Learn C# with Visual Studio 2022

Comprehensive guide to C# fundamentals, Core .NET concepts, advanced features, and building with Visual Studio 2022

Marcelo Guerra Hahn

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Dedicated to

My students, past and present

About the Author

Marcelo Guerra Hahn is an associate professor at **Lake Washington Institute of Technology** (**LWTech**). At LWTech, he has developed and taught various courses, including quality assurance methodologies, algorithms and data structures, C++ programming, C# programming, data analytics, cloud computing, big data application development, IT project, and job search and interviewing. Since 2017, he has also been a guest lecturer at the University of Washington.

His professional background includes significant engineering leadership roles, such as director of engineering at SoundCommerce, senior manager and manager at Tableau Software, and various roles, including senior software engineering manager at Microsoft Corporation, where he worked on technologies like C++, Azure AD, and the C# Compiler.

Academically, Marcelo Guerra Hahn holds multiple master of science degrees in areas such as computer science, applied mathematics, statistics, and data analytics, as well as other master's degrees and a certificate in applied machine learning.

He is the author of two other books, and his contributions include a patent related to two-way communication of events between a mobile device and remote client and publications on web data warehouses, web service compositions, and automatic scoring and feedback systems for programming assignments.

About the Reviewers

- **Yassin Lokhat** embarked on his programming journey in 2008 at the age of 15, discovering the vast world of C programming. His dedication and talent quickly became evident, and in 2010, he was qualified to represent Madagascar at the **International Olympiad in Informatics** (**IOI**). Driven by a passion for technology, Yassin pursued higher education at the Polytechnic High Institute of Madagascar.

  Throughout his five years of rigorous study, he learned and used C# and desktop development, graduating with honors in electronics, computer systems, and artificial intelligence. With his distinguished diploma, Yassin ventured to Mauritius to further his professional career, where he honed his skills and expertise, becoming a senior software engineer. After these productive years, he returned to Madagascar, taking on the leadership of the Malagasy team within his project. Currently, Yassin serves as the senior software engineer - technical lead for the Astek Group, where he continues to drive innovation and excellence in the field of development. His journey is a testament to his unwavering commitment to growth and his passion for technology.

- **Ockert J. Du Preez** is a passionate coder who is always willing to learn. Having been in the training and coding industry, he has a wealth of experience. He has written hundreds of developer articles over the years detailing his programming quests and adventures. These can be found on CodeGuru, Developer.com, and Database Journal.

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  Visual Studio 2019 In-Depth

  JavaScript for Gurus

  Cross-Platform Modern Apps with VS Code

  High Performance Enterprise Apps using C# 10 and .NET 6

  Visual Studio 2022 In-Depths

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Creating this book has been a journey shaped by many influences. My deepest gratitude is to my students, past and present, whose engagement in C# programming and object-oriented concepts inspired and proposed this work.

Microsoft, the creator of C# and the .NET platform, deserves special recognition. My experience on the C# Compiler team offered unique insights reflected throughout the book.

Thank you to the vibrant C# community for continuously enhancing this platform.

Finally, sincere thanks to the reviewers whose valuable feedback helped refine the manuscript.

Preface

Welcome to the world of C# programming. C# is a modern, versatile, robust, and adaptable programming language in today's rapidly evolving software development landscape. Developed by Microsoft, it is renowned for its object-oriented design, contemporary features, and ease of use. It is built on top of the .NET platform, which provides platform independence and a robust ecosystem for creating a wide range of applications.

This book explores the versatile C# and .NET ecosystem, covering syntax basics, control structures, methods, OOP concepts like classes, objects, interfaces, and polymorphism. It delves into collections, delegates, events, exception handling, file I/O, asynchronous, reflection, dynamic programming, and application frameworks like Windows Forms, WPF, ASP.NET Core, and Blazor. It introduces the C# programming language, aiming to provide a foundational understanding of its principles and practical applications. Whether you are new to programming or looking to deepen your knowledge of C#, this text is designed to equip you with the essential skills to tackle real-world programming challenges.

We begin by exploring the basics of C#, including its history, adaptability, essential features, and fundamental components, such as syntax rules, variables and data types, operators, and the basic structure of a C# program. You will learn to set up your development environment using Visual Studio 2022, a powerful and user-friendly code editor.

