嵌入式系统开发（影印版）

Making Embedded Systems

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Elecia White 著

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——Linux Journal

出版说明

随着计算机技术的成熟和广泛应用，人类正在步入一个技术迅猛发展的新时期。计算机技术的发展给人们的工业生产、商业活动和日常生活都带来了巨大的影响。然而，计算机领域的技术更新速度之快也是众所周知的，为了帮助国内技术人员在第一时间了解国外最新的技术，东南大学出版社和美国 O'Reilly Meida, Inc. 达成协议，将陆续引进该公司的代表前沿技术或者在某专项领域享有盛名的著作，以影印版或者简体中文版的形式呈献给读者。其中，影印版书籍力求与国外图书“同步”出版，并且“原汁原味”展现给读者。

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Preface

I love embedded systems. The first time a motor turned because I told it to, I was hooked. I quickly moved away from pure software and into a field where I can touch the world. Just as I was leaving software, the seminal work was done on design patterns.* My team went through the book, discussing the patterns and where we'd consider using them. As I got more into embedded systems, I found compilers that couldn't handle C++ inheritance, processors with absurdly small amounts of memory in which to implement the patterns, and a whole new set of problems where design patterns didn't seem applicable. But I never forgot the idea that there are patterns to the way we do engineering. By learning to recognize the patterns, we can use the robust solutions over and over. So much of this book looks at standard patterns and offers some new ones for embedded system development. I've also filled in a number of chapters with other useful information not found in most books.

About This Book

After seeing embedded systems in medical devices, race cars, airplanes, children's toys, and gunshot location systems, I've found a lot of commonalities. There are a lot of things I wish I knew then on how to go about designing and implementing software for an embedded system. This book contains some of what I've learned. It is a book about good software design in resource-constrained environments.

It is also a book about understanding what interviewers look for when you apply for an embedded systems job. Each section ends with an interview question. These are generally not language specific; instead, they attempt to divine how you think. Good interview questions don't have a single correct answer. Instead of trying to document all the paths, the notes after each question provide hints about what an interviewer might look for in your response. You'll have to get the job (and the answers) on your own merits.

* Gamma, Erich, Richard Helm, Ralph Johnson, and John Vlissides, 1995. *Design Patterns: Elements of Reusable Object-Oriented Software*. Boston: Addison-Wesley.

One note, though: my embedded systems don't have operating systems. The software runs on the bare metal. When the software says "turn that light on," it says it to the processor without an intermediary. This isn't a book about an embedded operating system (OS). But the concepts translate to processors running OSs, so if you stick around, you may learn about the undersides of OSs too. Working without one helps you really appreciate what an OS does.

This book describes the archetypes and principles that are commonly used in creating embedded system software. I don't cover any particular platform, processor, compiler, or language, because if you get a good foundation from this book, specifics can come later.

About the Author

In the field of embedded systems, I have worked on DNA scanners, inertial measurement units for airplanes and race cars, toys for preschoolers, a gunshot location system for catching criminals, and assorted medical and consumer devices.

I have specialized in signal processing, hardware integration, complex system design, and performance. Having been through FAA and FDA certification processes, I understand the importance of producing high-quality designs and how they lead to high-quality implementations.

I've spent several years in management roles, but I enjoy hands-on engineering and the thrill of delivering excellent products. I'm happy to say that leaving management has not decreased my opportunities to provide leadership and mentoring.

Acknowledgments

This book didn't happen in a vacuum. It started with a colleague who said, "Hey, do you know a book I can give to one of my junior engineers?" From that planted seed came months of writing; I learned to really appreciate understanding (and encouraging) friends. Then there were the engineers who gave their time to look at the technical material (any remaining issues are my fault, not theirs, of course). Finally, O'Reilly provided tremendous support through the whole process.

Thanking each person as they properly deserve would take pages and pages, so I will just go through them all in one breath, in no particular order: Phillip King, Ken Brown, Jerry Ryle, Matthew Hughes, Eric Angell, Scott Fitzgerald, John Catsoulis, Robert P. J. Day, Rebecca Demarest, and Jen Costillo. These folks made a difference in the flavor of this book. There are additional thank-yous spread throughout the book, where I got help from a particular person on a particular area, so you may see these names again (or a few different ones).

Two people are left out of that list. Andy Oram is an excellent editor at O'Reilly, and I was lucky to get him. He's made a big difference to this book and to my writing.

Finally, authors always give gushing thanks to their spouses; it is a cliché. However, having written a book, I see why. Christopher White, my favorite drummer, physicist, and embedded systems engineer, thank you most of all. For everything.

Organization of This Book

I read nonfiction for amusement. I read a lot more fiction than nonfiction, but still, I like any good book. I wrote this book to be read almost as a story, from cover to cover. The information is technical (extremely so in spots), but the presentation is casual. You don't need to program along with it to get the material (though trying out the examples and applying the recommendations to your code will give you a deeper understanding).

This isn't intended to be a technical manual where you can skip into the middle and read only what you want. I mean, you can do that, but you'll miss a lot of information with the search-and-destroy method. You'll also miss the jokes, which is what I really would feel bad about. I hope that you go through the book in order. Then, when you are hip-deep in alligators and need to implement a function fast, pick up the book, flip to the right chapter, and, like a wizard, whip up a command table or fixed point implementation of variance.

