

C# 5.0

IN A NUTSHELL

Fifth Edition

Joseph Albahari and Ben Albahari

O'REILLY®

Beijing • Cambridge • Farnham • Köln • Sebastopol • Tokyo

C# 5.0 in a Nutshell, Fifth Edition

by Joseph Albahari and Ben Albahari

Copyright © 2012 Joseph Albahari and Ben Albahari. All rights reserved.
Printed in the United States of America.

Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

O'Reilly books may be purchased for educational, business, or sales promotional use. Online editions are also available for most titles (<http://my.safaribooksonline.com>). For more information, contact our corporate/institutional sales department: 800-998-9938 or corporate@oreilly.com.

Editor: Rachel Roumeliotis
Production Editor: Melanie Yarbrough
Copyeditor: Nancy Reinhardt
Proofreader: Jennifer Knight

Indexer: Jay Marchand
Cover Designer: Karen Montgomery
Interior Designer: David Futato
Illustrator: Robert Romano

June 2012: Fifth Edition.

Revision History for the Fifth Edition:

2012-06-08 First release

See <http://oreilly.com/catalog/errata.csp?isbn=9781449320102> for release details.

Nutshell Handbook, the Nutshell Handbook logo, and the O'Reilly logo are registered trademarks of O'Reilly Media, Inc. *C# 5.0 in a Nutshell*, the cover image of a numidian crane, and related trade dress are trademarks of O'Reilly Media, Inc.

Many of the designations used by manufacturers and sellers to distinguish their products are claimed as trademarks. Where those designations appear in this book, and O'Reilly Media, Inc., was aware of a trademark claim, the designations have been printed in caps or initial caps.

While every precaution has been taken in the preparation of this book, the publisher and authors assume no responsibility for errors or omissions, or for damages resulting from the use of the information contained herein.

ISBN: 978-1-449-32010-2

[M]

1340210346

Table of Contents

| | |
|---|--------------|
| Preface | xi |
| 1. Introducing C# and the .NET Framework | 1 |
| Object Orientation | 1 |
| Type Safety | 2 |
| Memory Management | 2 |
| Platform Support | 3 |
| C#'s Relationship with the CLR | 3 |
| The CLR and .NET Framework | 3 |
| C# and Windows Runtime | 5 |
| What's New in C# 5.0 | 6 |
| What's New in C# 4.0 | 6 |
| What's New in C# 3.0 | 7 |
| 2. C# Language Basics | 9 |
| A First C# Program | 9 |
| Syntax | 12 |
| Type Basics | 15 |
| Numeric Types | 23 |
| Boolean Type and Operators | 30 |
| Strings and Characters | 32 |
| Arrays | 34 |
| Variables and Parameters | 38 |
| Expressions and Operators | 47 |
| Statements | 51 |
| Namespaces | 59 |

| | |
|--|----------------|
| 3. Creating Types in C# | 67 |
| Classes | 67 |
| Inheritance | 80 |
| The object Type | 89 |
| Structs | 93 |
| Access Modifiers | 94 |
| Interfaces | 96 |
| Enums | 102 |
| Nested Types | 105 |
| Generics | 106 |
| 4. Advanced C# | 119 |
| Delegates | 119 |
| Events | 128 |
| Lambda Expressions | 135 |
| Anonymous Methods | 139 |
| try Statements and Exceptions | 140 |
| Enumeration and Iterators | 148 |
| Nullable Types | 153 |
| Operator Overloading | 158 |
| Extension Methods | 162 |
| Anonymous Types | 164 |
| Dynamic Binding | 165 |
| Attributes | 173 |
| Caller Info Attributes (C# 5) | 175 |
| Unsafe Code and Pointers | 177 |
| Preprocessor Directives | 180 |
| XML Documentation | 182 |
| 5. Framework Overview | 187 |
| The CLR and Core Framework | 189 |
| Applied Technologies | 194 |
| 6. Framework Fundamentals | 201 |
| String and Text Handling | 201 |
| Dates and Times | 214 |
| Dates and Time Zones | 221 |
| Formatting and Parsing | 227 |
| Standard Format Strings and Parsing Flags | 233 |
| Other Conversion Mechanisms | 240 |
| Globalization | 244 |
| Working with Numbers | 245 |
| Enums | 249 |
| Tuples | 252 |
| The Guid Struct | 253 |

