MODERN DELPHI PROGRAMMING

BUILDING PROFESSIONAL APPLICATIONS WITH RAD STUDIO AND OBJECT PASCAL

MODERN TOOLS.
POWERFUL LANGUAGE.
PROFESSIONAL RESULTS.

DATABASE, REST,
CONCURRENCY,
TESTING AND MORE.

BUILD, DEPLOY AND
MODERNIZE REAL-WORLD
DELPHI APPLICATIONS.

CHARLES M. ASHFORD

Modern Delphi Programming

Building Professional Applications with RAD Studio and Object Pascal

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Building Professional Applications with RAD Studio and Object Pascal

This book teaches modern Delphi development from first principles through production-grade architecture. Using RAD Studio 13 Florence as the reference platform, it covers the Object Pascal language, the runtime library, VCL and FireMonkey UI frameworks, FireDAC database programming, REST integration, concurrency, testing, deployment and legacy code modernization. Every concept is explained with complete, compilable examples and practical guidance about when to use each technique, what tradeoffs exist, and which patterns fit real-world Delphi applications best.

Introduction

A Delphi application compiles to native machine code. It runs without a virtual machine, without a Just-In-Time compiler, without a runtime framework that must be installed on the target system. The executable is fast, small compared with many alternatives, and it can call operating system APIs directly or link against third-party C libraries without ceremony. At the same time, the development environment provides visual form designers, drag-and-drop data components, an integrated debugger, and a language that evolved continuously from its Pascal roots into something capable of modern idioms: generics, anonymous methods, extended RTTI, parallel programming primitives, and recently, a ternary operator and other syntactic conveniences.

This combination is unusual in contemporary software development. Most ecosystems force a choice between productivity and control. Delphi attempts to deliver both.

Why This Book Exists

Delphi has existed for more than three decades. That longevity is both a strength and a liability. The strength is an enormous installed base of production systems, a mature runtime library, and tooling refined over thousands of release cycles. The liability is that much of the public knowledge about Delphi is dated. Legacy patterns persist because they were once correct. New developers encounter codebases built with approaches that modern Delphi has superseded. Even experienced Delphi developers sometimes lack exposure to current best practices in areas like concurrency, REST integration, testing, or deployment automation.

This book addresses that gap. It presents Delphi as it is today, not as it was in 2005 or 2015. The reference platform throughout is RAD Studio 13 Florence, the latest stable release at the time of writing. Where features differ between versions, editions, or target platforms, those distinctions are stated explicitly. Historical techniques appear only when they explain current behavior or when you must encounter them in legacy code, and they are always qualified with modern alternatives.

What You Will Learn

The book progresses from fundamentals to production architecture:

- **Language and tooling:** Object Pascal syntax and semantics using current idioms, the RAD Studio IDE workflow, project structure, build configurations, debugging, and profiling.
- **Runtime library:** Collections, streams, JSON, XML, file system operations, encodings, dates and times, and other RTL utilities that every Delphi developer uses daily.
- **Architecture and design:** Object-oriented practices specific to Delphi, design patterns that genuinely improve applications, layered architecture, dependency injection, and strategies for keeping code maintainable as it grows.
- **User interfaces:** Deep coverage of both VCL for Windows desktop applications and FireMonkey for cross-platform development, including layout, graphics, styles, DPI handling, localization, and platform-specific behaviors.
- **Database programming:** Comprehensive FireDAC usage with SQLite and PostgreSQL examples, covering connections, queries, transactions, performance optimization, concurrency models, and secure credential handling.
- **Networking:** HTTP clients, REST API integration, authentication patterns, TLS configuration, resilience strategies, and simple API server development.
- **Concurrency:** Threads, tasks, the Parallel Programming Library, synchronization primitives, producer-consumer patterns, race conditions, deadlocks, and practical asynchronous designs.
- **Platform development:** Windows-specific capabilities including Win32/Win64 API calls, COM interop, services, DLLs, and cross-platform constraints for all supported targets.
- **Custom components:** Component design principles, packages, runtime packages, plugin architectures, and binary compatibility considerations.
- **Testing:** Unit testing with DUnitX, integration testing, mocking strategies, test data management, and CI execution.
- **Delivery:** Git workflows, command-line builds with MSBuild, CI/CD pipelines, installers with Inno Setup, code signing, update strategies, and production release checklists.

- **Legacy modernization:** Practical strategies for upgrading compiler versions, migrating from ANSI to Unicode strings, transitioning from 32-bit to 64-bit, refactoring tightly coupled code, and modernizing obsolete database and networking components without unnecessary rewrites.

How This Book Is Organized

The chapters build on each other in a deliberate sequence. Early chapters establish language and tooling foundations. Middle chapters cover architecture, UI frameworks, databases, networking, and concurrency. Later chapters address platform-specific development, testing, deployment, and legacy modernization. The final chapters present integrated case studies that demonstrate how multiple concepts combine in realistic applications.

Each chapter is written for continuous reading but also serves as reference material. Sections are self-contained enough that you can navigate directly to topics of interest once you have the foundational knowledge from earlier chapters. Cross-references point back to relevant material rather than repeating explanations.

Prerequisites

This book assumes basic programming literacy: familiarity with variables, control flow, functions, and object-oriented concepts at a conceptual level. No prior Delphi or Object Pascal experience is required. If you have programmed in C#, Java, Python, C++, or similar languages, many concepts will be familiar even if the syntax differs. Occasional comparisons to other languages appear where they clarify Delphi-specific behavior, but the book does not attempt to survey multiple ecosystems.

