



Newnes

INCLUDES

NEWNES ONLINE
MEMBERSHIP

EMBEDDED SOFTWARE

know it all

- Proven, real-world advice and guidance from our best-selling authors
- Popular architectures and languages fully discussed
- Gives a comprehensive, detailed overview of the techniques and methodologies for developing effective, efficient embedded software

Labrosse • Ganssle • Oshana • Walls • Curtis
Andrews • Katz • Gentile • Hyder • Perrin

Embedded Software

Newnes Know It All Series

PIC Microcontrollers: Know It All

Lucio Di Jasio, Tim Wilmshurst, Dogan Ibrahim, John Morton, Martin Bates, Jack Smith, D.W. Smith, and Chuck Hellebuyck

ISBN: 978-0-7506-8615-0

Embedded Software: Know It All

Jean Labrosse, Jack Ganssle, Tammy Noergaard, Robert Oshana, Colin Walls, Keith Curtis, Jason Andrews, David J. Katz, Rick Gentile, Kamal Hyder, and Bob Perrin

ISBN: 978-0-7506-8583-2

Embedded Hardware: Know It All

Jack Ganssle, Tammy Noergaard, Fred Eady, Lewin Edwards, David J. Katz, Rick Gentile, Ken Arnold, Kamal Hyder, and Bob Perrin

ISBN: 978-0-7506-8584-9

Wireless Networking: Know It All

Praphul Chandra, Daniel M. Dobkin, Alan Bensky, Ron Olexa, David Lide, and Farid Dowla

ISBN: 978-0-7506-8582-5

RF & Wireless Technologies: Know It All

Bruce Fette, Roberto Aiello, Praphul Chandra, Daniel Dobkin, Alan Bensky, Douglas Miron, David Lide, Farid Dowla, and Ron Olexa

ISBN: 978-0-7506-8581-8

For more information on these and other Newnes titles visit: www.newnespress.com

Embedded Software

Jean Labrosse
Jack Ganssle
Tammy Noergaard
Robert Oshana
Colin Walls
Keith Curtis
Jason Andrews
David J. Katz
Rick Gentile
Kamal Hyder
Bob Perrin



AMSTERDAM • BOSTON • HEIDELBERG • LONDON
NEW YORK • OXFORD • PARIS • SAN DIEGO
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO

Newnes is an imprint of Elsevier



Newnes is an imprint of Elsevier
30 Corporate Drive, Suite 400, Burlington, MA 01803, USA
Linacre House, Jordan Hill, Oxford OX2 8DP, UK

Copyright © 2008 by Elsevier Inc. All rights reserved.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher.

Permissions may be sought directly from Elsevier's Science & Technology Rights Department in Oxford, UK: phone: (+44) 1865 843830, fax: (+44) 1865 853333, E-mail: permissions@elsevier.com. You may also complete your request online via the Elsevier homepage (<http://elsevier.com>), by selecting "Support & Contact" then "Copyright and Permission" and then "Obtaining Permissions."

- ⊗ Recognizing the importance of preserving what has been written, Elsevier prints its books on acid-free paper whenever possible.

Library of Congress Cataloging-in-Publication Data

Embedded software/Jean Labrosse . . . [et al.]. – 1st ed.

p. cm. – (Newnes know it all series)

Includes bibliographical references and index.

ISBN-13: 978-0-7506-8583-2 (pbk. : alk. paper) 1. Embedded computer systems—Programming. 2. Computer software—Development. I. Labrosse, Jean J.
TK7895.E42E588 2008
005.26—dc22

2007023369

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library.

ISBN: 978-0-7506-8583-2

For information on all Newnes publications
visit our Web site at www.books.elsevier.com

07 08 09 10 9 8 7 6 5 4 3 2 1

Printed in the United States of America

Working together to grow
libraries in developing countries

www.elsevier.com | www.bookaid.org | www.sabre.org

ELSEVIER

BOOK AID
International

Sabre Foundation

Contents

About the Authors	x
Introduction	xiii
Chapter 1: Basic Embedded Programming Concepts	1
1.1 Numbering Systems	2
1.2 Signed Binary Numbers.....	5
1.3 Data Structures	13
1.4 Communications Protocols	29
1.5 Mathematics	37
1.6 Numeric Comparison.....	46
1.7 State Machines.....	59
1.8 Multitasking.....	74
Chapter 2: Device Drivers	85
2.1 In This Chapter	85
2.2 Example 1: Device Drivers for Interrupt-Handling	89
2.3 Example 2: Memory Device Drivers.....	110
2.4 Example 3: Onboard Bus Device Drivers	134
2.5 Board I/O Driver Examples.....	143
2.6 Summary	168
Chapter 3: Embedded Operating Systems	169
3.1 In This Chapter	169
3.2 What Is a Process?	175
3.3 Multitasking and Process Management	177
3.4 Memory Management.....	213
3.5 I/O and File System Management.....	230
3.6 OS Standards Example: POSIX (Portable Operating System Interface).....	232
3.7 OS Performance Guidelines	235
3.8 OSeS and Board Support Packages (BSPs).....	237
3.9 Summary	239