| | |
|---|----------------|
| Equality Comparison | 254 |
| Order Comparison | 264 |
| Utility Classes | 267 |
| 7. Collections | 271 |
| Enumeration | 271 |
| The ICollection and IList Interfaces | 279 |
| The Array Class | 282 |
| Lists, Queues, Stacks, and Sets | 291 |
| Dictionaries | 299 |
| Customizable Collections and Proxies | 306 |
| Plugging in Equality and Order | 312 |
| 8. LINQ Queries | 319 |
| Getting Started | 319 |
| Fluent Syntax | 321 |
| Query Expressions | 328 |
| Deferred Execution | 332 |
| Subqueries | 338 |
| Composition Strategies | 342 |
| Projection Strategies | 345 |
| Interpreted Queries | 347 |
| LINQ to SQL and Entity Framework | 354 |
| Building Query Expressions | 368 |
| 9. LINQ Operators | 375 |
| Overview | 377 |
| Filtering | 379 |
| Projecting | 383 |
| Joining | 395 |
| Ordering | 403 |
| Grouping | 406 |
| Set Operators | 409 |
| Conversion Methods | 410 |
| Element Operators | 413 |
| Aggregation Methods | 415 |
| Quantifiers | 419 |
| Generation Methods | 420 |
| 10. LINQ to XML | 423 |
| Architectural Overview | 423 |
| X-DOM Overview | 424 |
| Instantiating an X-DOM | 427 |
| Navigating and Querying | 430 |
| Updating an X-DOM | 435 |

| | |
|--|------------|
| Working with Values | 438 |
| Documents and Declarations | 441 |
| Names and Namespaces | 444 |
| Annotations | 450 |
| Projecting into an X-DOM | 450 |
| 11. Other XML Technologies | 457 |
| XmlReader | 458 |
| XmlWriter | 467 |
| Patterns for Using XmlReader/XmlWriter | 469 |
| XmlDocument | 473 |
| XPath | 477 |
| XSD and Schema Validation | 481 |
| XSLT | 484 |
| 12. Disposal and Garbage Collection | 485 |
| IDisposable, Dispose, and Close | 485 |
| Automatic Garbage Collection | 490 |
| Finalizers | 493 |
| How the Garbage Collector Works | 497 |
| Managed Memory Leaks | 501 |
| Weak References | 505 |
| 13. Diagnostics and Code Contracts | 509 |
| Conditional Compilation | 509 |
| Debug and Trace Classes | 512 |
| Code Contracts Overview | 516 |
| Preconditions | 520 |
| Postconditions | 524 |
| Assertions and Object Invariants | 527 |
| Contracts on Interfaces and Abstract Methods | 528 |
| Dealing with Contract Failure | 529 |
| Selectively Enforcing Contracts | 531 |
| Static Contract Checking | 533 |
| Debugger Integration | 535 |
| Processes and Process Threads | 536 |
| StackTrace and StackFrame | 537 |
| Windows Event Logs | 538 |
| Performance Counters | 541 |
| The Stopwatch Class | 545 |
| 14. Concurrency & Asynchrony | 547 |
| Introduction | 547 |
| Threading | 548 |
| Tasks | 565 |

