Applying the mbed in the curriculum, some case studies

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ARTS, DESIGN AND TECHNOLOGY

What’s your challenge?

IET accreditation

setting assessments

Electronic Systems

academic level

Introductory Embedded Systems

instrumentation

Final Year Projects

Electronics Club

control

Computer Science

C/C++ Programming

QAA benchmarks

prototyping a research rig

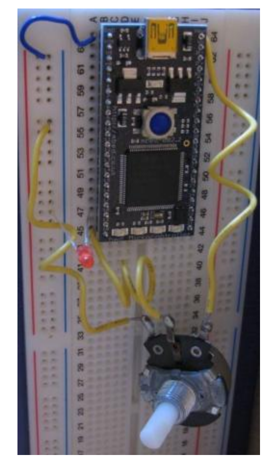
Using the mbed for learning

using the mbed for learning in:

- embedded systems,
- C/C++ programming,
- electronic systems,
- electronics club,
- final year project,
- MSc level work,

Our book ("*fast and effective*") as a resource

- Written with good support from the mbed team, yet an independent publication;
- Teaches C alongside the embedded work;
- Written around an ongoing series of design examples, mainly developed by placing an mbed on a breadboard;
- Complements mbed web site;
- Support material available:
  - all code examples downloadable;
  - one power point presentation per chapter;
  - answers to end of chapter quiz questions.



<u>Structure</u>

Chapters 1-10: Part 1 – Essentials of Embedded Systems, Using the mbed

Chapters 11-15: Part 2 – Moving to Advanced and Specialist Applications

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Part 1 – Essentials of Embedded Systems, Using the mbed

1. EMBEDDED SYSTEMS, MICROCONTROLLERS and ARM
2. INTRODUCING the MBED

general intro to the field

3. DIGITAL INPUT and OUTPUT
4. ANALOG OUTPUT
5. ANALOG INPUT

introduction to digital and analog input and output, and essentials of C

6. FURTHER PROGRAMMING TECHNIQUES
7. STARTING with SERIAL COMMUNICATIONS
8. LIQUID CRYSTAL DISPLAYS
9. INTERRUPTS, TIMERS and TASKS
10. MEMORY and DATA MANAGEMENT

stepping beyond the introductory

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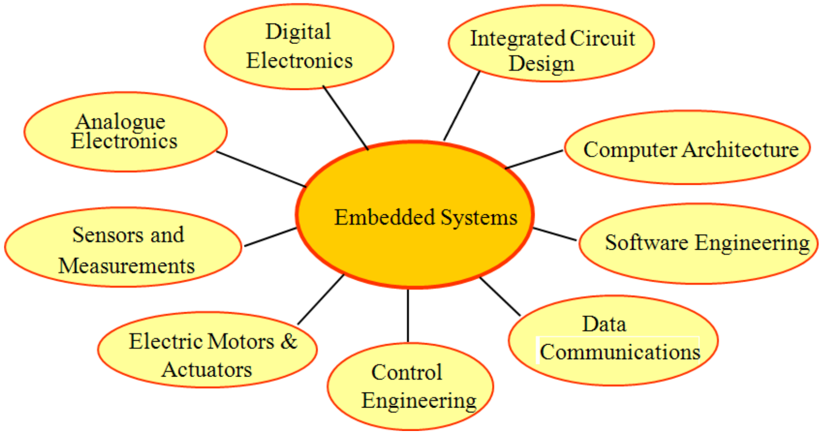
PART 2: MOVING TO ADVANCED AND SPECIALIST APPLICATIONS

Introductory or Specialist Embedded Systems

The need: a formal taught module, aiming to teach principles of embedded systems.

Where do we begin?



What is our learning philosophy?

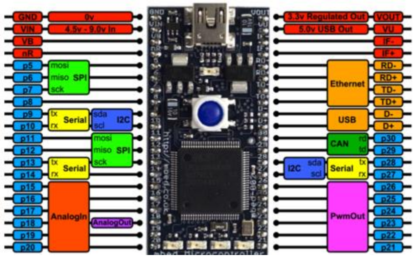
Top down? bottom up? Lecture-based? Problem-based? Guided practical?