Or you can skip around, reading about solutions to your crisis of the week. I understand. Sometimes you just have to solve the problem. If that is the case, I hope you find the chapter interesting enough to come back when you are done fighting that fire.

The order of chapters is:

Chapter 1, Introduction
: What is an embedded system? How is development different from traditional software?

Chapter 2, Creating a System Architecture
: How to create (and document) a system architecture.

Chapter 3, Getting Your Hands on the Hardware
: Hardware/software integration during board bring-up can be scary, but there are some ways to make it smoother.

Chapter 4, Outputs, Inputs, and Timers
: The embedded systems version of "Hello World" is making an LED blink. It can be more complex than you might expect.

Chapter 5, Managing the Flow of Activity
: This chapter describes how to set up your system, where to use interrupts (and how not to), and how to make a state machine.

Chapter 6, Communicating with Peripherals
: Different serial communication forms rule embedded systems (UART, SSP, SPI, I^2C, USB, etc.). Networking, bit-bang, and parallel buses are not to be discounted.

Chapter 7, Updating Code
: When you need to replace the program running in your processor, you have a few options ranging from internal updaters to building your own solution.

Chapter 8, Doing More with Less
: This covers methods for reducing consumption of RAM, code space, and processor cycles.

Chapter 9, Math
: Most embedded systems need to do some form of analysis. Understanding how mathematical operations and floating points work (and don't work) will make your system faster.

Chapter 10, Reducing Power Consumption
: From reducing processor cycles to system architecture suggestions, this chapter will help you if your system runs on batteries.

The information is presented in the order that I want my engineers to start thinking about these things. It may seem odd that architecture is first, considering that most people don't get to it until later in their careers. However, I want the people I work with to be thinking about how their code fits in the system long before I want them to worry about optimization.

Conventions Used in This Book

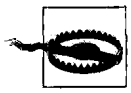
Typography

The following typographical conventions are used in this book:

Italic
: Indicates new terms, URLs, filenames, and file extensions.

`Constant width`
: Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, data types, and keywords.

This icon signifies a tip, suggestion, or general note.



This icon indicates a warning or caution.

Terminology

A *microcontroller* is a processor with onboard goodies like RAM, code space (usually flash), and various peripheral interfaces (e.g., I/O lines). Your code runs on a processor, or *central processing unit* (CPU). A *microprocessor* is a small processor, but the definition of "small" changes.

A DSP (*digital signal processor)* is a specialized form of microcontroller that focuses on signal processing, usually sampling analog signals and doing something interesting with the result. Usually a DSP is also a microcontroller, but it has special tweaks to make it perform math operations faster (in particular, multiply and add).

As I wrote this book, I wanted to use the correct terminology so you'd get used to it. However, with so many names for the piece of the system that is running your code, I didn't want to add confusion by changing the name. So, I stick with the term *processor* to represent whatever it is you're using to implement your system. Most of the material is applicable to whatever you actually have.

Using Code Examples

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About the Author

Elecia White has worked on DNA scanners, inertial measurement units for airplanes and race cars, toys for preschoolers, a gunshot location system for catching criminals, and assorted other medical and consumer devices. She is the founder of Logical Elegance, an embedded systems consulting company based in San Jose. Elecia has developed strong skills in signal processing, hardware integration, complex system design, and performance. Having been through FAA and FDA certification processes, she understands the importance of producing quality designs and how they lead to quality implementations.

Elecia has spent several years in management roles but enjoys hands-on engineering and the thrill of delivering excellent products. While continuing to provide leadership and mentoring, she prefers to focus on the technical aspects of a project. A graduate of Harvey Mudd College in Claremont, CA, Elecia enjoys sharing her passion for science, engineering, and interesting gizmos, particularly how these things can make the world a better place.

Colophon

The animal on the cover of *Making Embedded Systems* is a great-eared goatsucker.

Great-eared goatsuckers are members of the family *Caprimulgidae*, informally referred to as "nightjars." The term "goatsucker" stems from an inaccurate belief that the birds drink milk from goats; it is not to be confused with "chupacabra," the fabled cryptid believed by some to inhabit the Americas and drink the blood of goats. The name "great-eared nightjar" is more commonly used today.

Great-eared nightjars inhabit subtropical or tropical moist lowland forests in areas of Southeast Asia, including India, Bangladesh, Myanmar, Thailand, Malaysia, Indonesia, Laos, Cambodia, Vietnam, the Philippines, and China. They are crepuscular, meaning mostly active at dusk and at night, during which time they satisfy their diets of flying insects and moths and sound their distinctive calls: a sharp "tissk," followed by a two-syllable "ba-haw."

Great-eared nightjars are characterized by pronounced ear tufts, which, in addition to their average length of 16 inches, make them more conspicuous among nightjars. Their soft gray and brown plumage resembles their preferred habitat, leaf litter and bracken. They lay their eggs either directly on bare ground or in leaf-litter nests on the ground. Nightjar nestlings have been observed to be completely silent and motionless, which, in addition to their leaf-colored plumage, may help protect them from danger while nesting.

The cover image is from Wood's *Animate Creation*. The cover font is Adobe ITC Garamond. The text font is Linotype Birka; the heading font is Adobe Myriad Condensed; and the code font is LucasFont's TheSansMonoCondensed.

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