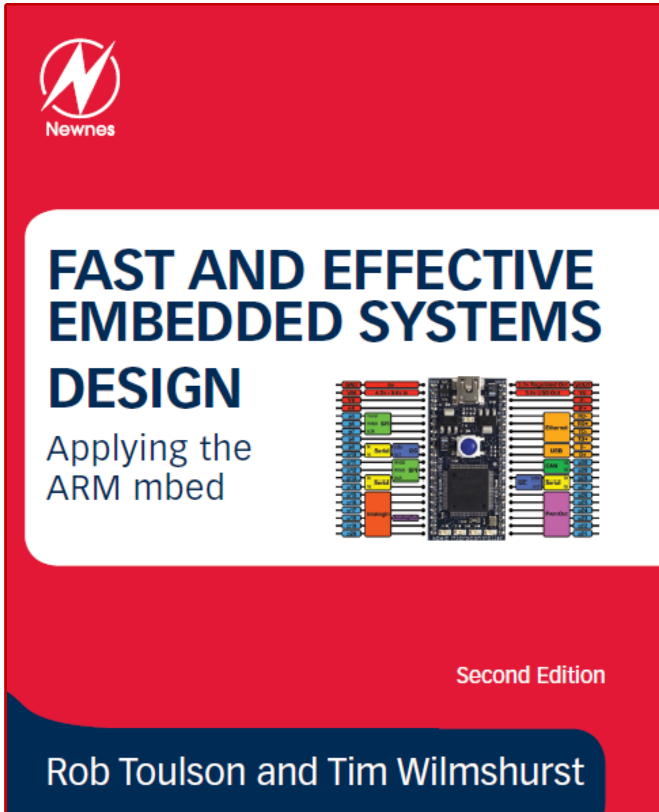

Chapter 16: Developing Commercial Products with mbed

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Embedded systems design process

Rapid prototyping is an essential part of the design process, as it is the point where engineers need to see if a design concept will work and how it should be implemented in hardware and software.

The speed of this process is important, because companies need to know where to invest their research and development resources and which products to develop into mass market systems.

The mbed is an excellent device for accelerating this process as its ease of use and high level libraries allow continuous testing during the prototyping and proof of concept cycle.The easier it is to test a system, the easier it is to develop accurate solutions in a short space of time.

There comes a time however when, if a prototype proves successful, a developer will wish to consider how the system could be engineered for mass manufacture and consumer use.