Most people still want/need a good lecture series, linked to a practical route of creative experimentation, with the need for assessment point(s) along the way.

Embedded Systems - possible lecture/lab plan

Week	Lecture (2 hours pw)	Practical (2 hours pw)	Book Ref.
1	**Introduction to Embedded Systems and mbed**. Computer architecture review. Development cycle, introduction to mbed.	Logging in to mbed. Trialling the “blinky” program. C preliminaries.	Chapters 1&2
2	**Digital input/output.** I/O characteristics of logic gates. Mbed digital i/o capability. Interfacing to switches and LEDs.	Using switches and LEDs. Simple looping and decision-making programs.	Chapter 3
3	**Analogue Output**. DAC fundamentals. Mbed DAC capability.	Generating waveforms.	Chapter 4 Sect. 4.1 - 4.2
4	**Pulse Width Modulation.** Principles. Mbed PWM capability.	Simple PWM outputs, for tone generation and motor control.	Chapter 4 Sect. 4.3 - 4.4
5	**Analogue Input**. ADC fundamentals. Mbed ADC capability. Data display on PC.	Acquiring and displaying analogue inputs, from potentiometer and simple sensors.	Chapter 5
6	**Further Programming Techniques**. Writing functions, modular programs, header files, et al.	Consolidation of above, through development of more advanced programs.	Chapter 6
7	**Starting with Serial Communication**. SPI, linking to intelligent instruments.	Mbed to mbed SPI links. Reading and displaying from SPI-capable sensors.	Chapter 7 Sect. 7.1 – 7.4
8	**I2C**. Master, slave, addressing, acknowledgement, signal waveforms. More on intelligent instruments	Mbed to mbed I2C links. Reading and displaying from I2C-capable sensors.	Chapter Sect. 7.5 – 7.8
9	**Liquid Crystal Displays**. Principles, interfacing, generating messages.	Display of analogue input variables. Develop larger systems integrating displays.	Chapter 8
10	**Interrupts**. Interrupt concepts, mbed interrupt capability. Prioritisation, latency.	Simple interrupt driven programs. Latency measurements.	Chapter 9 Sect. 9.1 – 9.4
11	**Counters and Timers**. Principles, use in embedded context. Mbed Timer, Ticker and Timeout capability. Event- and time-triggered program structures.	Reaction time and metronome programs.	Chapter 9 Sect. 9.5 – 9.8
12	**Memory and Data Management**. Memory types. Mbed local file system, and access through **stdio** library. Using external memory	Data logging mini-project	Chapter 10

Embedded Systems – the practical part



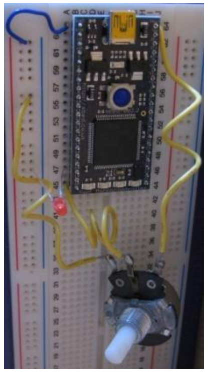
Wired on breadboard,

Follow book experimental path,

More open-ended,

More scope for student error,

End-point undefined…



Use an app board,

Very fast and reliable outcomes,

End-point determined by available hardware.