A significant focus is placed on **object-oriented programming** (**OOP**) in C#, which is integral to the language. We will delve into core OOP concepts, including defining and understanding classes and objects, encapsulation, inheritance, and polymorphism through interfaces and abstract classes. The book also covers essential programming constructs like control structures for directing program flow and methods for creating modular and reusable code.

Moving beyond the fundamentals, you will explore crucial topics for managing data and complex application logic. This includes working with collections and generics, essential tools for efficient data handling and manipulation. We will also cover delegates and events, key to building flexible and dynamic applications, and robust exception handling and debugging techniques for creating stable and reliable programs.

Further chapters introduce how C# handles file and stream I/O, enabling persistent data storage, and the principles of asynchronous programming for building responsive applications. You will also gain insights into advanced features like reflection and attributes, which allow for dynamic inspection and manipulation of code at runtime.

Finally, the book introduces major application development frameworks within the C# and .NET ecosystem. You will explore building desktop applications using Windows Forms and **Windows Presentation Foundation** (**WPF**), as well as modern web applications and interactive UIs using ASP.NET Core and Blazor. These frameworks demonstrate the versatility of C# as a gateway to various platforms such as desktop, web, and mobile applications.

Drawing upon years of experience as an associate professor teaching C# programming and object-oriented concepts and as a senior software engineering manager at microsoft, where I worked on the C# Compiler [Resume], this book aims to blend academic rigor with practical industry insights.

We are excited for you to embark on this journey. By mastering the concepts presented here, you will be well-equipped to develop efficient, scalable, and maintainable C# applications.

Let us begin.

Chapter 1: Introduction to the C# Programming Language - This chapter provides a foundational understanding of C#, a modern and versatile programming language developed by Microsoft. It begins with an overview of C#, including its history, adaptability, and essential features. The chapter guides you through setting up Visual Studio 2022 for C# programming, covering installation, customization, and interface acquaintance. You will learn the basics of C# programming, including fundamental components like syntax rules, variables, data types, and operators. The chapter also introduces the basics of object-oriented programming in C# and touches upon advanced concepts like delegates, events, generics, Lambda expressions, and LINQ. By the end of this chapter, you will understand C#, its evolution, benefits, and how to write your first C# program using Visual Studio 2022. This foundational knowledge is essential for anyone aspiring to become proficient in modern software development, serving as a gateway to various platforms such as desktop, web, and mobile applications.

Chapter 2: C# Basics - This chapter delves into the fundamental aspects of C# programming. It covers basic syntax rules, emphasizing case sensitivity, using semicolons to end statements, and curly brackets for code sections. You will learn the basic structure of a C# program, recognizing essential components and the significance of the Main function as the entry point. The chapter explains how to use comments effectively to improve code readability. A key focus is declaring and initializing variables and data types, highlighting C#'s strong typing system for early error identification. Finally, you will learn to perform basic operations using C# operators. By the end of this chapter, you will be able to understand and apply fundamental C# syntax, recognize program components, work with variables and data types, and perform basic operations, which is crucial for writing clear and maintainable code.

Chapter 3: Introduction to Control Structures - This chapter introduces control structures as essential components in programming that direct program execution. It covers understanding and using conditional statements like if, else if, and switch to allow programs to take different execution routes based on conditions. You will explore looping structures for while, do-while, and for each for automating repetitive processes and handling data efficiently. The chapter also discusses interrupting looping structures using branching statements like break and continue. It also introduces exception handling in C# for gracefully managing runtime errors. By the end of this chapter, you will effectively use control structures to manage program flow, write efficient, readable, and maintainable code, and handle exceptions.

Chapter 4: Introduction to Methods in C# - This chapter delves into the core concepts of methods in C#, which are fundamental building blocks for creating clean, efficient, and maintainable code by encapsulating functionality into reusable, modular pieces. It explores what methods are and how they are defined. You will learn about method parameters, including value, reference, output, and parameter arrays, and understand their different uses. The chapter covers method overloading, enabling multiple methods with the same name but different parameter lists. It also discusses the scope and lifetime of variables within methods. Finally, you will learn best practices for writing methods such as ensuring single responsibility, conciseness, meaningful naming conventions, documentation, and debugging and testing strategies like using breakpoints, stepping through code, inspecting variables, and writing unit tests. By the end of this chapter, you will have a comprehensive understanding of how to create, use, and maintain methods to develop efficient, scalable, and maintainable C# applications.