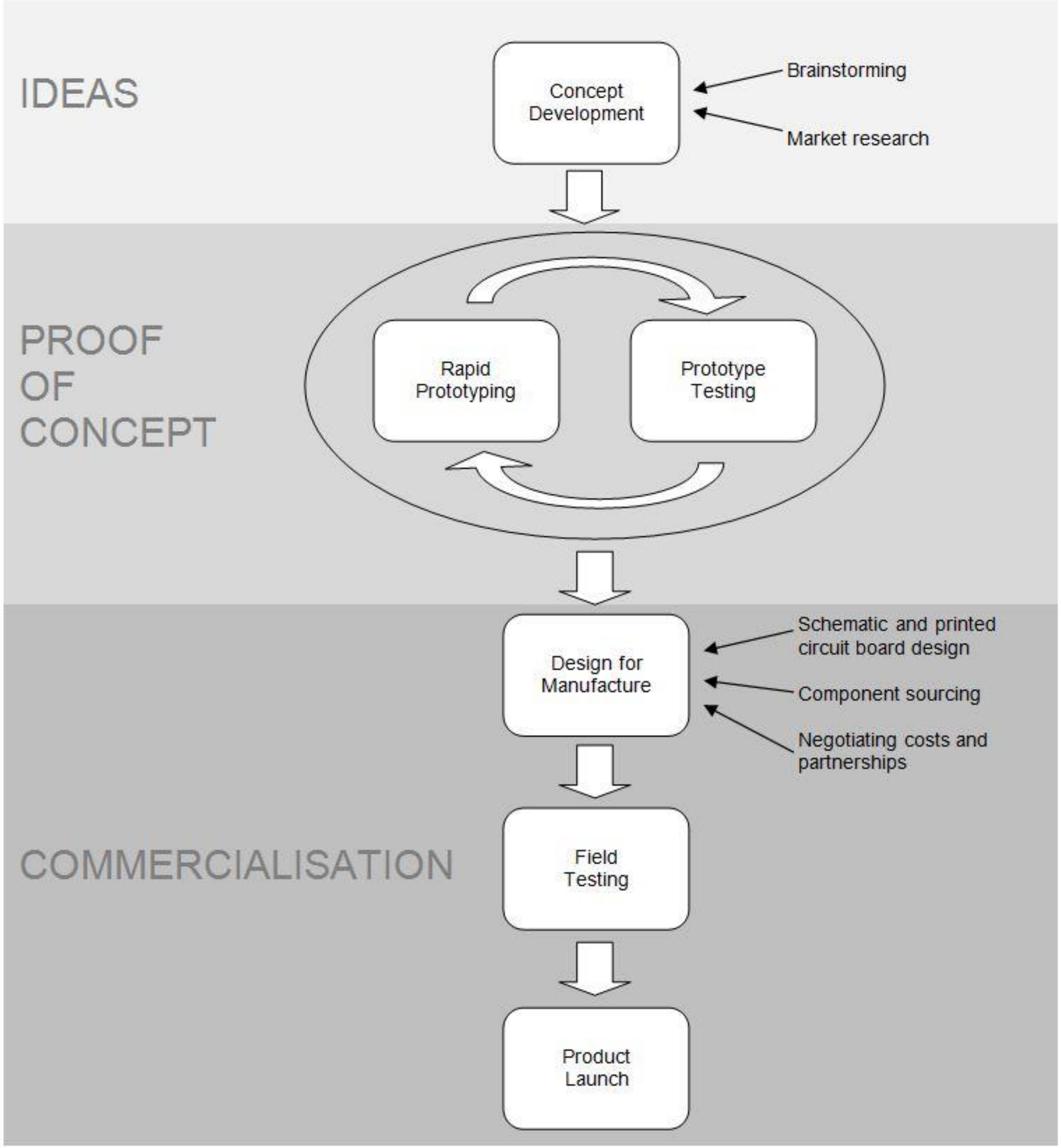
At this stage a number of issues should be considered, in particular size, cost, power consumption, manufacturing methods, component availability and reliability, and quality control.

Embedded systems design process

This figure summarises a product design cycle, from initial idea and concept development, through prototyping to final commercialisation.

The role and value of the mbed in the proof of concept phase can be very clearly seen.

Although the mbed is designed as a rapid prototyping device, it is intended to allow a simple development path from prototyping to commercialisation.



Embedded systems design process

- Once a project concept has been identified, it is normal to develop a *product design specification*, which details all the features and functionality that the product should include.

- It may also be valuable to identify *use cases,* which define a list of actions and scenarios that a user may expect to use the product in. Use case analysis can also include failure cases, where the user is expected to mis-use the product, or it can consider scenarios where the product is accidentally damaged or used in unexpected situations.

- Once the initial product design specification is in place, the embedded system design process usually moves to the proof of concept stage, which relies heavily on rapid prototyping, simulation and testing.

- Once the concept and design has been successfully prototyped and tested, the developers will have confidence to commercialise and launch the new product.

- At this stage a number of design stages will need to be implemented specifically with mass-manufacturing in mind. Mass-manufacturing will require a verified final circuit diagram and a PCB design that can be ordered in large quantities, ideally with components populated by the PCB manufacturer.

- It may also be necessary to minimize the size of components and the board as much as possible and to source the lowest price components that will realise the design without compromising the quality or performance of the product.

Embedded systems design process

- Once the design-for-manufacture stage is complete, the final productcan be tested for the first time in the environment it is designed for – we often call this *field testing*.