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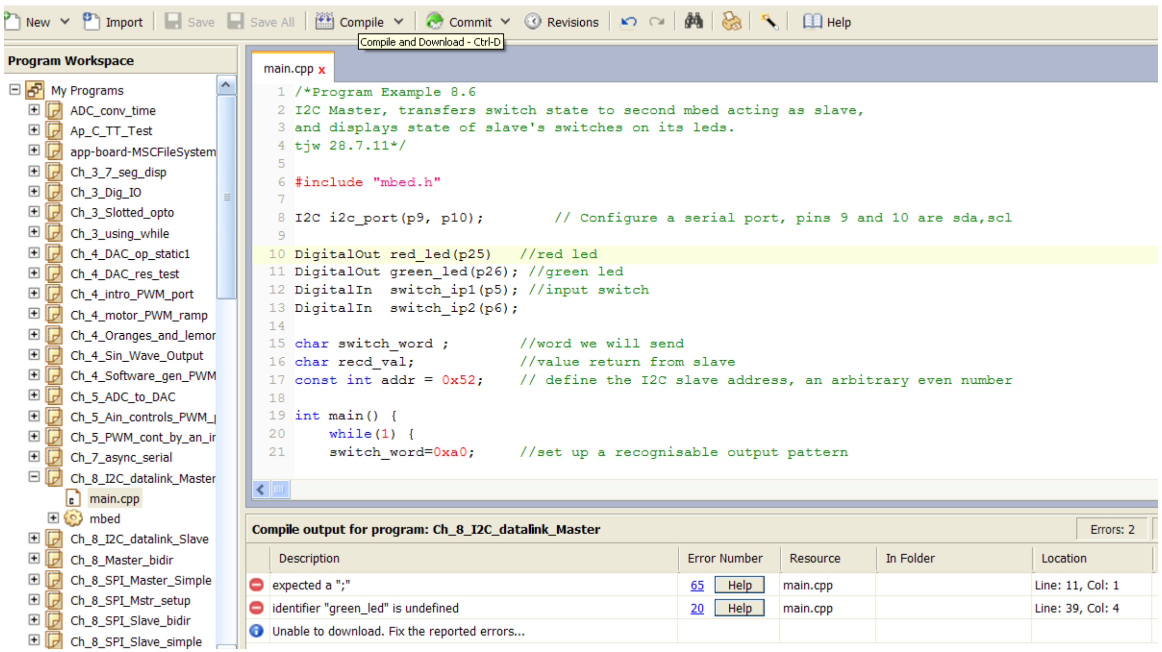
Introductory C/C++ and Software Engineering

The need: a full or partial taught module, teaching programming and software engineering principles.



A solution: the mbed environment provides a fully-featured C/C++ compiler, with detailed error messaging. The book provides C programming instruction from beginner level. Hardware considerations can be made subsidiary to programming needs. To add variety, use the debug features of the Keil MDK (Microcontroller Development Kit); advanced players can go on to RTOS.

Electronics Club

The need: to create a free space for enthusiastic students to engage in open-ended electronic creativity.

A solution: Loan students mbeds and breadboards (with a few components) and/or app boards. Direct them to first few book chapters, and mbed site. Stand back, and offer occasional support.

This is what happened at Georgia Tech

http://mbed.org/cookbook/How-to-setup-an-mbed-student-laboratory

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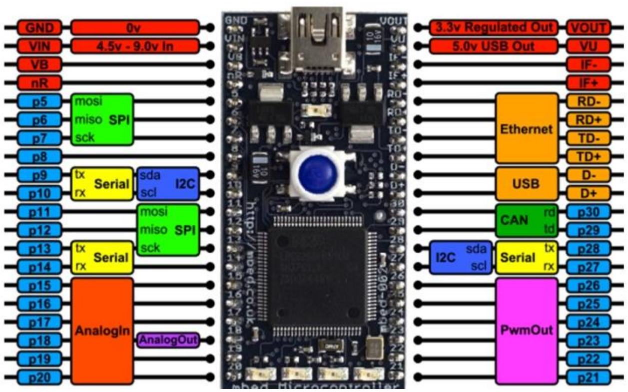
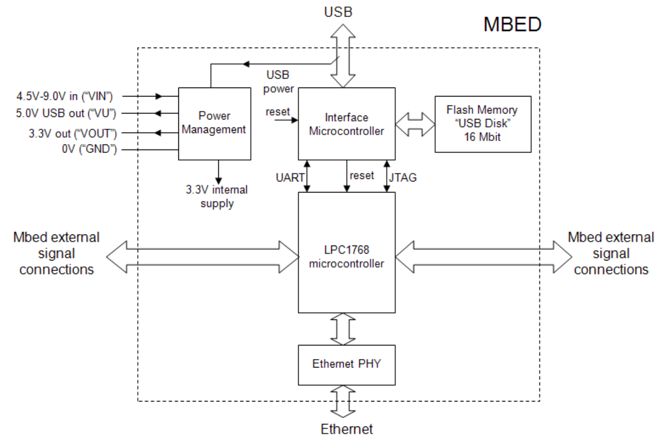
Electronic Systems