| | |
|---|------------|
| Principles of Asynchrony | 573 |
| Asynchronous Functions in C# 5.0 | 578 |
| Asynchronous Patterns | 594 |
| Obsolete Patterns | 601 |
| 15. Streams and I/O | 605 |
| Stream Architecture | 605 |
| Using Streams | 607 |
| Stream Adapters | 621 |
| Compression Streams | 629 |
| Working with Zip Files | 631 |
| File and Directory Operations | 632 |
| File I/O in Windows Runtime | 642 |
| Memory-Mapped Files | 644 |
| Isolated Storage | 647 |
| 16. Networking | 653 |
| Network Architecture | 653 |
| Addresses and Ports | 655 |
| URIs | 656 |
| Client-Side Classes | 658 |
| Working with HTTP | 671 |
| Writing an HTTP Server | 677 |
| Using FTP | 680 |
| Using DNS | 682 |
| Sending Mail with SmtpClient | 683 |
| Using TCP | 683 |
| Receiving POP3 Mail with TCP | 687 |
| TCP in Windows Runtime | 689 |
| 17. Serialization | 691 |
| Serialization Concepts | 691 |
| The Data Contract Serializer | 695 |
| Data Contracts and Collections | 705 |
| Extending Data Contracts | 707 |
| The Binary Serializer | 710 |
| Binary Serialization Attributes | 712 |
| Binary Serialization with ISerializable | 715 |
| XML Serialization | 719 |
| 18. Assemblies | 729 |
| What's in an Assembly | 729 |
| Strong Names and Assembly Signing | 734 |
| Assembly Names | 737 |
| Authenticode Signing | 739 |

| | |
|---|----------------|
| The Global Assembly Cache | 743 |
| Resources and Satellite Assemblies | 745 |
| Resolving and Loading Assemblies | 754 |
| Deploying Assemblies Outside the Base Folder | 759 |
| Packing a Single-File Executable | 760 |
| Working with Unreferenced Assemblies | 762 |
| 19. Reflection and Metadata | 765 |
| Reflecting and Activating Types | 766 |
| Reflecting and Invoking Members | 773 |
| Reflecting Assemblies | 785 |
| Working with Attributes | 786 |
| Dynamic Code Generation | 792 |
| Emitting Assemblies and Types | 799 |
| Emitting Type Members | 803 |
| Emitting Generic Methods and Types | 808 |
| Awkward Emission Targets | 810 |
| Parsing IL | 814 |
| 20. Dynamic Programming | 821 |
| The Dynamic Language Runtime | 821 |
| Numeric Type Unification | 823 |
| Dynamic Member Overload Resolution | 824 |
| Implementing Dynamic Objects | 830 |
| Interoperating with Dynamic Languages | 833 |
| 21. Security | 837 |
| Permissions | 837 |
| Code Access Security (CAS) | 842 |
| Allowing Partially Trusted Callers | 845 |
| The Transparency Model | 847 |
| Sandboxing Another Assembly | 855 |
| Operating System Security | 858 |
| Identity and Role Security | 861 |
| Cryptography Overview | 862 |
| Windows Data Protection | 863 |
| Hashing | 864 |
| Symmetric Encryption | 865 |
| Public Key Encryption and Signing | 870 |
| 22. Advanced Threading | 875 |
| Synchronization Overview | 876 |
| Exclusive Locking | 876 |
| Locking and Thread Safety | 884 |
| Non-Exclusive Locking | 890 |

| | | |
|------------|---|------------|
| | Signaling with Event Wait Handles | 895 |
| | The Barrier Class | 903 |
| | Lazy Initialization | 904 |
| | Thread-Local Storage | 907 |
| | Interrupt and Abort | 909 |
| | Suspend and Resume | 910 |
| | Timers | 911 |
| 23. | Parallel Programming | 915 |
| | Why PFX? | 915 |
| | PLINQ | 918 |
| | The Parallel Class | 931 |
| | Task Parallelism | 938 |
| | Working with AggregateException | 947 |
| | Concurrent Collections | 949 |
| | BlockingCollection<T> | 952 |
| 24. | Application Domains | 957 |
| | Application Domain Architecture | 957 |
| | Creating and Destroying Application Domains | 958 |
| | Using Multiple Application Domains | 960 |
| | Using DoCallback | 962 |
| | Monitoring Application Domains | 963 |
| | Domains and Threads | 963 |
| | Sharing Data Between Domains | 965 |
| 25. | Native and COM Interoperability | 971 |
| | Calling into Native DLLs | 971 |
| | Type Marshaling | 972 |
| | Callbacks from Unmanaged Code | 975 |
| | Simulating a C Union | 975 |
| | Shared Memory | 976 |
| | Mapping a Struct to Unmanaged Memory | 979 |
| | COM Interoperability | 983 |
| | Calling a COM Component from C# | 985 |
| | Embedding Interop Types | 988 |
| | Primary Interop Assemblies | 989 |
| | Exposing C# Objects to COM | 990 |
| 26. | Regular Expressions | 991 |
| | Regular Expression Basics | 992 |
| | Quantifiers | 996 |
| | Zero-Width Assertions | 997 |
| | Groups | 1000 |
| | Replacing and Splitting Text | 1001 |

| | |
|---|------------------------|
| Cookbook Regular Expressions | 1003 |
| Regular Expressions Language Reference | 1006 |
| Index | 1011 |