- Field testing allows the developers to consider the *user-experience* of the product and to evaluate if it performs in a way that resolves a consumer need or gives functionality that existing products do not.

- During field testing it is important to test for robustness and reliability:

  - Reliability is the idea that a product will continue to perform its intended task over and over again in all environments that it is designed for.

  - Robustness moreover refers to the ability of a product to continue to work effectively in situations that it wasn't designed for, such as in extreme temperatures or after being dropped from a height, so it is also often necessary to test these conditions also.

  - Robustness and reliability testing also involves legislative tests to confirm that products are safe and confirm to relevant regulations.

- One common necessity for electronic products is *electromagnetic compatibility* (EMC*) testing,* which confirms that products continue to work correctly in the presence of electromagnetic radiation.

- When all testing is complete, the product can be launched, which will involve the creation of packaging and a user manual, as well as marketing and launch materials.

Using mbed enabled platforms in commercial products

The mbed LPC1768is designed as a specific rapid-prototyping device, meaning that it is a relatively expensive component (with a recommended retail price of $49), which would make its inclusion in simple low-cost products unfeasible.

A number of more cost-effective *mbed enabled* platforms exist that are much more suited for inclusion in commercial products; two such platforms are the NXP FRDM-K64F and the NXP FRDM-KL25Z.

NXP FRDM-K64F

NXP FRDM-KL25Z

Comparison chart between example mbed platforms

	mbed platform		
Feature	**LPC1768**	**FRDM-K64F**	**FRDM-KL25Z**
Retail price	$49	$35	$15
ARM Cortex Chip	M3	M4	M0
Clock Speed	96 MHz	120 MHz	48 MHz
Flash Memory	512 KB	1024 KB	128 KB
RAM	32 KB	256 KB	16 KB
Digital IO	26	42	55
PWM	6	12	24
Analogue In	6 x 12-bit	12 x 16-bit	6 x 16-bit
Analogue Out	1 x 10-bit	2 x 12-bit	1 x 12-bit
Serial Ports	Ethernet USB 2 x SPI 2 x I2C 3 x UART 1 x I2S	Ethernet USB 3 x SPI 3 x I2C 6 x UART 1 x I2S	USB 2 x SPI 2 x I2C 3 x UART
On-Board Features	4 x LEDs	RGB LED Ethernet socket USB host socket 3 x analog comparators	RGB LED USB host socket 3-axis accelerometer Capacitive touch sensor

Implementing the mbed architecture on a bespoke PCB

Where thousands of units are to be developed and sold, cost becomes very important – clearly reducing the electronics cost by $1 equates to $100,000 total if 100,000 products are to be manufactured and sold.

Additionally, the mbed platforms may be too power hungry for your product, which might need to be battery powered - so you are keen to develop you own, more efficient, power management circuitry.

Size may also be an issue; you might be developing a product for use in a very small space and the mbed platforms are just not small enough for your application.

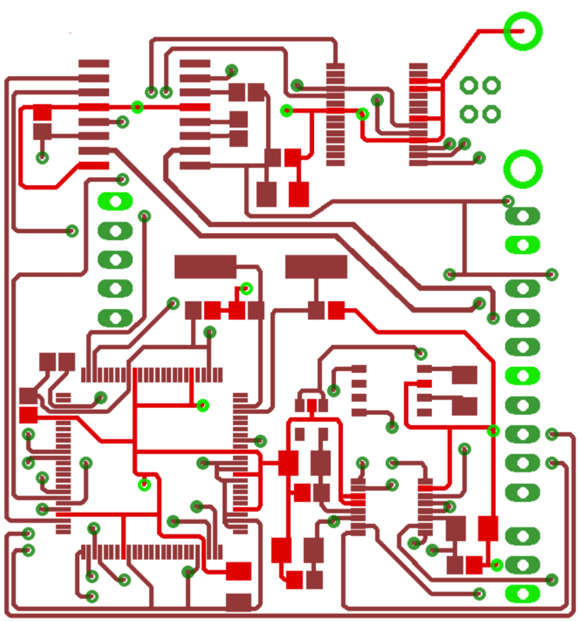
It can therefore be desirable to implement the mbed hardware components on a custom printed circuit board design, in order to minimize the number of electronic components used and hence reduce size, cost and/or power.