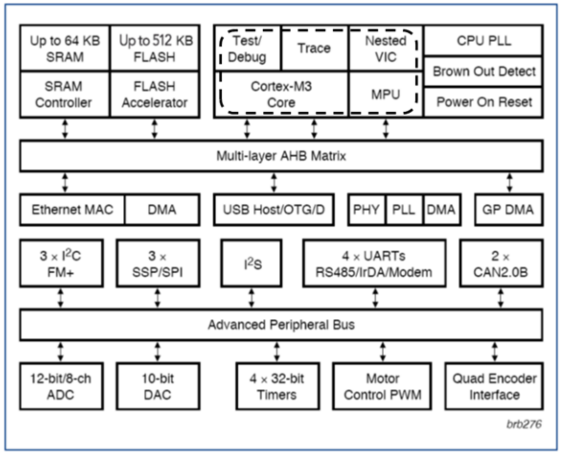
The need: a module which teaches electronics at a systems level, requiring an experimental platform to explore system elements (e.g. power supply, ADC, DAC), and to demonstrate programmable electronic system (choosing from say FPGA, PSoC and microcontroller…)

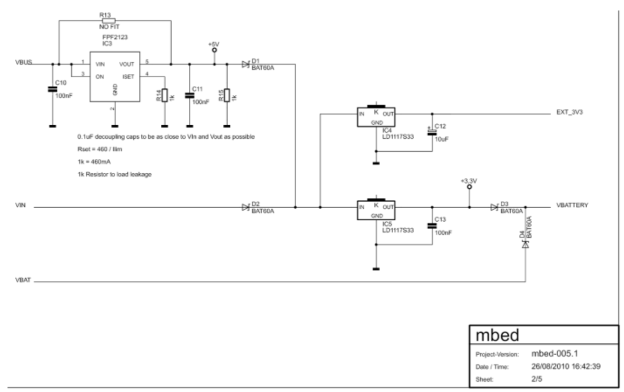
Electronic Systems

A solution: It wasn't the main focus of what the mbed designers set out to do, but the mbed (along with its supporting documentation), forms an interesting case study in programmable electronic systems, on topics as diverse as power supply, data conversion, system configuration…









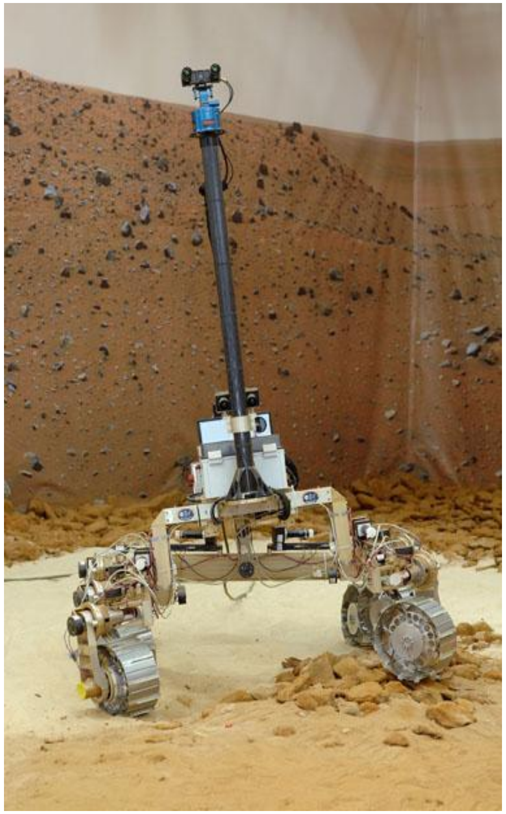
Applying mbed at Masters level

The need: to introduce and apply microcontrollers in advanced and sophisticated control and instrumentation settings; microcontroller(s) is/are used as system elements in a complex system.

A solution: A Problem-Based Learning approach was applied, in the form of a “moon buggy” team project.