Chapter 5: Classes and Objects in C# - This chapter explores classes and objects, which form the backbone of OOP in C#, allowing developers to model real-world entities and abstract concepts. You will learn to define classes, which act as blueprints, and create objects, which are instances of those classes. The chapter covers managing properties, methods, constructors, and access modifiers like public and private for encapsulation. You will also explore static members, nested, and partial classes for organizing and sharing code. By the end of this chapter, you will understand core OOP concepts implemented through classes and objects, apply these skills to build practical applications, and have a strong foundation in C# OOP for developing scalable and maintainable software.

Chapter 6: C# Interfaces and Polymorphism - This chapter introduces interfaces and polymorphism as crucial features for creating flexible, reusable, and maintainable code in C#. You will learn that interfaces act as contracts, defining methods and properties without implementation, ensuring consistency across classes. You will explore implementing interfaces in a class. The chapter covers understanding polymorphism, which enables objects of different classes to be treated uniformly based on a common superclass or interface. You will learn to differentiate between compile-time and run-time polymorphism. Additionally, it discusses abstract classes and methods and how to use them alongside interfaces for flexible design. By the end of this chapter, you will understand the purpose and structure of interfaces, implement them, leverage polymorphism to write adaptable code, and apply these concepts to design robust software systems.

Chapter 7: C# Collections and Generics - This chapter focuses on collections, generics, and LINQ as essential tools for efficiently managing and manipulating data in C#. You will understand collections like lists, dictionaries, queues, and stacks for storing and organizing groups of objects, learning when and how to use each. The chapter explains generics, which allow creating reusable, type-safe classes, methods, and collections that work with any data type without sacrificing performance. You will also learn to concisely leverage LINQ to query, filter, sort, group, and join data across various sources. By the end of this chapter, you will effectively use collections and generics to handle complex data structures and manipulate collections efficiently using LINQ, writing more efficient, scalable, and maintainable code.

Chapter 8: C# Delegates and Events - This chapter covers delegates and events, which are crucial for understanding C#'s event-driven architecture. You will learn about delegate basics, understanding them as type-safe function pointers that allow methods to be passed as parameters and invoked dynamically, enhancing flexibility. The chapter explores multicast delegates, anonymous methods, and Lambda expressions. You will understand event basics, how they build on delegates to provide a structured way for objects to communicate, and how to implement and manage them. By the end of this chapter, you will be equipped to use delegates and events effectively, utilize anonymous methods and Lambda expressions in event handling, and differentiate between delegates and events to build interactive, event-driven C# applications.

Chapter 9: C# Exception Handling and Debugging - This chapter addresses managing unexpected code behavior using exception handling and debugging to create stable and reliable applications in C#. You will understand that an exception is an event disrupting normal program flow and how C# uses exception objects to represent error conditions. It covers basic exception handling using the try-catch block to manage errors and multiple exceptions, and the finally block for cleanup actions. You will also learn to create custom exceptions to depict application-specific conditions. The chapter introduces debugging, involving running an application under controlled conditions to identify and resolve issues. By the end of this chapter, you will implement basic and custom exception handling, apply best practices, and use debugging tools like breakpoints and step-through code execution to build resilient and error-handling-capable applications.

Chapter 10: C# File and Stream Input/Output - This chapter explores I/O operations, fundamental components for managing data beyond a program's lifespan. You will understand the basic concepts of file and stream I/O using the System.IO namespace. The chapter covers file handling in C#, including creating, reading, writing, and deleting files using classes like File and FileInfo, and working with directories using Directory and DirectoryInfo. You will learn to read from and write to text and binary files using StreamReader, StreamWriter, and FileStream. Furthermore, it explores streams in C# as abstract representations of data sequences, introducing types like BufferedStream, MemoryStream, and NetworkStream to optimize performance. By the end of this chapter, you will have a solid understanding of integrating file and stream operations into your C# projects, enhancing their functionality and reliability.