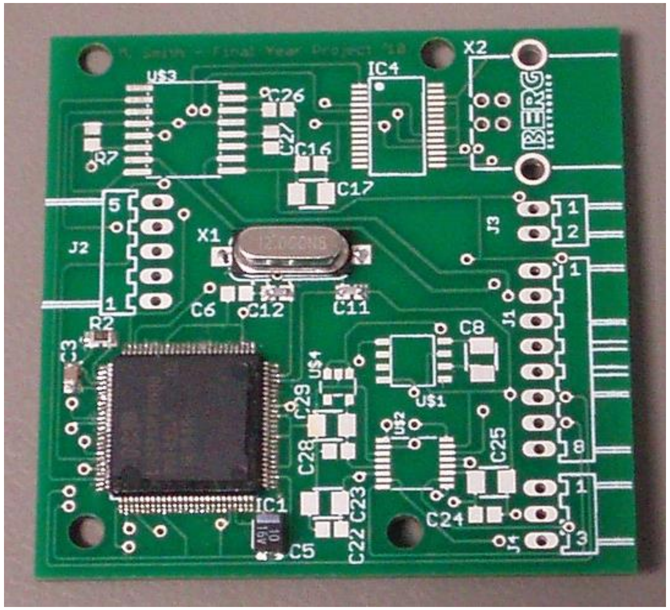
For example, the USB hardware features on the mbed (those which allow drag and drop downloading of the .bin file) are only required for prototyping. Furthermore, if the application doesn’t use Ethernet, then the Ethernet features can be left off the PCB design too.

Implementing the mbed architecture on a bespoke PCB

An excellent open access example is presented by developer Martin Smith on the mbed website. The example describes the circuit diagram for a prototype PCB layout, which utilises the LPC1768 and supports code developed in the mbed programming environment.

The circuit diagrams for power supply rails, external ADC chip, the LPC1768 itself and a number of other peripheral are included, as well as links to download the PCB manufacture files that have been drawn in a design and prototyping package called Eagle.



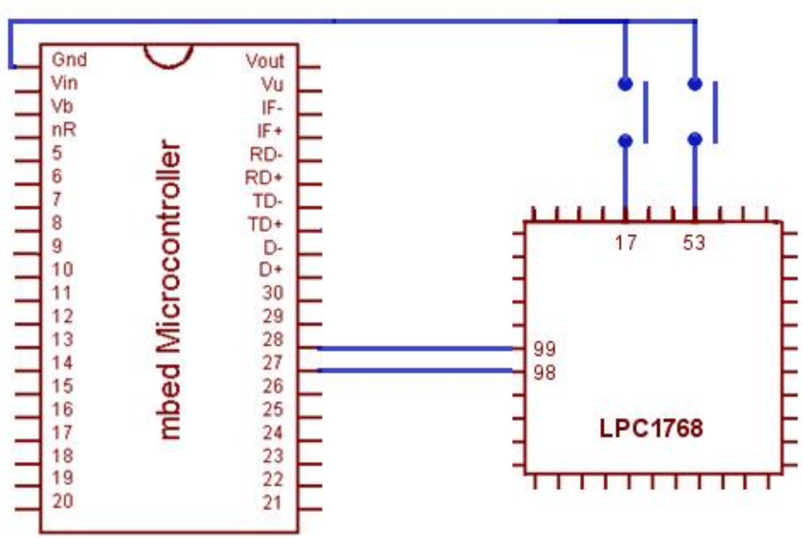


Programming the LPC1768 directly

Once a PCB based on the LPC1768 chip has been prototyped, it is necessary to program the device. However, with the bespoke PCB there is no luxury of the onboard USB drag and drop feature that is provided by the standard mbed platform.