In this assignment you are required to work as a team to develop the control system for a prototype explorer AGV, configured to perform a given task…

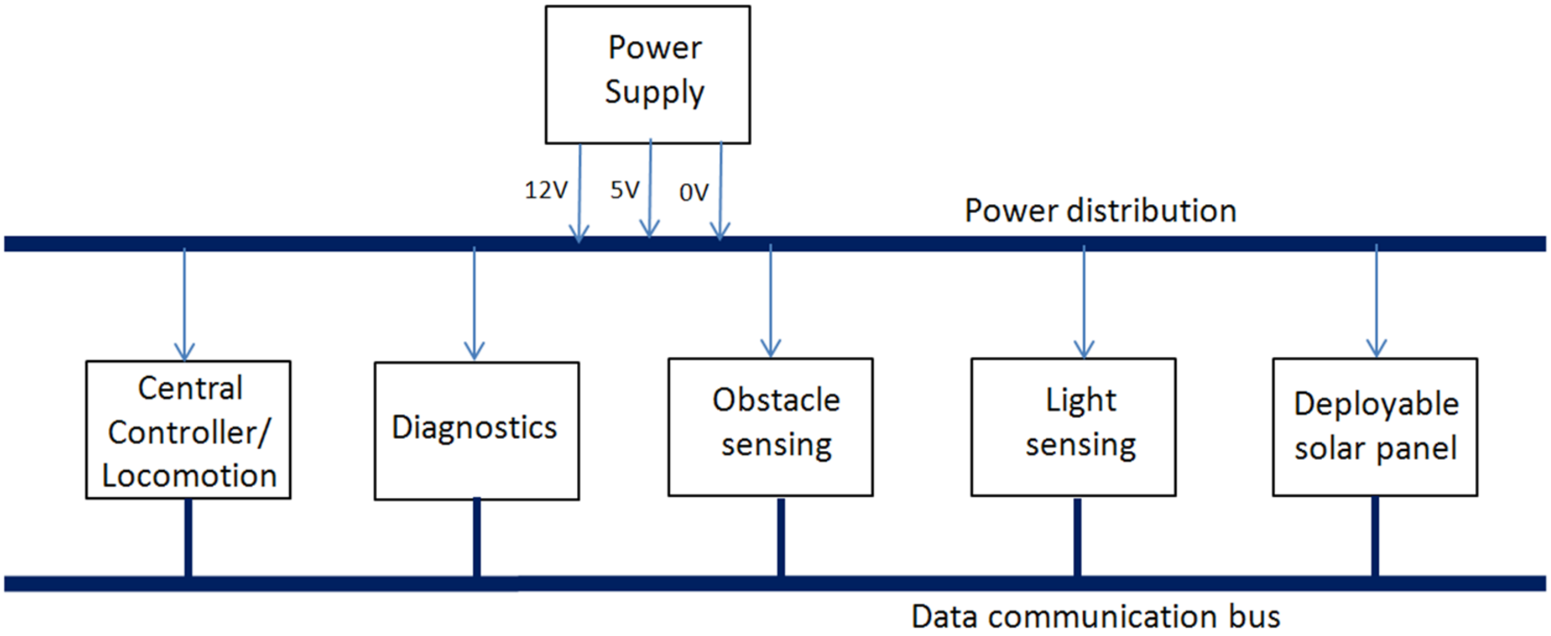
<u>Trial Task: Project Demonstration</u>
The AGV will be placed in an area of uneven light, in a space approx. 10m x 10m. The ground surface will be comparatively even, but there will be distributed obstacles. These will be approximately square in cross-section, have minimum height of 200mm approximately, and width around 200mm. There will be a space of at least 1m between obstacles. If light is perceived to be uniform, or it is dark, the AGV should remain still. When a light differential is detected, the AGV must navigate to the place where the light is brightest, and then open its solar panel. There is limited time pressure in the AGV completing this task, but all obstacles must be avoided.



http://www.astrium.eads.net/en/

Applying mbed at Masters level

A proposed system level design.