Target Platform and Version Notes

The primary reference throughout is RAD Studio 13 Florence (Delphi 13), released in September 2025, with updates through version 13.1 released in March 2026. Key distinguishing features of this release include:

- A 64-bit IDE running alongside the traditional 32-bit version
- New language extensions including a ternary conditional operator implemented via the `if` keyword, a `NameOf` intrinsic function, "is not" and "not in" operators, and tighter generic constraints
- A native Arm64EC compiler toolchain for Windows on ARM devices
- Updated platform support for Android API level 36 and iOS 26
- Enhanced FireDAC drivers for PostgreSQL 16, Firebird 5, Oracle with OAuth support, and several others

Where features were introduced in versions prior to 13 or differ between editions (Community, Professional, Enterprise, Architect), those distinctions are noted inline. Community Edition users should be aware that some features, particularly RAD Server deployment capabilities and certain database tools, require higher editions.

Code Examples

Every code example in this book is complete and compilable. No implementation details are omitted behind phrases like "implementation left as an exercise." When an example requires a particular unit, form component, database schema, configuration value, or build setting, those prerequisites are stated explicitly. Small examples introduce individual concepts; larger multi-unit projects demonstrate architectural patterns.

Code style is consistent throughout: Hungarian notation is not used, camelCase applies to local variables and parameters, PascalCase applies to types and public members, and units follow descriptive naming conventions. These choices reflect common modern Delphi practice rather than any single organizational standard.

When Delphi Is a Strong Fit

Delphi excels in several domains:

- **Desktop business applications:** Data-intensive Windows applications with rich user interfaces, tight database integration, and rapid development cycles.

- **Cross-platform desktop tools:** Applications that must run on Windows, macOS, and Linux from a single codebase using FireMonkey.
- **Database-centric systems:** Applications where data access is central to the domain logic and performance matters.
- **Legacy application maintenance:** The vast installed base of existing Delphi applications makes it the natural choice for ongoing development.
- **Embedded and industrial applications:** Native executables with minimal runtime dependencies suit constrained or specialized environments.

Delphi is less suitable when:

- You need a large, mature web framework ecosystem comparable to what Node.js, Python, or Java offer.
- Your team requires cloud-native microservice tooling as a first-class citizen.
- Mobile development demands access to the latest platform-specific UI components and animations that native Swift or Kotlin provide.
- The project depends heavily on third-party libraries available only in other ecosystems.

These are tradeoffs, not verdicts. Many successful Delphi applications integrate with web services, run alongside cloud infrastructure, and communicate with mobile clients through REST APIs. The language and platform are capable; the ecosystem is simply smaller than those of more widely adopted alternatives.

A Note on Practice Categorization

Throughout this book, techniques and patterns fall into four categories:

1. **Modern recommended practice:** Current best practices for new development using RAD Studio 13 features and idioms.
2. **Acceptable situational practice:** Approaches that are not ideal but justified in specific contexts, such as interoperability constraints or performance requirements.
3. **Legacy practice retained for compatibility:** Patterns found in older codebases that still work but should be replaced when feasible.

4. **Deprecated or discouraged practice:** Techniques that are actively harmful, obsolete, or likely to cause problems and should be avoided in new code.

Each category is labeled where relevant so you can distinguish between what you should write today and what you might encounter while maintaining existing systems.

The rest of this book delivers on the promise stated at the beginning: a complete, practical, technically rigorous guide to modern Delphi development that leaves you capable of building production-grade applications from scratch or evolving existing ones into maintainable, secure, performant systems. Let us begin.

Chapter 1: The Delphi Ecosystem Today

Before writing code, you need to understand the environment in which you will work. This chapter covers what modern Delphi is, the RAD Studio tooling suite, supported platforms and editions, the compiler model, IDE layout, project structure, build configurations, packages, and guidance on when Delphi is an appropriate technology choice.

What Is Modern Delphi

Delphi is a programming language and integrated development environment for building native applications. The language is Object Pascal, an evolution of Pascal with object-oriented features, generics, anonymous methods, attributes, extended RTTI, and other modern capabilities. The IDE is RAD Studio, which bundles the Delphi compiler with C++Builder for C++ development, visual form designers, database tools, debugging facilities, and deployment utilities.

"Modern Delphi" refers to the language and tooling as they exist in recent releases, specifically from Delphi 2009 onward when Unicode support was introduced, but more precisely from Delphi XE2 (version 10) onward when generics, anonymous methods, and parallel programming primitives became available. The current reference release is RAD Studio 13 Florence, released in September 2025 with update 13.1 in March 2026 [1][2].

Key characteristics that distinguish modern Delphi:

- **Native code generation:** Applications compile directly to machine code for the target platform without an intermediate virtual machine or Just-In-Time compilation step.
- **Single-source cross-platform development:** A single codebase can target Windows, macOS, Linux, iOS, and Android using conditional compilation and framework abstraction layers [3].

- **Visual component architecture:** Both VCL (Windows-only) and FireMonkey (cross-platform) provide drag-and-drop form designers with rich control libraries.
- **Integrated database access:** FireDAC provides native drivers for major database systems including SQLite, PostgreSQL, MySQL, SQL Server, Oracle, InterBase, and others [4].
- **Continuous evolution:** The language has added features in every major release, including the ternary operator, `NameOf` intrinsic, and tighter generic constraints in version 13 [5].

RAD Studio Editions and Licensing Landscape

RAD Studio is sold in three commercial editions plus a free Community Edition for qualifying developers. Each edition includes both Delphi and C++Builder compilers and tooling. The editions differ primarily in deployment capabilities, database tools and web development features [6][7].

Community Edition is free for individual developers earning less than $50,000 annually or organizations with gross revenue under $50,000. It includes full access to the Delphi compiler, IDE, VCL, FireMonkey, FireDAC, and most development features. Limitations include restrictions on commercial use, no RAD Server deployment licenses, limited RTL source code access, and exclusion from Kai AI assistant features [8]. Community Edition currently tracks version 12.1 Athens rather than the latest 13.x release, though Delphi 13 Community Edition was announced in August 2026 [9].

Professional Edition is the entry-level commercial license. It supports full commercial development for Windows, macOS, iOS, and Android desktop applications. It includes InterBase ToGo Lite for embedded database scenarios but lacks Linux client/server support, RAD Server deployment, and advanced database tools.

