Unit 46: Embedded Systems

Unit code          A/615/1514
Unit level         5
Credit value       15

Introduction

An embedded system is a device or product which contains one or more tiny computers hidden inside it. This ‘hidden computer’, usually a microcontroller, is used to control the device and give it added ‘intelligence’. Embedded systems are a key aspect of modern engineering and are applied in areas as diverse as automotive, medical, and industrial, and in the home and office. In many cases, embedded systems are linked together in networks. Embedded systems are the basis of a new wave of engineering design and practice, notably in machine-to-machine communication and in the Internet of Things.

This unit builds on introductory knowledge students have already gained in electronic circuits. It develops their knowledge of computer hardware, focussing on the small, low-cost type of computer (i.e. a microcontroller), usually used in embedded systems. It then develops skill in devising circuits which 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 and cause it 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, construction and commissioning of an embedded system, meeting 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:

1. Explore the principle features of a microcontroller and explain the purpose of its constituent parts.

2. Design and implement simple external circuitry, interfacing with a given microcontroller.

3. Write well-structured code in an appropriate programming language, to simulate, test and debug it.

4. Evaluate the applications of embedded systems in the wider environment, including in networked systems.
Essential Content

LO1 Explore the principle features of a microcontroller and explain the purpose of its constituent parts

*Microcontroller architecture:*

CPU (Central Processing Unit), the instruction set, programme memory, data memory, input/output (I/O), data and address buses, van Neumann and Harvard structures

Peripherals, to include digital I/O, counter/timers, analogue to digital converter (ADC), pulse width modulation (PWM), Serial Peripheral Interface (SPI), Universal Asynchronous Receiver/Transmitter (UART)

Memory types (overview only): Flash, Static RAM (Random Access Memory), EEPROM (Electrically Erasable Read Only Memory) and their applications

Simple interrupt concepts

LO2 Design and implement simple external circuitry, interfacing with a given microcontroller

*Simple digital interfacing:*

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

*DC and ADC applications:*

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

ADC application, including range and resolution

Signal conditioning for analogue inputs, including simple op amp circuits to provide gain or level shifting

Interfacing to external devices with serial capability, applying SPI and UART

Power supply and clock oscillator
LO3 Write well-structured code in an appropriate programming language, to simulate, test and debug it

The development cycle:
Integrated Development Environment, 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 language (which is likely to be C). Language structure, data types, programme flow, looping, branching, and conditional
Developing application code: initialisation, data input, conditional branching and looping, data output
Code simulation, download, test and debug

LO4 Evaluate the applications of embedded systems in the wider environment, including in networked systems

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 and machine-to-machine
### Learning Outcomes and Assessment Criteria

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<tr>
<th>Pass</th>
<th>Merit</th>
<th>Distinction</th>
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<tr>
<td><strong>LO1</strong> Explore the principle features of a microcontroller and explain the purpose of its constituent parts</td>
<td><strong>P1</strong> Examine the hardware interfaces and the software architecture of a selected microcontroller</td>
<td><strong>D1</strong> Critically evaluate microcontroller architectures and subsystems, exploring characteristics such as electrical, timing and size (e.g. of memory or ALU)</td>
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<tr>
<td><strong>M1</strong> Evaluate microcontroller architectures and subsystems, exploring characteristics such as electrical, timing and size (e.g. of memory or ALU)</td>
<td><strong>P2</strong> Explain the function of the main microcontroller elements</td>
<td><strong>D2</strong> Critically evaluate the functionality of external circuitry under a range of operating conditions</td>
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<tr>
<td><strong>M2</strong> Evaluate microcontroller architectures and subsystems, exploring characteristics such as electrical, timing and size (e.g. of memory or ALU)</td>
<td><strong>LO2</strong> Design and implement simple external circuitry, interfacing with a given microcontroller</td>
<td><strong>M3</strong> Adapt and improve simple external circuits, sensors and actuators, from available designs</td>
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<td><strong>P3</strong> Design simple external circuits, sensors and actuators, from available designs</td>
<td><strong>M4</strong> Adapt and improve given examples to produce well-structured and reliable code with meaningful programme identifiers, to meet an identified need</td>
<td><strong>LO3</strong> Write well-structured code in an appropriate programming language, to simulate, test and debug it</td>
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<td><strong>P4</strong> Apply simple external circuits, demonstrating effective interfacing and adequate functionality</td>
<td><strong>M5</strong> Test and de-bug code through simulation in the hardware, demonstrating functionality</td>
<td><strong>D3</strong> Critically evaluate the code developed through simulation and in the hardware, demonstrating excellent functionality</td>
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<td><strong>M3</strong> Assess simple external circuits and evaluate functionality</td>
<td><strong>M6</strong> Evaluate current and emerging applications of embedded systems, clearly identifying trends and recognising technical and economic factors</td>
<td><strong>D4</strong> Critically evaluate emerging applications of embedded systems, clearly identifying trends and recognising technical and economic factors</td>
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<td><strong>LO3</strong> Write well-structured code in an appropriate programming language, to simulate, test and debug it</td>
<td><strong>LO4</strong> Evaluate the applications of embedded systems in the wider environment, including in networked systems</td>
<td><strong>P7</strong> Explain the uses of embedded systems in current and emerging applications</td>
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<td><strong>P5</strong> Write well-structured working code, to meet an identified need</td>
<td><strong>M4</strong> Adapt and improve given examples to produce well-structured and reliable code with meaningful programme identifiers, to meet an identified need</td>
<td><strong>M5</strong> Evaluate current and emerging applications of embedded systems, e.g. in motor vehicles, health or the Internet of Things</td>
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Recommended Resources

Textbooks


Links

This unit links to the following related units:

*Unit 52: Further Electrical, Electronic and Digital Principles*

*Unit 54: Further Control Systems Engineering*