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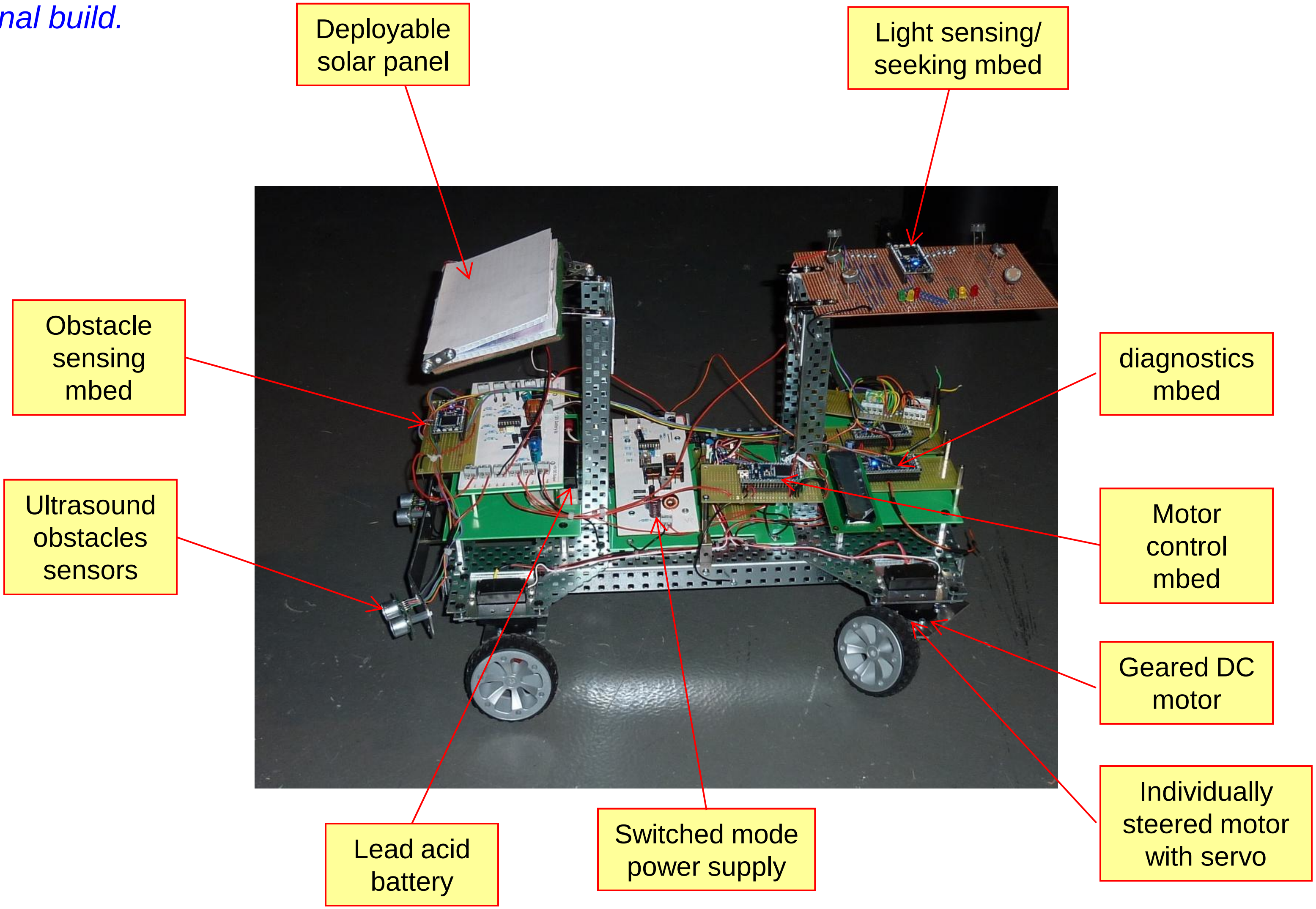
Applying mbed at Masters level

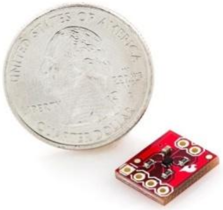
The final build.