Enterprise Edition adds Linux client and server support (both compilation targets), remote FireDAC connectivity features, a single-site RAD Server deployment license for building REST APIs and web services, and additional database utilities [10].

Architect Edition is the top-tier license. It includes everything in Enterprise plus multi-site RAD Server deployment licenses, Ext JS Pro for web

UI development, Aqua Data Studio for advanced database management and InterBase ToGo with encryption support [11].

For learning purposes and small projects, Community Edition is sufficient. For production commercial applications targeting multiple platforms or requiring web service capabilities, Professional or higher is necessary.

Supported Platforms and Target Architectures

RAD Studio 13 Florence supports the following target platforms for Delphi development [3][12]:

- **Windows:** Win32 (32-bit x86), Win64 (64-bit x86-64), and starting with version 13.1, Windows on ARM via a native Arm64EC compiler toolchain that produces binaries running on ARM-based Windows devices without Intel emulation [13].
- **macOS:** 64-bit applications for both Intel and Apple Silicon (ARM) CPUs, supporting macOS 15 Sequoia and macOS 14 Sonoma with universal binary capability [14].
- **iOS:** 64-bit ARM applications targeting iOS 26 as of version 13.1, using real devices only (no simulator support for development builds) [15].
- **Android:** 32-bit and 64-bit ARM applications targeting Android API level 36 as of version 13.1, which is the minimum required for Google Play Store submissions by August 2026 [16]. Real devices only, no emulator support.
- **Linux:** 64-bit x86-64 applications using FireMonkey for the UI layer, supported on distributions including Ubuntu and others with appropriate runtime libraries [17].

Important constraints to understand:

- VCL is Windows-only. Cross-platform projects must use FireMonkey.
- Android and iOS deployment requires connecting physical devices via USB during development and debugging.
- Linux desktop support uses FireMonkey exclusively; there is no Linux VCL port.
- The Windows on ARM target in version 13.1 is a significant addition for developers deploying to ARM-based Surface devices or virtual machines running on Apple Silicon Macs [18].

The Compiler Model and Native Code Generation

Delphi uses a native ahead-of-time compiler that translates Object Pascal source code directly into machine code for the target architecture. This differs fundamentally from languages like C# (.NET), Java (JVM), or Python, which compile to an intermediate representation executed by a runtime environment.

The implications are significant:

- **Startup performance:** Delphi applications start immediately without waiting for a virtual machine to initialize or JIT compilation to warm up.
- **Runtime independence:** The executable does not require installation of a language runtime on the target system, though it may depend on platform-specific frameworks (such as Windows API libraries or macOS system frameworks).
- **Direct OS access:** Code can call operating system APIs directly without abstraction layers, enabling fine-grained control over system resources.
- **Smaller deployment footprint:** A simple console application compiles to a few hundred kilobytes; even complex applications typically deploy smaller than equivalent .NET or Java applications with their runtime dependencies.

The Delphi compiler consists of several components:

- **DCC32.exe:** The 32-bit Windows compiler (Win32 target).
- **DCC64.exe:** The 64-bit Windows compiler (Win64 target).
- **DCCOSXARM64.exe and DCCIOSARM64.exe:** Compilers for macOS ARM and iOS ARM targets.
- **DCCOSX64.exe:** Compiler for macOS Intel target.
- **DCCILR32.exe and DCCILR64.exe:** Compilers for Linux 32-bit and 64-bit targets.
- **DCCARMW.exe:** Compiler for Android ARM targets.

Starting with RAD Studio 12.3, a 64-bit binary version of the Win32 and Win64 compilers became available, improving compilation performance for very large projects by reducing memory constraints [19]. Version 13 added a native Arm64EC compiler (DCCARM64.exe) for Windows on ARM [20].

Compilation is fast compared with many alternatives. A typical medium-sized application compiles in seconds rather than minutes. The IDE uses incremental compilation, rebuilding only units that have changed since the last build, which keeps development cycles tight even for large projects.

IDE Overview and Workspace Layout

The RAD Studio IDE is a comprehensive development environment that combines code editing, visual design, debugging, profiling, database tools, and project management in a single application. Version 13 introduced a 64-bit version of the IDE installed alongside the traditional 32-bit version, improving stability and performance with large projects [21].

Key workspace areas:

- **Code Editor:** The central editing area with syntax highlighting, code completion (Code Insight), refactoring tools, inline documentation, and error squiggles. Version 13 reintroduced Classic CodeInsight as an alternative to the newer autocomplete behavior for developers who prefer it [22].
- **Form Designer:** A visual canvas for designing VCL or FireMonkey forms with drag-and-drop controls, property editing, event wiring, and layout tools.
- **Object Inspector:** Displays properties and events of the currently selected component, allowing design-time configuration without writing code.
- **Project Manager:** Shows project structure including source files, units, packages, target platforms, and build configurations in a tree view.
- **Tool Palette:** A palette of available components organized by category (Standard, Additional, System, Data Access, etc.) for dragging onto forms.
- **Search Tool:** Version 13 added an enhanced IDE-wide search capability that indexes project files for faster navigation [23].
- **Output and Messages windows:** Display build output, compiler errors and warnings, and runtime messages.

The IDE supports multiple document tabs, dockable windows, customizable toolbars, keyboard shortcuts, and color themes. Productivity features include Go to Declaration, Find References, Rename Identifier, Extract Method, and other refactoring operations accessible via right-click context menus or keyboard shortcuts.

Project Groups, Projects, Units, and Source Organization

Understanding Delphi's project structure is essential before writing code. The hierarchy is:

- **Project Group (.groupproj):** An optional container that holds multiple related projects and defines build order dependencies between them. Useful for solutions containing an application, shared libraries, test projects, and installer projects.
- **Project (.dproj):** A single compilable unit such as a console application, VCL forms application, FireMonkey application, package, or DLL. Each project has its own configuration settings, target platforms, and output type.
- **Unit (.pas):** The fundamental code organization unit in Object Pascal. A unit contains declarations (types, variables, procedures, functions) organized into an interface section (public API) and an implementation section (private details). Every source file is a unit.
- **Program (.dpr):** The project source file containing the program directive that specifies which units to include and defines the application entry point.

