
P7 Investigate the operation of a standard operational amplifier circuit. **P8** Simulate a standard operational amplifier circuit to a given design specification.	**M4** Analyse the performance of an operational amplifier circuit in terms of bandwidth, input impedance and output impedance.	**D4** Evaluate the performance of an operational amplifier compared to its small-signal model.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Floyd, T.L. (2015) *Digital Fundamentals*. 11th Ed. Pearson.

Horowitz, P. and Hill, W. (2015) *The Art of Electronics*. 3rd Ed. Cambridge University Press.

Malvino, A.P., Bates, D.J. and Hoppe, P.E. (2020) *Electronic Principles.* 8th Ed. McGraw Hill Education.

Storey, N. (2017) *Electronics: A Systems Approach*. 6th Ed. Pearson.

Tokheim, R.L. and Hoppe, P.E. (2021) *Digital Electronics Principles and Applications.* 9th Ed. McGraw Hill.

Websites

digital-library.theiet.org	IET Digital Library 'IET Circuits, Devices and Systems journal' (Research)

Links

This unit links to the following related units:

Unit 4022: Electronic Circuits and Devices

Unit 4067: Digital Devices and Systems

Unit 5014: Analogue Electronic Systems

Unit 5044: Digital Electronic Systems.