Preface

C# 5.0 represents the fourth major update to Microsoft's flagship programming language, positioning C# as a language with unusual flexibility and breadth. At one end, it offers high-level abstractions such as query expressions and asynchronous continuations, while at the other end, it provides low-level power through constructs such as custom value types and the optional use of pointers.

The price of this growth is that there's more than ever to learn. Although tools such as Microsoft's IntelliSense—and online references—are excellent in helping you on the job, they presume an existing map of conceptual knowledge. This book provides exactly that map of knowledge in a concise and unified style—free of clutter and long introductions.

Like the past two editions, *C# 5.0 in a Nutshell* is organized entirely around concepts and use cases, making it friendly both to sequential reading and to random browsing. It also plumbs significant depths while assuming only basic background knowledge—making it accessible to intermediate as well as advanced readers.

This book covers C#, the CLR, and the core Framework assemblies. We've chosen this focus to allow space for difficult topics such as concurrency, security, and application domains—without compromising depth or readability. Features new to C# 5.0 and the associated Framework are flagged so that you can also use this book as a C# 4.0 reference.

Intended Audience

This book targets intermediate to advanced audiences. No prior knowledge of C# is required, but some general programming experience is necessary. For the beginner, this book complements, rather than replaces, a tutorial-style introduction to programming.

If you're already familiar with C# 4.0, you'll find a reorganized section on concurrency, including thorough coverage of C# 5.0's asynchronous functions and its

associated types. We also describe the principles of asynchronous programming and how it helps with efficiency and thread-safety.

This book is an ideal companion to any of the vast array of books that focus on an applied technology such as WPF, ASP.NET, or WCF. The areas of the language and .NET Framework that such books omit, *C# 5.0 in a Nutshell* covers in detail—and vice versa.

If you're looking for a book that skims every .NET Framework technology, this is not for you. This book is also unsuitable if you want to learn about APIs specific to tablet or Windows Phone development.

How This Book Is Organized

The first three chapters after the introduction concentrate purely on C#, starting with the basics of syntax, types, and variables, and finishing with advanced topics such as unsafe code and preprocessor directives. If you're new to the language, you should read these chapters sequentially.

The remaining chapters cover the core .NET Framework, including such topics as LINQ, XML, collections, code contracts, concurrency, I/O and networking, memory management, reflection, dynamic programming, attributes, security, application domains, and native interoperability. You can read most of these chapters randomly, except for Chapters 6 and 7, which lay a foundation for subsequent topics. The three chapters on LINQ are also best read in sequence, and some chapters assume some knowledge of concurrency, which we cover in [Chapter 14](#).

What You Need to Use This Book

The examples in this book require a C# 5.0 compiler and Microsoft .NET Framework 4.5. You will also find Microsoft's .NET documentation useful to look up individual types and members (which is available online).

While it's possible to write source code in Notepad and invoke the compiler from the command line, you'll be much more productive with a *code scratchpad* for instantly testing code snippets, plus an *Integrated Development Environment* (IDE) for producing executables and libraries.

For a code scratchpad, download LINQPad 4.40 or later from www.linqpad.net (free). LINQPad fully supports C# 5.0 and is maintained by one of the authors.

For an IDE, download Microsoft Visual Studio 2012; any edition is suitable for what's taught in this book, except the free express edition.