The LPC1768 can be programmed though the *In System Programming* (ISP) protocol using the LCP1768 *flash boot loader* code. The boot loader code runs every time the LPC1768 is powered up or reset, and it is possible to inform the device that new program code is to be loaded into flash memory.

An excellent way to send the serial data to the LPC1768 is using another mbed LPC1768 as a communications bridge. It is possible to connect the mbed to a host terminal application and use control code to pass through serial ASCII messages from the mbed to the LPC1768 that is being programmed.



Read further:
Full details on programming a bespoke mbed PCB with the ISP protocol is given in Section 16.4

Case study: Irisense temperature logger with touchscreen display

Irisense Ltd, develop innovative measurement and control technologies for industrial applications. In 2014 Irisense saw a market opportunity to develop a miniature temperature logger with a touch screen interface.

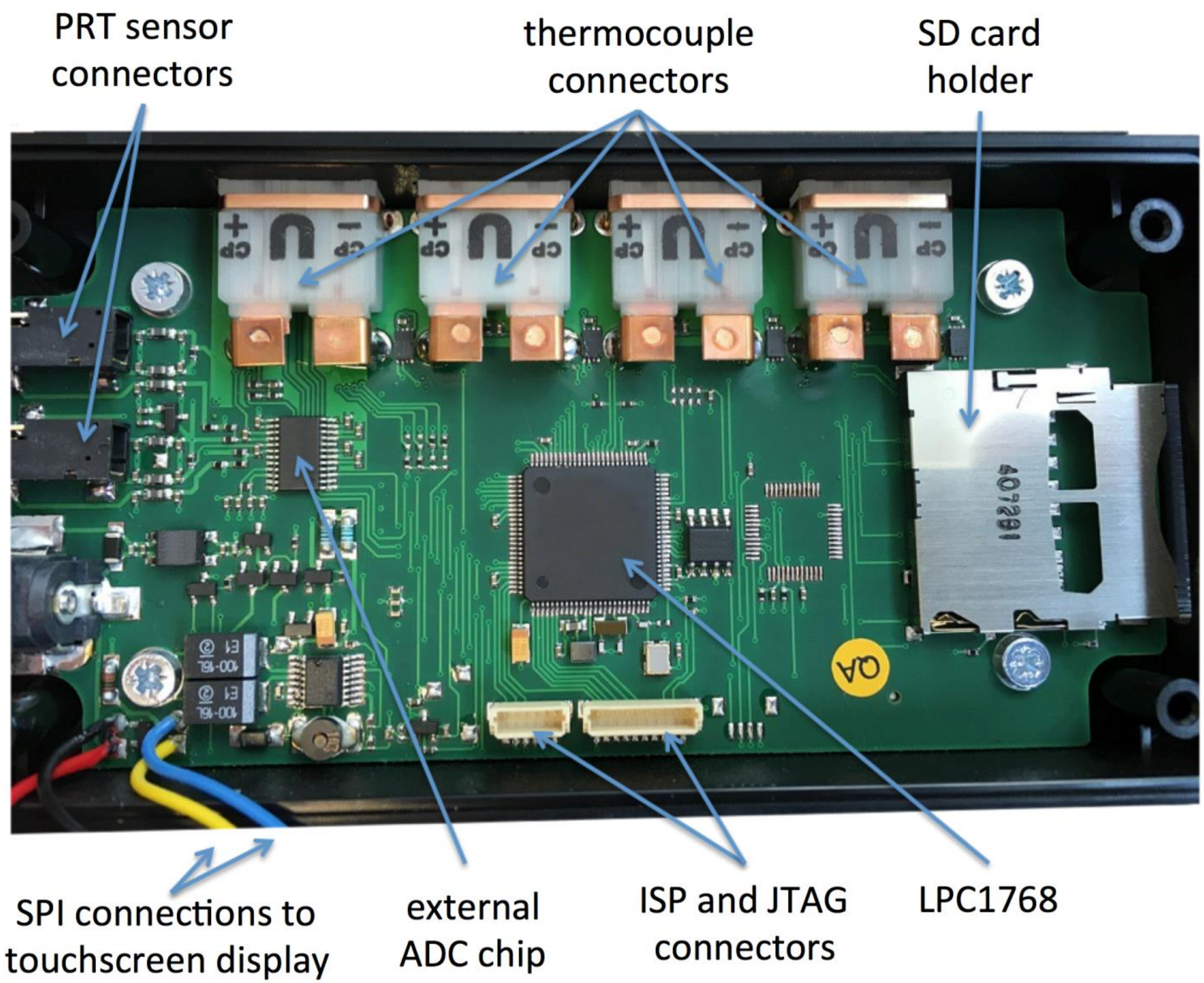
They knew if they could develop this product quickly then they could corner a growing market and release a product that would put them ahead of their competitors. Irisense utilized the mbed platform in their proof of concept and prototyping development of their Excelog Temperature Logger

