Unit 20: Digital Principles

Unit code	**T/615/1494**
Unit level	**4**
Credit value	**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 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 are 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:

1. Explain and analyse simple combinational logic circuits.
2. Explain and analyse simple sequential logic circuits.
3. Describe and evaluate the technologies used to implement digital electronic circuits.
4. Describe and analyse a range of digital subsystems, hence establishing the building blocks for larger systems.

Essential Content

LO1 **Explain and analyse simple combinational logic circuits**

Concepts of combinational logic:

Simple 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 **Explain and analyse simple 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 and evaluate 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

LO4 **Describe and 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

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explain and analyse simple combinational logic circuits</td><td rowspan="2">D1 Analyse, optimise and enhance combinational logic circuits, making best use of Truth Table, Boolean Algebra and Karnaugh Map</td></tr>
<tr><td>P1 Explain and analyse the operation of a simple combinational logic circuit, making limited use of Truth Table, Boolean Algebra and Karnaugh Map</td><td>M1 Analyse and optimise the operation of a combinational logic circuit making good use of Truth Table, Boolean Algebra and Karnaugh Map</td></tr>
<tr><td colspan="2">LO2 Explain and analyse simple sequential logic circuits</td><td rowspan="2">D2 Analyse, optimise and enhance a sequential logic circuit, making use of Timing Diagrams</td></tr>
<tr><td>P2 Explain and analyse the operation of a simple sequential logic circuit, making use of Timing Diagrams</td><td>M2 Analyse and optimise a simple sequential logic circuit, making use of Timing Diagrams</td></tr>
<tr><td colspan="2">LO3 Describe and evaluate the technologies used to implement digital electronic circuits</td><td rowspan="2">D3 Apply lab equipment to configure, test and evaluate digital circuits, comparing and evaluating characteristics of different technologies</td></tr>
<tr><td>P3 Apply lab equipment to describe and evaluate simple digital circuits</td><td>M3 Apply lab equipment to configure and test simple digital circuits</td></tr>
<tr><td colspan="2">LO4 Describe and analyse a range of digital subsystems, hence establishing the building blocks for larger systems</td><td rowspan="2">D4 Describe and critically 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</td></tr>
<tr><td>P4 Describe and analyse the principles of a range of different logic subsystems</td><td>M4 Describe and analyse a range of different logic subsystems, indicating the place they might take in a larger system</td></tr>
</table>

Recommended Resources

Textbooks

FLOYD, T.L. (2015) *Digital Fundamentals*. Pearson.

HUGHES, E., HILEY, J., BROWN, K. and MCKENZIE-SMITH, I. (2012) *Electrical and Electronic Technology*. Pearson.

Links

This unit links to the following related units:

Unit 19: Electrical and Electronic Principles

Unit 22: Electronic Circuits and Devices

Unit 52: Further Electrical, Electronic and Digital Principles