Unit 4020: Digital Principles

Unit Code: J/651/0739

Level: 4

Credits: 15

Introduction

While the broad field of electronics covers many aspects, it is digital electronics which now has the greatest impact. This is immediately evident in the mobile phone, laptop, and numerous other everyday devices and systems. Digital electronics allows us to process, store, and transmit data in digital form in robust ways, which minimises data degradation.

The unit introduces digital principles and the two main branches of digital electronics, combinational and sequential. Thus, the student gains familiarity in the fundamental elements of digital circuits, notably different types of logic gates and bistables. The techniques by which such circuits are analysed, introduced, and applied, including Truth Tables, Boolean Algebra, Karnaugh Maps, and Timing Diagrams.

The theory of digital electronics has little use unless the circuits can be built – at low cost, high circuit density, and in large quantity. Thus, the key digital technologies are introduced. These include the conventional TTL (Transistor-Transistor Logic) and CMOS (Complementary Metal Oxide Semiconductor). Importantly, the unit moves on to programmable logic, including the Field Programmable Gate Array (FPGA). Finally, some standard digital subsystems, which become important elements of major systems such as microprocessors, are introduced and evaluated.

On successful completion of this unit students will have a good grasp of the principles of digital electronic circuits, and will be able to proceed with confidence to further study.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain combinational logic circuits

LO2 Interpret sequential logic circuits

LO3 Describe the technologies used to implement digital electronic circuits

LO4 Analyse a range of digital subsystems, hence establishing the building blocks for larger systems.

Essential Content

LO1 Explain combinational logic circuits

Concepts and applications:

Digital principles, logic design and logic circuits, real-world applications, and history and future trends.

Concepts of combinational logic:

Logic circuits implemented with electro-mechanical switches and transistors. Circuits built from AND, OR, NAND, NOR, XOR gates to achieve logic functions, e.g. majority voting, simple logical controls, adders.

Number systems, and binary arithmetic:

Binary, Decimal, Hexadecimal number representation, converting between, applications and relative advantages. Addition and subtraction in binary, range of *n*-bit numbers.

Analysis of logic circuits:

Truth Tables, Boolean Algebra, de Morgan's theorem, Karnaugh Maps

Simplification and optimisation of circuits using these techniques.

LO2 Interpret sequential logic circuits

Sequential logic elements and circuits:

SR latch built from NAND or NOR gates

Clocked and edge-triggered bistables, D and JK types

Simple sequential circuits, including shift registers and counters

Timing Diagrams.

Memory technologies:

Memory terminology, overview of memory technologies including Static RAM, Dynamic RAM and Flash memory cells

Relative advantages in terms of density, volatility and power consumption

Typical applications, e.g., in memory stick, mobile phone, laptop.

LO3 **Describe the technologies used to implement digital electronic circuits**

Logic values represented by voltages:

The benefit of digital representation of information

The concept of logic input and output values and thresholds.

Digital technologies:

Introduction to discrete logic families, CMOS and TTL, relative advantages in terms of speed, power consumption, density

Programmable logic, FPGAs, relative advantages and applications

Practical applications and the future of digital technologies.

LO4 **Analyse a range of digital subsystems, hence establishing the building blocks for larger systems**

User interface:

Examples to include switches, light emitting diodes and simple displays

Digital subsystems:

Examples to be drawn from adders (half, full, *n*-bit), multiplexers and demultiplexers, coders and decoders, counters applied as timers, shift registers applied to serial data transmission, elements of the ALU (Arithmetic Logic Unit). Emphasis on how these can be applied, and how they might fit into a larger system.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain combinational logic circuits		
P1 Explain the operation of combinational logic circuits, making use of Truth Table, Boolean Algebra and Karnaugh Map.	**M1** Analyse the operation of a combinational logic circuit making good use of Truth Table, Boolean Algebra and Karnaugh Map.	**D1** Design combinational logic circuits by making best use of Truth Table, Boolean Algebra and Karnaugh Map.
LO2 Interpret sequential logic circuits		
P2 Interpret the operation of a sequential logic circuit, making use of Timing Diagrams.	**M2** Analyse simple sequential logic circuits, making use of Timing Diagrams.	**D2** Design sequential logic circuits, making use of Timing Diagrams.
LO3 Describe the technologies used to implement digital electronic circuits		
P3 Describe the technologies used to implement electronic circuits.	**M3** Apply techniques using lab equipment to configure and test simple digital circuits.	**D3** Apply techniques using lab equipment to configure, test and evaluate digital circuits, comparing and evaluating characteristics of different technologies.
LO4 Analyse a range of digital subsystems, hence establishing the building blocks for larger systems		
P4 Analyse the principles of a range of different logic subsystems.	**M4** Analyse a range of different logic subsystems in context of larger systems.	**D4** Evaluate a range of different logic subsystems, comparing these with other techniques or subsystems available, indicating the place they might take in a larger system.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Dally W.J. and Harting, R.C. (2012) *Digital Design: A systems approach.* Cambridge University Press

Fadali M.S. and Visioli A. (2019) *Digital Control Engineering.* 3rd Ed. Academic Press

Floyd T.L. (2017) *Digital Fundamentals*. Global Edition. 11th Ed. Pearson

Hughes E., Hiley J., Brown K. and McKenzie-Smith, I. (2016) *Electrical and Electronic Technology*. 12th Ed. Pearson

Kleitz W. (2013) *Digital Electronics.* 9th Ed. Pearson

Kolawole M. O. (2021) *Electronics: from Classical to Quantum.* 1st Ed. CRC Press.

Mano M. (2016) *Digital Logic and Computer Design Paperback.* 4th Ed. Pearson.

Mazumder P. and Ebong i.e. (2023) *Lectures on Digital Design Principles.* 1st Ed. River Publishers

Plonus M. (2020) *Electronics and Communications for Scientists and Engineers*. 2nd Ed. Butterworth-Heinemann

Twomey J. (2023) *Applied Embedded Electronics.* O'Reilly Media, Inc.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Electronics

Electronic Letters

e-Prime – Advances in Electrical Engineering, Electronics and Energy

IEEE Digital Circuits and Systems

IET Computers and Digital Techniques

International Journal of Digital Electronics

International Journal of Electronics

International Journal of Electronics and Communications

Links

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 4022: Electronic Circuits and Devices

Unit 5019: Further Electrical, Electronic and Digital Principles.