A typical desktop application project structure:

```
MyApplication/
├── MyApplication.dproj          # Project file (IDE metadata)
├── MyApplication.dpr            # Program file (entry point)
├── UnitMain.pas                 # Main form unit
├── UnitMain.dfm                 # Form design file (VCL only)
├── UnitDataModule.pas           # Data access layer
├── UnitDataModule.dfm           # Data module design file
├── UnitModels.pas               # Domain model types
└── UnitServices.pas             # Business logic services
```

The `.dfm` (Design-time Form) files are binary or text representations of form layouts and component configurations. They are automatically generated and modified by the IDE when you design forms visually. Modern Delphi supports text-mode DFM files, which are more friendly to source control diff tools.

Build Configurations, Targets, and Conditional Compilation

Delphi projects support multiple build configurations and target platforms:

- **Configurations** define compiler options, optimization settings, debug information levels, and conditional defines. Common configurations are Debug (with full debugging symbols and no optimization) and Release (optimized with stripped debug information).
- **Target Platforms** specify which operating system and architecture to compile for. A single project can target Win32, Win64, macOS, iOS, Android, Linux, or Windows on ARM (13.1+), each potentially with its own configuration settings.

The combination of configuration and platform is called a "build target." The Project Manager displays available targets in a dropdown, and you select the active target before building.

Conditional compilation allows code to vary based on target platform, configuration, or custom symbols:

```
{$IFDEF MSWINDOWS}
  // Windows-specific code
{$ENDIF}

{$IFDEF POSIX}
  // macOS/Linux/Android/iOS code
{$ENDIF}

{$IFDEF CPUX64}
  // 64-bit specific code
{$ENDIF}

{$IFDEF DEBUG}
  // Debug-only code
{$ENDIF}
```

Common predefined conditional symbols include `MSWINDOWS`, `POSIX`, `MACOS`, `IOS`, `ANDROID`, `LINUX`, `CPU32BITS`, `CPUX64`, `CPUARM`, `DEBUG`, and version-specific symbols like `VER370` for RAD Studio 13. Conditional compilation is essential for cross-platform development but should be used judiciously to avoid fragmenting the codebase into unreadable conditional spaghetti.

Packages: Design-Time vs Runtime

Packages are a Delphi mechanism for compiling multiple units together into a single loadable module. They serve different purposes depending on context:

Design-time packages (.dpk with design-time components): Contain component implementations that appear in the IDE's Tool Palette at design time. When you install a third-party component library, it typically installs as a design-time package. The package registers components with the IDE so they can be dropped onto forms visually.

Runtime packages: Compiled units loaded dynamically at runtime rather than statically linked into the executable. Runtime packages enable:

- Code sharing between multiple applications without duplicating compiled code
- Hot-swapping of functionality by replacing package files without rebuilding dependent applications
- Reduced executable size when many applications share common libraries

However, runtime packages add complexity:

- Deployment must include all required package files (.bpl) alongside the executable
- Version mismatches between packages and applications cause runtime errors
- Debugging across package boundaries can be more difficult

For most applications, static linking (including units directly in the executable without packages) is simpler and more reliable. Runtime packages are appropriate for large component libraries, plugin architectures, or scenarios where code sharing across many applications justifies the added deployment complexity.

When Delphi Is a Strong Fit (and When It Is Not)

Choosing a technology involves tradeoffs. Understanding where Delphi excels helps you make informed decisions about whether it is appropriate for your project.

Delphi is particularly strong for:

- **Windows desktop business applications:** Data-intensive applications with rich user interfaces, grid-heavy reporting, and tight database integration. VCL provides mature, stable components for these scenarios [24].
- **Cross-platform desktop tools:** Applications that must run on Windows, macOS, and Linux from a single codebase. FireMonkey enables this with acceptable platform integration, though it lacks the polish of fully native UI toolkits on each platform [25].
- **Database-centric systems:** FireDAC's native drivers and dataset components make data access straightforward and performant. Applications built around relational databases benefit from Delphi's integrated data architecture.
- **Rapid prototyping and development:** The visual designer, component library, and fast compilation cycles enable quick iteration on UI and business logic.
- **Legacy application maintenance:** Thousands of existing production systems are written in Delphi. Maintaining or extending these systems is most efficiently done in Delphi rather than rewriting in another language.
- **Embedded and industrial applications:** Native executables with minimal runtime dependencies suit constrained environments, kiosks, manufacturing equipment, and medical devices.

Delphi is less suitable when:

- **Web application development is the primary goal:** While Delphi offers RAD Server for REST APIs and WebStencils for web UIs, the ecosystem is small compared with Node.js, Python, Ruby, Java, or PHP alternatives. Third-party frameworks like MVC Framework exist but lack the maturity and community support of mainstream web stacks.
- **Cloud-native microservice architectures are required:** Delphi can build REST services that run in containers, but tooling for service mesh integration, configuration management, distributed tracing, and other cloud-native concerns is not first-class.
- **Mobile development demands cutting-edge platform features:** FireMonkey supports iOS and Android but lags behind native Swift and Kotlin development in accessing the latest platform-specific UI components, animations, and hardware integrations. Apple's policy changes have also made iOS deployment more complex over time [26].

- **Heavy reliance on third-party libraries is expected:** The Delphi package ecosystem exists but is smaller than NuGet (C#), Maven/Central (Java), PyPI (Python), or npm (JavaScript). Many popular libraries in other ecosystems have no Delphi equivalents.
- **Team hiring is a constraint:** Finding experienced Delphi developers is harder than finding developers with C#, Java, Python, or JavaScript skills, especially for new hires without prior exposure to the ecosystem.

