Unit 5013: Embedded Systems

Unit Code: **L/651/0867**

Level: **5**

Credits: **15**

Introduction

Embedded systems are a key element of modern engineering systems, applied in areas as diverse as agriculture, automotive, medical, and space, in industrial setting, and in the home and office. In many cases, embedded systems are linked together in networks and consist of a combination of hardware and software components to performs specific functions. Embedded systems are the basis of modern engineering design and practice, notably in machine-to-machine communication and the Internet of Things (IoT).

This unit develops the knowledge of computer hardware, focussing on the small, low-cost type of computer (i.e., a *microcontroller*), that are used in embedded systems. It then develops skill in selecting peripheral devices that operate external to the microcontroller and interface with it; generally, these relate to sensors, actuators, human interface, or data transfer. In parallel with this, students will be developing programming skills, writing programmes which download straight to the microcontroller, to interact with its external circuit. Students will also explore the wider context of embedded systems, learning how they are applied in 'hi-tech' applications, in many cases revolutionising our ability to undertake certain activities.

Unit assessment will require the design, development, and testing of an embedded system, to meet a given design brief; this will develop skills which are in much demand in industry. A written assignment, exploring one or more of the many fast-moving embedded system applications in use today, will also be completed.

Learning Outcomes

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

LO1 Examine embedded system technology

LO2 Design an embedded system using available interfaces to perform a range of functions

LO3 Implement embedded system design by writing code in an appropriate programming language, to simulate, test and debug the system

LO4 Evaluate applications of embedded systems in the wider environment.

Essential Content

LO1 **Examine embedded system technology**

Embedded systems:

Embedded system overview

Embedded systems by example: Microcontroller/microprocessor based systems; architecture, key units and peripherals, interfaces, memory etc.; industry case studies

Embedded system design process

Hardware (CPU, memory, digital and analogue I/Os etc.)

Software (IDE, Python, simplified C/C++ etc.)

Communication protocols (network, wireless, IoT)

LO2 **Design an embedded system using available interfaces to perform a range of functions**

Simple digital interfacing:

Arduino shields and carriers to utilise a range of components

Switches, light emitting diodes (LEDs), keypads, and 7-segment displays

DC load switching (e.g., of small motor or solenoid), use of PWM to provide variable DC motor speed control

Interfacing to external devices

ADC application, including range and resolution.

LO3 **Implement embedded system design by writing code in an appropriate programming language, to simulate, test and debug the system**

The development cycle:

Integrated Development Environment (IDE), Assembler and High-Level Languages, compilers, simulators, completing an in-circuit debug

Devising a code structure e.g., using flow diagrams and pseudo code.

Programming languages and codes:

Review of an appropriate high level programming languages Language constructs − data types, programme flow, looping, branching, and conditional statements etc.

Developing application code: initialisation, data input, conditional branching and looping, data output

Latest IDEs for controller programming

Development using e.g.: Python, C/C++ or a suitable language/platform

Code simulation, download, test plans and testing (e.g. unit testing, system testing, acceptance testing), and debug, troubleshoot.

LO4 **Evaluate applications of embedded systems in the wider environment**

Review of application of embedded systems:

Using example sectors e.g., motor vehicle, smart buildings, medical, office, wearable. Review possible limiting factors in an embedded design e.g., power supply, reliability, security

Review of current trends in embedded systems, including the Internet of Things (IOT), machine learning, cloud computing, artificial intelligence, sustainability, green engineering and so on

Embedded systems for future societies

Review and select technologies for performance optimisation

Embedded systems and Industry 4.0/5.0. Integration and impact on organisations

Suitability of embedded systems to meet accessibility, inclusive and diversity considerations; application context, job roles, and engagement with stakeholder groups.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine embedded system technology		
P1 Examine the main architecture of a selected microcontroller. **P2** Explain the function of the main microcontroller elements.	**M1** Analyse methods by which controllers communicate with external environment	**D1** Critically analyse the microcontroller architecture selected in terms of its limitations and suitability for various applications.
LO2 Design an embedded system using available interfaces to perform a range of functions		
P3 For a given application, design an embedded system to meet the specified functional requirements.	**M2** Review selected devices in terms of their functionality for a given design task. **M3** Discuss the trade-off for the choices made in terms of performance, power, cost etc. to meet the given design objectives.	**D2** Critically appraise the functionality of the entire embedded system, including further design improvements.
LO3 Implement embedded system design by writing code in an appropriate programming language, to simulate, test and debug the system		
P4 Implement an embedded system by writing a well-structured code to perform a selection of functions as per the design. **P5** Develop an initial test plan to demonstrate a subset of functionality of the proposed system.	**M4** Produce a refined test plan to test all functions of the given system.	**D3** Evaluate a fully working embedded system with real peripherals, in discussion with a peer group of developers.
LO4 Evaluate applications of embedded systems in the wider environment		
P6 Evaluate current uses of embedded systems in a chosen sector.	**M4** Explore emerging trends in developing embedded systems, for example artificial intelligence, the Internet of Things or sustainability.	**D4** Critically appraise ongoing research on future applications of embedded systems, clearly identifying societal demands and needs and recognising technical and economic factors in a global context.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bertolotti C. and Hu T. (2020). *Embedded Software Development: The Open-Source Approach*. 1st Ed. CRC Press

Blum J. (2019) *Exploring Arduino: Tools and Techniques for Engineering Wizardry*. 2nd Ed. Wiley

Cheich M. (2021) *Arduino book for beginners*. eBook. Kindle edition.

Hobbs C. (2020) *Embedded Software Development for Safety-Critical Systems.* Auerbach Publications

Ibrahim D. (2019) *ARM-based Microcontroller Projects Using mbed*. 1st Ed. Newnes

Lacamera D. (2023) *Embedded Systems Architecture*. 2nd Ed. Packt Publishing

Monk S. (2023) *Programming Arduino: Getting Started with Sketches* 3rd Ed. McGraw Hill TAB

Motahhir S. (2023) *Smart Embedded Systems and Applications*. 1st Ed. River Publishers

Pachari R.K., Pandey J.K., Sharmu A., Nautiyal O. and Ram M. (2021) *Applied Soft Computing and Embedded System Applications in Solar Energy*. CRC Press

Rossi M., Toscani N. Mauri M. and Dezza F.C. (2022) *Introduction to Microcontroller Programming for Power Electronics Control Applications – Coding with MATLAB and Simulink*. 1st Ed. CRC Press

White E. (2023) *Making Embedded Systems*. 2nd Ed. 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.

Design Automation for Embedded Systems

IEEE Embedded Systems Letters

IEEE Internet of Things Magazine

IEEE Internet of Things Journal

International Journal of Embedded Systems

Journal of Embedded Systems

Journal of System Architecture

Microprocessors and Microsystems

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Links

This unit links to the following related units:

Unit 5019: Further Electrical, Electronic and Digital Principles

Unit 5021: Further Control Systems Engineering.