Chapter 4: Networking.....	241
4.1 Introduction to the RCM3200 Rabbit Core	243
4.2 Introduction to the Dynamic C Development Environment	244
4.3 Brief Introduction to Dynamic C Libraries	246
4.4 Memory Spaces in Dynamic C	247
4.5 How Code Is Compiled and Run.....	256
4.6 Setting Up a PC as an RCM3200 Development System	259
4.7 Time to Start Writing Code!.....	259
4.8 Embedded Networks	274
4.9 Dynamic C Support for Networking Protocols	275
4.10 Typical Network Setup.....	279
4.11 Setting Up a Core Module's Network Configuration	282
4.12 Project 1: Bringing Up a Rabbit Core Module for Networking.....	288
4.13 The Client Server Paradigm	293
4.14 The Berkeley Sockets Interface	294
4.15 Using TCP versus UDP in an Embedded Application.....	298
4.16 Important Dynamic C Library Functions for Socket Programming.....	300
4.17 Project 2: Implementing a Rabbit TCP/IP Server	303
4.18 Project 3: Implementing a Rabbit TCP/IP Client	311
4.19 Project 4: Implementing a Rabbit UDP Server	322
4.20 Some Useful (and Free!) Networking Utilities	328
4.21 Final Thought.....	331
Chapter 5: Error Handling and Debugging.....	333
5.1 The Zen of Embedded Systems Development and Troubleshooting.....	333
5.2 Avoid Debugging Altogether—Code Smart.....	340
5.3 Proactive Debugging	341
5.4 Stacks and Heaps	342
5.5 Seeding Memory	344
5.6 Wandering Code.....	346
5.7 Special Decoders	347
5.8 MMUs.....	348
5.9 Conclusion	349
5.10 Implementing Downloadable Firmware with Flash Memory.....	350
5.11 The Microprogrammer	350
5.12 Advantages of Microprogrammers	351
5.13 Disadvantages of Microprogrammers	351
5.14 Receiving a Microprogrammer	352
5.15 A Basic Microprogrammer	354
5.16 Common Problems and Their Solutions	355
5.17 Hardware Alternatives	362
5.18 Memory Diagnostics	364
5.19 ROM Tests.....	365

5.20	RAM Tests	367
5.21	Nonvolatile Memory	372
5.22	Supervisory Circuits	372
5.23	Multibyte Writes	374
5.24	Testing	378
5.25	Conclusion	378
5.26	Building a Great Watchdog	379
5.27	Internal WDTs	382
5.28	External WDTs	384
5.29	Characteristics of Great WDTs	386
5.30	Using an Internal WDT	389
5.31	An External WDT	391
5.32	WDTs for Multitasking	393
5.33	Summary and Other Thoughts	395
Chapter 6: Hardware/Software Co-Verification		399
6.1	Embedded System Design Process	399
6.2	Verification and Validation	401
6.3	Human Interaction	403
6.4	Co-Verification	405
Chapter 7: Techniques for Embedded Media Processing		443
7.1	A Simplified Look at a Media Processing System	445
7.2	System Resource Partitioning and Code Optimization	451
7.3	Event Generation and Handling	452
7.4	Programming Methodology	455
7.5	Architectural Features for Efficient Programming	456
7.6	Compiler Considerations for Efficient Programming	465
7.7	System and Core Synchronization	472
7.8	Memory Architecture—the Need for Management	476
7.9	Physics of Data Movement	488
7.10	Media Processing Frameworks	495
7.11	Defining Your Framework	497
7.12	Asymmetric and Symmetric Dual-Core Processors	505
7.13	Programming Models	507
7.14	Strategies for Architecting a Framework	510
7.15	Other Topics in Media Frameworks	523
Chapter 8: DSP in Embedded Systems		529
8.1	Overview of Embedded Systems and Real-Time Systems	536
8.2	Real-Time Systems	536
8.3	Hard Real-Time and Soft Real-Time Systems	537
8.4	Efficient Execution and the Execution Environment	541

8.5	Challenges in Real-Time System Design	542
8.6	Summary	553
8.7	Overview of Embedded Systems Development Life Cycle Using DSP	554
8.8	The Embedded System Life Cycle Using DSP.....	554
8.9	Optimizing DSP Software	580
8.10	What Is Optimization?	580
8.11	The Process	581
8.12	Make the Common Case Fast	584
8.13	Make the Common Case Fast—DSP Architectures.....	584
8.14	Make the Common Case Fast—DSP Algorithms	587
8.15	Make the Common Case Fast—DSP Compilers	588
8.16	An In-Depth Discussion of DSP Optimization	595
8.17	Direct Memory Access.....	595
8.18	Using DMA	596
8.19	Loop Unrolling	604
8.20	Software Pipelining	610
8.21	More on DSP Compilers and Optimization	620
8.22	Programmer Helping Out the Compiler.....	633
8.23	Profile-Based Compilation.....	646
8.24	References	653
 Chapter 9: Practical Embedded Coding Techniques.....		655
9.1	Reentrancy	655
9.2	Atomic Variables	656
9.3	Two More Rules.....	658
9.4	Keeping Code Reentrant	659
9.5	Recursion.....	661
9.6	Asynchronous Hardware/Firmware	661
9.7	Race Conditions	662
9.8	Options	664
9.9	Other RTOSes	665
9.10	Metastable States	666
9.11	Firmware, Not Hardware	668
9.12	Interrupt Latency	671
9.13	Taking Data	674
9.14	Understanding Your C Compiler: How to Minimize Code Size.....	677
9.15	Modern C Compilers	677
9.16	Tips on Programming	687
9.17	Final Notes	695
9.18	Acknowledgments	696

Chapter 10: Development Technologies and Trends	697
10.1 How to Choose a CPU for Your System on Chip Design.....	697
10.2 Emerging Technology for Embedded Systems Software Development	700
10.3 Making Development Tool Choices	707
10.4 Eclipse—Bringing Embedded Tools Together	721
10.5 Embedded Software and UML	725
10.6 Model-based Systems Development with xtUML	739
10.7 The Future	743
Index	745