These assessments are practical observations, not value judgments. Many successful systems combine Delphi desktop clients with web APIs built in other languages. Delphi's strengths in native performance, productivity, and database integration remain relevant even in modern technology stacks. The key is matching the tool to the problem rather than forcing a single technology to solve everything.

Chapter Summary

This chapter established the context for modern Delphi development: RAD Studio 13 Florence as the reference platform, the edition landscape, supported target platforms and their constraints, the native compilation model that distinguishes Delphi from virtual-machine-based languages, IDE workspace layout, project structure with groups, projects, and units, build configurations and conditional compilation, package types and their tradeoffs, and practical guidance on when Delphi is an appropriate technology choice.

The next chapter moves from concepts to hands-on practice by walking through installation, creating different application types, building, running, and debugging code using the IDE workflow that you will use throughout development.

Chapter 2: Your First Applications: Tooling Workflow

This chapter gets you writing, building, running, and debugging Delphi code immediately. You will create console applications, VCL desktop applications, and FireMonkey cross-platform applications while learning the essential IDE operations: creating projects, editing code, building, running with the debugger, setting breakpoints, inspecting variables, and navigating project settings.

Installing RAD Studio and SDK Requirements

Before writing code, you must install RAD Studio. The installation process varies slightly by edition but follows a consistent pattern.

System requirements for RAD Studio 13 Florence:

- Windows 10 version 2004 or later (64-bit) as the development host operating system
- Minimum 8 GB RAM (16 GB recommended for comfortable development)
- At least 10 GB free disk space for base installation, more if you select all platform SDKs
- An active internet connection during installation for downloading SDK components

Installation steps:

1. Download the installer from the Embarcadero website or your license portal [27].
2. Run the installer and choose your edition (Community, Professional, Enterprise, or Architect).
3. Select installation components: Delphi language support is required; C++Builder is optional if you only develop in Object Pascal.

4. Choose target platforms to install SDKs for. For learning purposes, installing Windows targets (Win32 and Win64) is sufficient initially. Android, iOS, macOS, and Linux SDKs add significant disk space requirements and are needed only when you plan to deploy to those platforms.
5. Complete the installation and launch RAD Studio from the Start menu.

SDK considerations for cross-platform development:

- **Android:** Requires the Android SDK, NDK, and JDK. RAD Studio's installer can download these automatically. As of version 13.1, the toolchain targets Android API level 36 [28].
- **iOS:** Requires a macOS build server because Apple does not allow iOS code signing from Windows. RAD Studio communicates with the Mac over the network during builds and deployment. A licensed copy of Xcode must be installed on the Mac build server.
- **macOS desktop:** Also requires a macOS build server for the same code signing reasons.
- **Linux:** Does not require a separate build server; cross-compilation happens from Windows using included toolchains.

For this chapter's examples, Windows targets are sufficient. You can add other platform SDKs later when you reach the relevant chapters.

Creating a Console Application End to End

A console application is the simplest Delphi project type: no graphical interface, just code that runs in a command prompt window and produces text output. It is ideal for learning language syntax without UI framework complexity.

Creating the project:

1. Open RAD Studio.
2. Select File | New | Other (or press Ctrl+Shift+N).
3. In the New Items dialog, expand the "Multi-Device" or "Windows" category depending on your installation layout, then select "Console Application". Alternatively, in newer versions, look under "Delphi Projects" for "Console Application".

4. Click OK. RAD Studio creates a new project with a default program file.

The IDE opens with a code editor showing the generated skeleton:

```
program Project1;

{$APPTYPE CONSOLE}

uses
  System.SysUtils;

begin
  try
    // Add your code here
  except
    on E: Exception do
      Writeln(E.ClassName, ': ', E.Message);
  end;
end.
```

Let us create a meaningful example that demonstrates basic syntax. Replace the entire file contents with this code:

```
program HelloWorld;

{$APPTYPE CONSOLE}

uses
  System.SysUtils;

const
  GREETING = 'Hello from Delphi!';

var
  Name: string;
  Year: Integer;

begin
  try
    Writeln(GREETING);
    Writeln('Current year: ', YearOf(Now));

    Write('Enter your name: ');
    Readln(Name);

    if Name <> '' then
      Writeln('Welcome, ', Name, '!')
```

```
25      else
26        Writeln('Welcome, anonymous developer!');
27
28      Writeln;
29      Writeln('Press Enter to exit...');
30      Readln;
31    except
32      on E: Exception do
33        Writeln(E.ClassName, ': ', E.Message);
34    end;
35  end.
```

This example introduces several concepts:

- `program` declares a console application entry point.
- `{$APPTYPE CONSOLE}` is a compiler directive telling the linker to create a console subsystem executable rather than a GUI application.
- The `uses` clause imports units whose declarations you want to use; `System.SysUtils` provides utility functions like `YearOf` and `Now`.
- `const` declares compile-time constants.
- `var` declares runtime variables.
- `Writeln` writes text to the console with a trailing newline; `Write` writes without a newline.
- `Readln` reads a line of input from the console.
- The `try..except` block catches and reports any unexpected exceptions, a defensive pattern recommended for all Delphi applications.

Building and running:

1. Save the project by selecting File | Save All (Ctrl+Shift+S). Choose a directory and accept the default names or rename the project to "HelloWorld".
2. Build the project by selecting Project | Build HelloWorld (F9 also builds if no errors exist, otherwise use Ctrl+F9 for Build without running).
3. Watch the Message window at the bottom of the IDE. It shows compilation progress and any errors or warnings. A successful build ends with a message like "Build successfully completed."
4. Run the application by pressing F9 or selecting Run | Run. A console window opens, displays the greeting, prompts for your name, and waits for input.

The executable file is created in the project directory under a subfolder matching the active target platform and configuration, such as `Win64\Debug\HelloWorld.exe`.

Creating a VCL Desktop Application

VCL (Visual Component Library) is Delphi's Windows-only UI framework. It provides native-looking controls, mature data-aware components, and decades of refinement for building desktop applications.