Chapter 11: C# Asynchronous Programming - This chapter focuses on asynchronous programming in C# to handle time-consuming tasks without blocking the main thread, ensuring responsiveness and efficiency. You will learn how the async and await keywords enable writing asynchronous code that looks similar to synchronous code. The chapter discusses when and why asynchronous programming is preferred for improved performance and scalability. It covers strategies for combining multiple async methods, whether sequentially or concurrently. You will learn to manage task cancellations using CancellationToken and set timeouts for long-running operations. Finally, it explores exception handling in asynchronous programming using try-catch blocks and the Task—exception property to build resilient applications. By the end of this chapter, you will effectively use asynchronous programming to create scalable, high-performance applications.

Chapter 12: C# Reflection and Attributes - This chapter explores reflection and attributes in C#, which enhance applications' flexibility and dynamic capabilities. You will understand reflection, which allows inspecting a program's structure during runtime and dynamically accessing and manipulating types, methods, and properties using the system. Reflection namespace. The chapter covers reflection and assemblies. You will explore working with attributes, which provide a way to associate metadata with your code. Finally, you will gain skills to retrieve and process attributes dynamically using reflection. By the end of this chapter, you will have a thorough understanding of C# reflection and attributes, enabling dynamic interaction with objects, dynamic method invocation, instance creation, and creating more flexible and maintainable applications.

Chapter 13: C# Dynamic Programming - This chapter delves into C# programming primarily through the dynamic type, which brings flexibility and adaptability. You will understand how dynamic typing differs from traditional static typing by bypassing compile-time type checking and resolving types at runtime. The chapter explores practical applications like interoperability with COM objects and integration with dynamic languages. You will gain insight into concepts such as the DLR. It covers Dynamic LINQ queries. By the end of this chapter, you will understand the fundamentals of dynamic programming, use the dynamic type effectively while implementing error handling, and learn best practices for building adaptable and maintainable applications.

Chapter 14: Windows Forms and Windows Presentation Foundation - This chapter covers Windows Forms and Windows Presentation Foundation, two key frameworks for building desktop applications in C#. You will understand Windows Forms as a GUI toolkit for creating traditional Windows-style interfaces with familiar controls and rapid prototyping. You will learn to develop basic Windows Forms applications with essential controls and event handling. The chapter introduces WPF as a more advanced framework, exploring the role of XAML for declarative UI design, and learning to implement data binding and layout management. By the end of this chapter, you will understand the fundamental concepts of both frameworks, develop basic Windows Forms applications, explore WPF features, and identify the key differences to choose the appropriate framework for your project needs.

Chapter 15: ASP.NET Core and Blazor - This chapter introduces ASP.NET Core and Blazor, powerful tools in the C# ecosystem for building modern web applications. You will learn about ASP.NET Core as an open-source, cross-platform framework for creating web applications, APIs, and real-time applications, covering critical concepts like the middleware pipeline, MVC architecture, and routing. The chapter then explores Blazor, a web framework enabling interactive web applications using C# for client-side development, covering Blazor components and data binding. By the end of this chapter, you will have a solid understanding of these frameworks, set up environments, create basic applications, implement key ASP.NET Core features, and develop interactive web applications using Blazor components, leveraging C# for both server and client-side development.

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Introduction to the C# Programming Language

Introduction

In the first chapter, we will dive into the basics of C# and learn how it integrates with Visual Studio 2022. We will start with an overview of C#, briefly covering its history, adaptability, and essential features for use in the current market. The next step will be to set up Visual Studio 2022 for C# programming. We will guide you through the entire installation process. After that comes the customization and getting acquainted with the IDE's user interface. We will handle the setup process before working on our first C# program.

Structure

This chapter covers the following topics:

- Introduction to C#
- Basics of C# programming
- C-Class language family
- Visual Studio 2022

Objectives

In this chapter, you will learn about C#, a modern and versatile programming language that can be used to create various types of applications. You will explore the features and benefits of C# as a language and how it has evolved over the years to incorporate new paradigms and technologies. You will also learn the basics of object-oriented programming in C# and how to use advanced C# concepts such as delegates, events, generics, lambda expressions, and LINQ. Finally, you will write your first C# program using Visual Studio 2022, a powerful and user-friendly code editor with many tools and features to help you write and debug your code.