Final Year Projects

The need: a reliable control element that can be rapidly prototyped, and adapted to new and emerging configurations. Student may or may not have embedded or C experience.

This can benefit from a new generation of low-cost, intelligent instrumentation…



TMP102 digital temperature sensor

HMC6343 compass

SRF08 range finder, with light sensor

ADXL345 triple axis accelerometer

… and a new generation of low-cost networking techniques

The Wixel wireless module

Bluetooth plug-in modules

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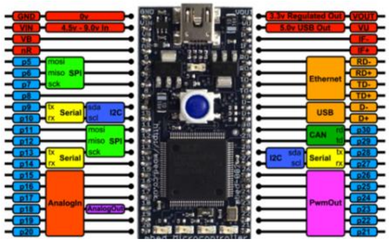
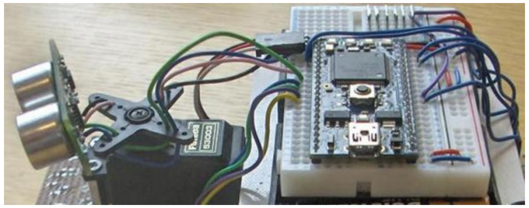
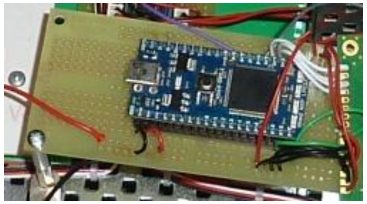
Final Year Projects

A solution: mbed can readily applied as the core of a project, a possible development path is shown (not all from same project).





Breadboard prototype



Prototyping pcb replicates breadboard build – just transfer across

A custom pcb

Our book ("*fast and effective*") as a resource

one power point presentation per chapter

Chapter 9: Interrupts, Timers and Tasks

C introduced in parallel to mbed, with C learning points highlighted

C code feature

It is an easy step from here to generate a sine wave. We will apply the **sin( )** function, which is part of the C standard library (see Section B.9.2). Take a look at Program Example 4.3. To produce one cycle of the sine wave, we want to take

Around 80 fully-tested and carefully sequenced program examples, all code examples down-loadable from book site

```
#include "LCD.h"

int main() {
  LCD_init();                    // call the initialise function
  display_to_LCD(0x48);          // 'H'
  display_to_LCD(0x45);          // 'E'
  display_to_LCD(0x4C);          // 'L'
  display_to_LCD(0x4C);          // 'L'
  display_to_LCD(0x4F);          // 'O'
  for(char x=0x30;x<=0x39;x++){
    display_to_LCD(x);           // display numbers 0-9
  }
}
```

Our book ("*fast and effective*") as a resource

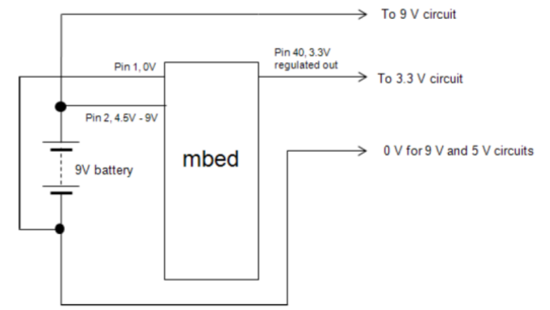
A continuous sequence of student activity

Exercise 5.3

Connect the servo to the mbed as indicated in Figure 4.10a, with the potentiometer connected as in Figure 5.5a. Write a program which allows the potentiometer to control servo position. Scale values so that the full range of potentiometer adjustment leads to the full range of servo position changes.

end of chapter quiz questions, answers available

7. **An mbed is part of a circuit which is to be powered from a 9 V battery. After programming the mbed is disconnected from the USB. One part of the circuit external to the mbed needs to be supplied from 9 V, and another part from 3.3 V. No other battery or power supply is to be used. Draw a diagram which shows how these power connections should be made.**



Authors readily accessible by email, and keen to hear from you!

Let’s keep in contact.

Any questions or discussion points?

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