Creating the project:

1. Select File | New | VCL Forms Application - Delphi.
2. RAD Studio creates a project with a main form, opens the Form Designer showing a blank form, and displays the Object Inspector on the right side.

The generated code looks like this:

```
unit Unit1;

interface

uses
  Winapi.Windows, Winapi.Messages, System.SysUtils, System.Variants,
  System.Classes, Vcl.Graphics, Vcl.Controls, Vcl.Forms, Vcl.Dialogs;

type
  TForm1 = class(TForm)
    procedure FormCreate(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;

var
  Form1: TForm1;

implementation

{$R *.dfm}

procedure TForm1.FormCreate(Sender: TObject);
begin
end;

end.
```

Key observations:

- The unit declares a class `TForm1` that inherits from `TForm`, the base class for all VCL forms.
- The `FormCreate` method is an event handler called when the form is created at runtime.
- The `{$R *.dfm}` directive links the form's design-time resource file (Unit1.dfm) containing control layout information.
- Visibility sections (`private`, `public`) control access to class members, a fundamental OOP concept covered in depth later.

Building a simple interactive application:

Let us create a form with a button that counts clicks and displays the count. This demonstrates component placement, property setting, event handling, and variable persistence.

1. With the form open in the designer, select the Button component from the Tool Palette's "Standard" page and click on the form to place it.
2. In the Object Inspector, change the button's `Name` property to `btnCount` and its `Caption` property to "Click Me".
3. Add a Label component from the Standard page, place it above the button, set its `Name` to `lblCount`, and its `Caption` to "Count: 0".
4. Double-click the button to create an event handler for its `OnClick` event. The IDE generates a method stub and opens the code editor.

Replace the unit with this complete code:

```
unit UnitMain;

interface

uses
  Winapi.Windows, Winapi.Messages, System.SysUtils, System.Variants,
  System.Classes, Vcl.Graphics, Vcl.Controls, Vcl.Forms, Vcl.Dialogs,
  Vcl.StdCtrls;

type
  TFormMain = class(TForm)
    btnCount: TButton;
    lblCount: TLabel;
    procedure btnCountClick(Sender: TObject);
    procedure FormCreate(Sender: TObject);
  private
```

```
    FClickCount: Integer;
  public
    { Public declarations }
  end;

var
  FormMain: TFormMain;

implementation

{$R *.dfm}

procedure TFormMain.FormCreate(Sender: TObject);
begin
  FClickCount := 0;
  Caption := 'VCL Counter Application';
end;

procedure TFormMain.btnCountClick(Sender: TObject);
begin
  Inc(FClickCount);
  lblCount.Caption := Format('Count: %d', [FClickCount]);
end;

end.
```

Also update the program file (Unit1.dpr or similar) to reference the renamed form:

```
program VCLCounter;

uses
  Vcl.Forms,
  UnitMain in 'UnitMain.pas' {FormMain};

{$R *.res}

begin
  Application.Initialize;
  Application.MainFormOnTaskbar := True;
  Application.CreateForm(TFormMain, FormMain);
  Application.Run;
end.
```

Key concepts demonstrated:

- `FClickCount` is a private field (prefixed with F by convention) that persists across button clicks because it belongs to the form instance.

- `Inc` is a built-in routine that increments an integer variable by one.
- `Format` creates formatted strings using placeholders like `%d` for integers.
- The program file uses `Application.CreateForm` to instantiate the main form and `Application.Run` to start the message loop that processes user interactions.

Save all files and press F9 to run. Click the button several times and observe the count incrementing. This is your first VCL application, and it demonstrates the basic workflow: design the form visually, wire up event handlers in code, build, and run.

Creating a FireMonkey Cross-Platform Application

FireMonkey (FMX) is Delphi's cross-platform UI framework supporting Windows, macOS, Linux, iOS, and Android from a single codebase. Unlike VCL, which wraps native OS controls, FMX renders its own controls using hardware-accelerated graphics, enabling visual consistency across platforms at the cost of slightly different appearance than fully native applications.

Creating the project:

1. Select File | New | FireMonkey Desktop Application - Delphi (for a desktop-focused app) or FireMonkey Mobile Application - Delphi (for mobile-first layout).
2. RAD Studio creates a project with a blank FireMonkey form and opens the FMX Form Designer.

The generated unit differs noticeably from VCL:

```
unit Unit1;

interface

uses
  System.SysUtils, System.Types, System.UITypes, System.Classes,
  System Variants, FMX.Types, FMX.Controls, FMX.Forms, FMX.Graphics,
  FMX.Dialogs;

type
  TForm1 = class(TForm)
  private
    { Private declarations }
  public
    { Public declarations }
  end;

var
  Form1: TForm1;

implementation

{$R *.fmx}

end.
```

Key differences from VCL:

- FMX units (`FMX.Types`, `FMX.Controls`, etc.) replace VCL units.
- The form resource directive uses `.fmx` instead of `.dfm`.
- FMX forms inherit from `FMX.Forms.TForm` rather than `Vcl.Forms.TForm`.

Building a simple FireMonkey application:

Let us create a similar counter application using FireMonkey components.

1. Place a `TButton` from the Tool Palette's "Standard" page onto the form.
2. In the Object Inspector, set its `Name` to `btnCount`, `Text` to "Click Me" (note: FMX uses `Text` where VCL uses `Caption`).
3. Add a `TLabel`, set its `Name` to `lblCount`, and `Text` to "Count: 0".
4. Double-click the button to create an `OnClick` handler.