Introduction to C#

C# (pronounced "C sharp") is a high-level, general-purpose programming language created by Microsoft. It is a robust and adaptable programming language renowned for its object-oriented design, contemporary features, and ease of use. It is built on top of the .NET framework, which provides platform independence, enabling programmers to create code only once and execute it on several different systems. C# promotes code safety and scalability across a wide range of applications, including desktop software, web development, game programming, and enterprise-level applications, thanks to its static type system and integration. Some of its salient characteristics are object-oriented programming, type safety, contemporary language structures, and smooth integration with frameworks like the gaming engine Unity and the web development tools in ASP. NET Core. If you are developing desktop apps, web services, business software, or games, C# has the capabilities and tools required to meet your development objectives.

History and evolution of C#

A team of engineers led by Microsoft's architect *Anders Hejlsberg* developed the C# programming language in 2000. It became an international standard in 2002, being registered with ECMA. After ECMA, ISO, and IEC accepted C#'s international standards status in 2003. Microsoft released C# together with the.NET Framework and Visual Studio. Microsoft did not have any open-source products then, so Mono's open-source project was launched in 2004, offering a cross-platform compiler and runtime environment for the C# programming language. Ten years later, Microsoft introduced the free, open-source, cross-platform Visual Studio Code code editor, Roslyn compiler, and unified .NET platform software framework, all of which supported C#. The language's most current stable version, as of 2025, is C# 13.0, which was made available in November 2024 with .NET 9.0.

Basics of C# programming

This section will examine the fundamental components that make up C# programming. Let us take a look at them:

- **Operators and expressions**: The basic units of C# expressions are operators, which allow programmers to work with data in bitwise, logical, and arithmetic ways. To efficiently handle numeric and Boolean data, C# provides a wide range of operators for addition, subtraction, and comparison.

- **Syntax**: C# syntax takes a while to understand as it uses characters not commonly used in ordinary writing. C# is an object-oriented language with data at the program's center, with classes, objects, and methods reflecting data structures and their functions.

- **Control flow**: The execution flow of a C# program is managed using control flow statements, which give programmers the ability to make selections, cycle through data, and handle exceptions dynamically. C# has a range of control flow structures to support different programming scenarios, from if-else statements for conditional branching to switch statements for multi-branching logic. Developers can design code that intelligently reacts to changing conditions and user inputs skillfully using control flow statements.

- **Variables and data types**: In C#, data types define the sorts of data stored in variables and the operations performed on them. C# has many built-in data types to satisfy various programming needs, such as strings (text), whole numbers (integers), arrays, and floating-point numbers. Furthermore, by allowing the creation of custom data types using classes and structures, C# enables developers to express complicated entities and connections accurately.

Object-orientation in C#

As stated earlier, C# was initially designed as an object-oriented programming language. Programmers can quickly define data structures (and types) in **object-oriented programming** (**OOP**). Objects are formed from classes. Consider classes as blueprints and objects as the things you construct from them. Data encapsulation, inheritance, polymorphism, and interfaces are supported in C#. In Java, primitive types (int, float, and double) cannot be objects. However, C# provides structures that allow these to become objects—creating, maintaining, and reusing code when data is grouped as this is simpler. It also reduces error-proneness and facilitates code correction. Some characteristics of C# include the following:

- **Inheritance and polymorphism**: A fundamental component of OOP is inheritance, which lets classes inherit attributes and functions from other classes, encouraging code reuse and supporting a hierarchical structure. Developers may design versatile and extendable class hierarchies in C# by leveraging interfaces to establish numerous base classes or single inheritance to inherit from a single base class. Conversely, polymorphism allows objects to display distinct behaviors according to their underlying.

  These types allow for runtime flexibility and dynamic method dispatch. Through the use of inheritance and polymorphism, developers may build codebases that are resilient and flexible enough to change as needed.

