



Embedded Systems (Introduction to Arm/xae Cortex/u2122-M Microcontrollers)

Jonathan Valvano

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This book, now in its fourth edition, is the second in a series of three books that teach the fundamentals of embedded systems as applied to ARM® Cortex™-M microcontrollers. The three books are primarily written for undergraduate electrical and computer engineering students. They could also be used for professionals learning the ARM platform. The first book *Embedded Systems: Introduction to ARM® Cortex™-M Microcontrollers* is an introduction to computers and interfacing focusing on assembly language and C programming. This second book focuses on interfacing and the design of embedded systems. The third book *Embedded Systems: Real-Time Operating Systems for ARM® Cortex™-M Microcontrollers* is an advanced book focusing on operating systems, high-speed interfacing, control systems, and robotics.

An embedded system is a system that performs a specific task and has a computer embedded inside. Topics include microcontrollers, design, verification, hardware/software synchronization, interfacing devices to the computer, timing diagrams, real-time systems, data collection and processing, motor control, analog filters, digital filters, and real-time signal processing.

In general, the area of embedded systems is an important and growing discipline within electrical and computer engineering. The educational market of embedded system is dominated by simple microcontrollers like the PIC, 9S12, and 8051. This is because of their market share, low cost, and historical dominance. However, as problems become more complex, so must the systems that solve them. A number of embedded system paradigms must shift in order to accommodate this growth in complexity. First, the number of calculations per second will increase from about 1 million/sec to 1 billion/sec. Similarly, the number of lines of software code will also increase from 1000's to 10 to 100 million. Thirdly, systems will involve multiple microcontrollers supporting many simultaneous operations. Lastly, the need for system verification will continue to grow as these systems are deployed into safety critical applications. These changes are more than a simple growth in size and bandwidth. These systems must employ parallel programming, DMA synchronization, real-time operating systems, fault tolerant design, priority interrupt handling, and networking. Consequently, it will be important to provide our students with these types of design experiences. The ARM platform is both low cost and provides the high performance features required in future embedded systems. The ARM market share is currently large and growing. Furthermore, students trained on the ARM will be equipped to design systems across the complete spectrum from simple to complex. The purpose of writing this book at this time is to bring engineering education into the 21st century.

This book employs many approaches to learning. It will not include an exhaustive recapitulation of the information in data sheets. First, it begins with basic fundamentals, which allows the reader to solve new problems with new technology. Second, the book presents many detailed design examples. These examples illustrate the process of design. There are multiple structural components that assist learning. Checkpoints, with answers in the back, are short easy to answer questions providing immediate feedback while reading. Simple homework, with answers to the odd questions on the web, provide more detailed learning opportunities. The book includes an index and a glossary so that information can be searched. The most important learning experience in a class like this are of course the laboratories. Each chapter has suggested lab assignments. More detailed lab descriptions are available on the web.

The book will cover embedded systems for the ARM® Cortex™-M with specific details on the LM3S811, LM3S1968, TM4C123 and TM4C1294. Although the solutions are specific for the TI LM3S and TM4C, it will be possible to use this book for other ARM derivatives.

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