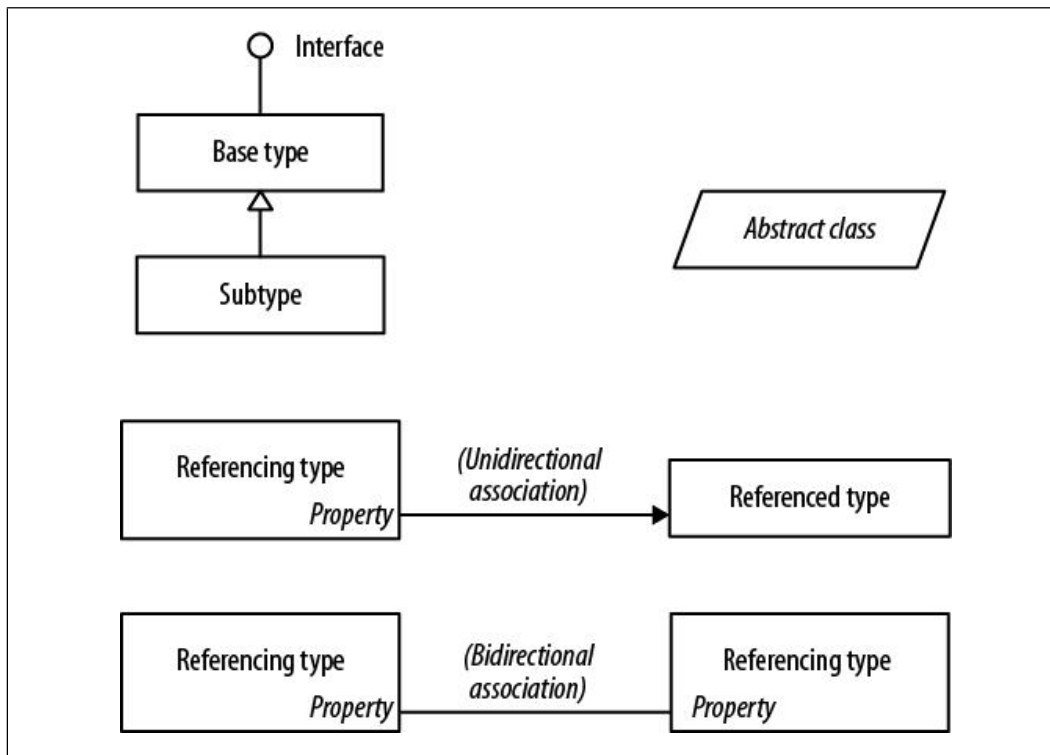


Figure P-1. Sample diagram



All code listings for [Chapter 2](#) through [Chapter 10](#), plus the chapters on concurrency, parallel programming, and dynamic programming are available as interactive (editable) LINQPad samples. You can download the whole lot in a single click: go to LINQPad's Samples tab at the bottom left, click "Download more samples," and choose "C# 5.0 in a Nutshell."

Conventions Used in This Book

The book uses basic UML notation to illustrate relationships between types, as shown in [Figure P-1](#). A slanted rectangle means an abstract class; a circle means an interface. A line with a hollow triangle denotes inheritance, with the triangle pointing to the base type. A line with an arrow denotes a one-way association; a line without an arrow denotes a two-way association.

The following typographical conventions are used in this book:

Italic

Indicates new terms, URIs, filenames, and directories

Constant width

Indicates C# code, keywords and identifiers, and program output

Constant width bold

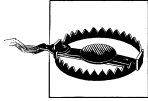
Shows a highlighted section of code

Constant width italic

Shows text that should be replaced with user-supplied values



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



This icon indicates a warning or caution.

Using Code Examples

This book is here to help you get your job done. In general, you may use the code in this book in your programs and documentation. You do not need to contact us for permission unless you're reproducing a significant portion of the code. For example, writing a program that uses several chunks of code from this book does not require permission. Selling or distributing a CD-ROM of examples from O'Reilly books *does* require permission. Answering a question by citing this book and quoting example code does not require permission. Incorporating a significant amount of example code from this book into your product's documentation *does* require permission.

We appreciate, but do not require, attribution. For example: “*C# 5.0 in a Nutshell* by Joseph Albahari and Ben Albahari. Copyright 2012 Joseph Albahari and Ben Albahari, 978-1-449-32010-2.”

If you feel your use of code examples falls outside fair use or the permission given here, feel free to contact us at permissions@oreilly.com.