- **Interfaces and abstract classes**: In C#, interfaces and abstract classes are useful tools for creating agreements and standardizing class behavior. To enable polymorphic behavior and promote code compatibility, an interface creates a contract outlining a set of methods and attributes a class must implement. Conversely, abstract classes give derived classes a path to follow, enabling programmers to specify shared behavior and guarantee uniformity between related classes. Developers may create adaptable and extensible systems that can handle various requirements and future improvements by utilizing interfaces and abstract classes in their design process.

- **Classes and objects**: Classes and objects, the basic building blocks of OOP in C#, simulate real-world objects and behaviors. An object's state and behavior are encapsulated in a class, which is a blueprint that defines its methods and attributes. In contrast, objects are just instances of classes that stand in for distinct entities with their special characteristics and behaviors. Developers can assist in better program logic structure, code reuse, and modularization by generating classes and instantiating objects.
- **Encapsulation**: OOP's core concepts of encapsulation encourage modularity, information hiding, and code maintainability. Encapsulation is the process of grouping procedures and data within a class, protecting the internal state of an object from outside interference, and guaranteeing data integrity. Conversely, abstraction entails hiding implementation details, revealing critical aspects to the outside world, and describing complicated systems using simpler models. Developers may design self-contained, reusable components that are simple to understand and manage by abstracting behavior and encapsulating data.

Advanced C# concepts

Advanced language features, including lambda expressions, delegates, events, generics, extension methods, and attributes, are available in C#. We will briefly discuss a few:

- **Generics**: C# generics offer a robust approach for building reusable components compatible with any data. Using generics, developers may construct type-safe code without compromising efficiency or flexibility. Custom data structures, algorithms, and collections (like List<T>) are common use cases for generics.
- **Delegates and events**: In C#, delegates and events effectively create loosely connected components and implement callback functionality. By acting as function pointers, delegates enable the dynamic invocation and passing of methods as parameters. Events offer a practical means of putting the observer pattern into practice by allowing objects to subscribe to and get alerts about actions or changes.
- **Lambda expressions**: In C#, anonymous functions may be defined with a clear and expressive syntax thanks to lambda expressions. They are beneficial for constructing inline functions, such as predicates for collections filtering or defining asynchronously executed actions. For LINQ queries, code readability may be increased, and the boilerplate may be reduced.

- **Asynchronous programming with async/await**: A key component of contemporary C# development is asynchronous programming with async/await, which makes programs responsive and scalable. By enabling developers to create asynchronous code synchronously using async/await, they may escape callback hell and reason about asynchronous processes more efficiently. Developers may create responsive user interfaces, optimize resource usage, and effectively manage CPU and I/O-bound processes by utilizing async/await.

Error handling and debugging in C#

Debugging and error handling are crucial components of C# program development. Keeping mistakes and defects under control makes your apps more reliable and speeds up development. This section will cover a variety of methods and best practices for managing errors and debugging C# code:

- **Debugging techniques**: The practice of finding and fixing errors in software code is known as debugging. To help with this process, developers working in C# have access to various practical debugging tools and methodologies. The primary IDE for C# development, Visual Studio, has tools like watch windows, step-through debugging, and breakpoints that let programmers examine the state of their application and follow its execution path. Developers may increase productivity and code quality by effectively identifying and resolving problems in their code by learning debugging techniques.
- **Exception handling**: In C# programs, exception handling addresses runtime failures. Try-catch blocks allow developers to handle errors gracefully and avoid unplanned crashes. Furthermore, C# has features like exception filters and finally blocks, enabling fine-grained exception management and resource cleaning. For software systems to be robust and dependable, robust exception-handling techniques must be implemented.
- **Logging and tracing**: In production contexts, logging and tracing are essential tools for tracking program activity and troubleshooting problems. To log events, failures, and performance data in C#, developers can utilize frameworks like log4net and Serilog. Furthermore, distributed tracing and structured logging are supported natively by .NET Core and .NET 5+, giving developers further visibility into microservices architectures and distributed systems. Software engineers may create more stable and dependable software by proactively identifying and resolving issues using logging and tracing.

Working with collections and Language Integrated Query

A fundamental component of C# programming is working with collections and **Language Integrated Query** (**LINQ**), which allows programmers to manage and query data