The early rapid prototyping quickly showed that a temperature logger with a touch screen interface could easily be developed and mass-manufactured with the mbed platform.

Once the initial prototyping was complete, Irisense developed their own mass-manufacture printed circuit board that is based also on the mbed platform.

Case study: Irisense temperature logger with touchscreen display

The Excelog PCB is shows the LPC1768 chip and a number of other peripheral devices.



Case study: Irisense temperature logger with touchscreen display

Dr Tim Barry of Irisense Ltd explains that:

“before mbed, the proof of concept stage took many months of design and experimentation, whereas with the mbed this was reduced to approximately one month.”

“*we probably wouldn't have taken on the Excelog project at all if it wasn’t for the mbed, because the investment in R&D would have been too much for Irisense to risk*.”

Irisense’s more recent products have all been developed first through mbed prototyping and with an agile development that leads to mass-manufacture very quickly.

The result has been that Irisense can develop designs quickly and confidently, and realise new products in a short space of time.

The ability to use the high level mbed libraries to improve the user experience of their products, for example by incorporating touch screen displays, has been invaluable and ensures that Irisense stay ahead of their competitors.

Chapter quiz questions

1. What is a *product design specification*?
2. What design processes are fundamental to the proof-of-concept stage of embedded systems product development?
3. What activities make up the design-for-manufacture stage of embedded systems product development?
4. What types of product testing are required at the commercialisation stage of embedded systems product development?
5. What are the issues associated with incorporating the mbed LPC1768 in a commercial product hardware design?
6. Describe the mbed Enabled program and how it can be of benefit to product manufacturers.
7. Describe the process for programming an LPC1768 directly in ISP mode, using the mbed as a communications bridge.
8. What does CRP stand for? Describe the key features of CRP on the LPC1768.
9. What advantages and disadvantages are there when using a standalone development environment, such as the Keil development tools, over the online mbed compiler?
10. What commercial benefits can product developers achieve by using the ARM mbed as a rapid-prototyping platform.

Chapter review

- Developing embedded systems products usually involves design stages of ideas generation, proof of concept, and commercialisation
- At the ideas stage, market research and brainstorming are used to develop design concepts that realise successful products
- Proof of concept development involves rapid prototyping to quickly build and test potential designs and products
- Commercialisation requires a specific design for manufacture stage which focuses on the final hardware design and reducing component and manufacturing costs to realise a viable product
- The mbed LPC1768 is generally too expensive to be included in mass manufacture products, though the NXP FRDM-K64F and FRDM-KL25Z boards are lower cost solutions that may be viable for use in some high cost and niche market products
- For mass-market products that will be sold in many thousands of units, a bespoke printed circuit board design will be required. The PCB design can be built around the mbed platform to allow smooth transition from prototyping to commercialisation.
- A bespoke mbed platform PCB can be programmed either through the LPC1768’s ISP or JTAG interfaces.
- The Irisense Excelog product provides a case study of a successful commercial product that utilised the mbed development platform as a basis for its design and functionality.