Replace the unit with this complete code:

```
unit UnitMain;

interface

uses
  System.SysUtils, System.Types, System.UITypes, System.Classes,
  System.Variants, FMX.Types, FMX.Controls, FMX.Forms, FMX.Graphics,
  FMX.Dialogs, FMX.StdCtrls;

type
  TFormMain = class(TForm)
    btnCount: TButton;
    lblCount: TLabel;
    procedure btnCountClick(Sender: TObject);
    procedure FormCreate(Sender: TObject);
  private
    FClickCount: Integer;
  public
    { Public declarations }
  end;

var
  FormMain: TFormMain;

implementation

{$R *.fmx}

procedure TFormMain.FormCreate(Sender: TObject);
begin
  FClickCount := 0;
  Caption := 'FMX Counter Application';
end;

procedure TFormMain.btnCountClick(Sender: TObject);
begin
  Inc(FClickCount);
  lblCount.Text := Format('Count: %d', [FClickCount]);
end;

end.
```

Update the program file similarly to the VCL example, referencing `FMX.Forms` instead of `Vcl.Forms`.

Run the application with F9. The visual appearance differs from the VCL version because FMX renders its own controls rather than using Windows native controls. If you later add macOS or Linux as target platforms and build for those systems, the same code produces a working application on each

platform, though layout adjustments may be needed for different screen sizes and input methods.

The Build Process Explained Step by Step

Understanding what happens when you press F9 clarifies many aspects of Delphi development.

1. **Dependency analysis:** The IDE's build system (MSBuild) examines all units in the project and determines which ones have changed since the last successful build. It also checks transitive dependencies: if UnitA uses UnitB, and UnitB changed, then UnitA must be rebuilt even if UnitA itself did not change.
2. **Compilation:** Each unit that needs rebuilding is compiled by the appropriate compiler (DCC32 for Win32, DCC64 for Win64, etc.). The compiler translates Object Pascal source code into object files (.dcu for Delphi Compiled Units), which contain machine code and type metadata.
3. **Linking:** The linker combines all object files, along with required runtime library units and resource files (such as .dfm or .fmx form resources), into a single executable (.exe on Windows, .app bundle on macOS, etc.).
4. **Post-build steps:** If configured, post-build events run after linking completes. These might include code signing, file copying, or running external tools.

The Message window shows each step's progress. Errors stop the build immediately with a description and source location. Warnings allow the build to continue but flag potential issues. Hints provide informational suggestions. Double-clicking an error in the Message window opens the source file at the problematic line.

For large projects, incremental compilation keeps rebuild times short because only changed units and their dependents are recompiled. A full rebuild (Project | Build, or Ctrl+F9) forces recompilation of all units regardless of change status, useful when you suspect stale compiled files or after changing compiler options.

Running and Debugging: Breakpoints, Watches, Call Stack

The RAD Studio debugger is one of Delphi's strongest productivity tools. It allows you to pause execution, inspect state, modify variables, and step through code line by line.

Setting breakpoints:

A breakpoint pauses program execution when it reaches a specific line of code. To set one:

- Click in the gray margin to the left of the line number in the code editor, or
- Place the cursor on the line and press F5 (Toggle Breakpoint), or
- Right-click the line and select Toggle Breakpoint.

A red dot appears in the margin indicating the breakpoint is active.

Running under the debugger:

Press F9 with breakpoints set. When execution hits a breakpoint, the IDE enters break mode:

- The current line is highlighted in yellow.
- The Call Stack window shows the sequence of procedure calls that led to the current point.
- The Locals window displays all local variables in the current scope with their values.
- You can hover over any variable in the code to see its current value in a tooltip.

Stepping through code:

Once paused at a breakpoint, use these commands:

- **F7 (Step Over):** Execute the current line and pause at the next line in the same procedure. If the current line calls another procedure, that procedure runs completely without pausing inside it.
- **F8 (Step Into):** Execute the current line. If it calls another procedure, pause at the first line inside that procedure instead of skipping over it.

- **Shift+F8 (Step Out):** Execute until the current procedure returns to its caller, then pause.
- **F9 (Run):** Resume execution until the next breakpoint or program completion.

Watches:

A watch lets you monitor a specific expression continuously while debugging. To add one:

1. Select the expression in the code editor.
2. Right-click and select Add Watch, or drag it into the Watches window.

The Watches window updates the expression's value whenever execution pauses, even if the watched variable is not in the current scope (as long as it is accessible).

Inspecting and modifying values:

In break mode, you can:

- View any accessible variable by hovering over it or checking the Locals/Watch windows.
- Modify variable values directly in the Locals or Watches windows by double-clicking the value field and typing a new value. The change takes effect immediately when you resume execution.
- Evaluate arbitrary expressions using the Evaluate/Modify dialog (Ctrl+F5), which lets you type an expression and see its result without changing code.

Call stack inspection:

The Call Stack window shows every active procedure call from the current point back to the entry point. Double-clicking any frame in the call stack jumps the editor to that source location, allowing you to inspect state at any level of the call hierarchy. This is invaluable for understanding how execution reached a particular point, especially when debugging complex interactions or unexpected behavior.

Inspecting Variables and Evaluating Expressions

Beyond basic breakpoint inspection, Delphi's debugger supports advanced variable examination:

- **Object inspection:** Click the expand arrow next to an object reference to see all its published and visible fields and properties.
- **Array and collection inspection:** Expand arrays, dynamic arrays, lists, and dictionaries to view their contents element by element.
- **String inspection:** Long strings display truncated in the Locals window but show fully when you hover or expand them.
- **Memory view:** The Memory window (View | Debug Windows | Memory) lets you examine raw memory at any address, useful for low-level debugging of pointer operations or buffer issues.

The Evaluate/Modify dialog (Ctrl+F5) is particularly powerful:

- Type any valid expression using currently accessible variables and functions.
- The debugger evaluates it in the current execution context and displays the result.
- You can also assign a new value to a variable by typing an assignment expression like `MyVar := 42`.

This capability lets you test hypotheses about code behavior without modifying source files, adding temporary logging statements, or rebuilding.

Project Options and Key Settings

Project options control compilation behavior, application appearance, and deployment settings. Access them via Project | Options (Alt+F11).