Safari® Books Online



Safari Books Online (www.safaribooksonline.com) is an on-demand digital library that delivers expert [content](#) in both book and video form from the world's leading authors in technology and business.

Technology professionals, software developers, web designers, and business and creative professionals use Safari Books Online as their primary resource for research, problem solving, learning, and certification training.

Safari Books Online offers a range of [product mixes](#) and pricing programs for [organizations](#), [government agencies](#), and [individuals](#). Subscribers have access to thousands of books, training videos, and prepublication manuscripts in one fully searchable database from publishers like O'Reilly Media, Prentice Hall Professional, Addison-Wesley Professional, Microsoft Press, Sams, Que, Peachpit Press, Focal Press, Cisco Press, John Wiley & Sons, Syngress, Morgan Kaufmann, IBM Redbooks, Packt, Adobe Press, FT Press, Apress, Manning, New Riders, McGraw-Hill,

Jones & Bartlett, Course Technology, and dozens [more](#). For more information about Safari Books Online, please visit us [online](#).

How to Contact Us

Please address comments and questions concerning this book to the publisher:

O'Reilly Media, Inc.
1005 Gravenstein Highway North
Sebastopol, CA 95472
800-998-9938 (in the United States or Canada)
707-829-0515 (international or local)
707-829-0104 (fax)

We have a web page for this book, where we list errata, examples, and any additional information. You can access this page at:

http://oreil.ly/csharp5_IAN

To comment or ask technical questions about this book, send email to:

bookquestions@oreilly.com

For more information about our books, courses, conferences, and news, see our website at <http://www.oreilly.com>.

Find us on Facebook: <http://facebook.com/oreilly>

Follow us on Twitter: <http://twitter.com/oreillymedia>

Watch us on YouTube: <http://www.youtube.com/oreillymedia>

Acknowledgments

Joseph Albahari

First, I want to thank my brother, Ben Albahari, for persuading me to take on *C# 3.0 in a Nutshell*, whose success has spawned two subsequent editions. Ben shares my willingness to question conventional wisdom, and the tenacity to pull things apart until it becomes clear how they *really* work.

It's been an honor to have superb technical reviewers on the team. This edition owes much to two legendary individuals at Microsoft: Eric Lippert (C# compiler team) and Stephen Toub (Parallel Programming team). I can't thank you enough for your extensive and useful feedback—and for answering all my questions. I'm also immensely grateful to C# MVP Nicholas Paldino, whose keen eye and ability to pick up things that others miss, shaped this book and two previous editions.

This book was built on *C# 4.0 in a Nutshell*, whose technical reviewers I owe a similar honor. Chris Burrows (C# compiler team) significantly polished the chapters on concurrency, dynamic programming, and the C# language. From the CLR team, I received invaluable input on security and memory management from Shawn

Farkas, Brian Grunkemeyer, Maoni Stephens, and David DeWinter. And on Code Contracts, the feedback from Brian Grunkemeyer, Mike Barnett, and Melitta Andersen raised the chapter to the next quality bar.

I have the highest praise for Jon Skeet (author of *C# in Depth* and Stack Overflow extraordinaire), whose perceptive suggestions shaped the previous edition, C# MVPs Mitch Wheat and Brian Peek, and reviewers of the 3.0 edition, including Krzysztof Cwalina, Matt Warren, Joel Pobar, Glyn Griffiths, Ion Vasilian, Brad Abrams, Sam Gentile, and Adam Nathan.

Finally, I want to thank the O'Reilly team, including my editor, Rachel Roumeliotis (a joy to work with), my excellent copy editor, Nancy Reinhardt, and members of my family, Miri and Sonia.

Ben Albahari

Because my brother wrote his acknowledgments first, you can infer most of what I want to say. :) We've actually both been programming since we were kids (we shared an Apple IIe; he was writing his own operating system while I was writing Hangman), so it's cool that we're now writing books together. I hope the enriching experience we had writing the book will translate into an enriching experience for you reading the book.

I'd also like to thank my former colleagues at Microsoft. Many smart people work there, not just in terms of intellect but also in a broader emotional sense, and I miss working with them. In particular, I learned a lot from Brian Beckman, to whom I am indebted.