Important option categories:

- **Compiler:** Controls optimization level (`{$OPTIMIZATION ON/OFF}`), debug information generation, range checking (`{$R+}`), overflow checking (`{$Q+}`), stack frames (`{$+D}`), and warning/hint levels. Debug builds typically have checks enabled and optimization off; release builds optimize aggressively and disable most checks for performance.

- **Linker:** Controls output file name, subsystem (console or GUI), entry point, and whether to generate map files showing memory layout.
- **Application:** Sets the application title, main form, icon, version info, and high-DPI awareness settings critical for modern Windows displays.
- **Version Info:** Defines fields like File Version, Product Version, Company Name, and Legal Copyright that appear in Windows file properties and are used by deployment tools.
- **Target Platforms:** Manages which platforms the project can build for and allows platform-specific overrides of compiler options, conditional defines, and resource files.
- **Build Events:** Scripts or commands that run before or after building, useful for automated tasks like copying files, running tests, or triggering deployments.

For new projects, most defaults are appropriate. As your application grows, you will adjust optimization settings for release builds, configure version info for deployment tracking, and possibly add build events for automation.

Navigating Code: Go to Declaration, Find References, Quick Fix

Efficient code navigation is essential in any non-trivial project. RAD Studio provides several tools:

- **Go to Declaration (Ctrl+Click or F12):** Jump from a symbol usage to where it is declared. Works for types, variables, procedures, functions, properties, and constants.
- **Find References (Shift+F12):** Shows all locations in the project where a symbol is used. Critical before renaming or removing code to understand impact.
- **Quick Fix (Ctrl+.) :** When the cursor is on code with an error, warning, or improvement opportunity, Quick Fix suggests automatic corrections: adding missing `uses` clauses, fixing type mismatches, extracting variables, converting loops, and more.
- **Navigate Back/Forward (Alt+F12 / Shift+Alt+F12):** After using Go to Declaration or similar navigation, return to your previous location quickly.

- **Unit Outline (Ctrl+U):** Shows a collapsible tree of all types, procedures, and functions in the current unit for quick navigation within large files.

These tools reduce time spent searching through files manually and help you understand code structure without memorizing every detail. They become indispensable as projects grow beyond a few units.

Chapter Summary

This chapter moved from theory to practice by walking through the complete workflow of creating, building, running, and debugging Delphi applications. You created console, VCL, and FireMonkey applications; learned how compilation and linking work; used breakpoints, watches, and stepping commands in the debugger; explored project options; and practiced code navigation techniques.

These tooling skills form the foundation for everything that follows. The next chapters dive into Object Pascal language fundamentals: syntax, types, control flow, procedures, functions and the constructs you will use in every Delphi program you write.

Chapter 3: Object Pascal Language Fundamentals, Part I

This chapter covers the core syntax and semantics of Object Pascal: unit structure, constants, variables, scope rules, primitive types, strings and Unicode handling, enumerations, arrays, records, sets, and type aliases. Every concept is explained with complete examples that compile and run.

Program Structure: Units, Interfaces, Implementations

Delphi organizes code into units. A unit is a compilation module containing declarations (types, variables, procedures, functions, classes) split into two sections: interface and implementation. The interface declares what other units can use; the implementation contains the actual code and private helpers.

A basic unit structure:

```
unit UnitName;

interface

uses
  UnitA, UnitB;   // Units whose declarations this unit exposes to its callers

type
  TMyType = Integer;

const
  PublicConstant = 42;

var
  PublicVariable: Integer;

procedure PublicProcedure;
function PublicFunction(X: Integer): Integer;

implementation

```

```
22  uses
23    UnitC, UnitD;   // Units used only internally, not exposed to callers
24
25  const
26    PrivateConstant = 99;
27
28  var
29    PrivateVariable: Integer;
30
31  procedure HelperRoutine;   // Not visible outside this unit
32
33  procedure PublicProcedure;
34  begin
35    Writeln('Hello');
36  end;
37
38  function PublicFunction(X: Integer): Integer;
39  begin
40    Result := X * 2;
41  end;
42
43  procedure HelperRoutine;
44  begin
45    PrivateVariable := 10;
46  end;
47
48  end.
```

Key rules:

- Everything in the `interface` section is publicly visible to any unit that lists this unit in its `uses` clause.
- Everything in the `implementation` section (except items explicitly declared in the interface) is private to this unit. Other units cannot see or call implementation-only routines or access implementation-only variables.
- The `uses` clause in the interface section transitively exposes those units to callers. If UnitX uses UnitY in its interface, any unit using UnitX automatically has access to UnitY's interface declarations without listing UnitY explicitly. This is convenient but can create hidden dependencies; prefer placing units used only internally in the implementation `uses` clause to minimize coupling.
- The unit ends with a final `end.` (with a period), distinguishing it from the `end;` that terminates blocks within the unit.

A program file (.dpr) is a special kind of unit that defines the application entry point:

```
program MyApp;

uses
  System.SysUtils,
  MyUnit in 'MyUnit.pas';

begin
  try
    MyUnit.PublicProcedure;
  except
    on E: Exception do
      Writeln(E.ClassName, ': ', E.Message);
  end;
end.
```

The `in 'filename.pas'` clause associates the unit name with its source file. The IDE manages these associations automatically when you add files to a project.

Constants, Variables, and Scope Rules

Constants are immutable values known at compile time (unless declared as typed constants with runtime initialization):

```
const
  MaxRetries = 3;                  // Untyped constant, type inferred from usage
  PiValue: Double = 3.14159265358979; // Typed constant
  DefaultTimeout = 5000;             // Milliseconds
```

Untyped constants have no fixed type until used; the compiler chooses the most appropriate type at each usage site. Typed constants always have the declared type. For clarity and to avoid subtle type inference issues, prefer typed constants in production code.

Variables hold mutable runtime values:

```
var
  Count: Integer;
  Name: string;
  IsActive: Boolean := True;   // Variables can have initializers
```

Variables are uninitialized by default (except when given an explicit initializer). Reading an uninitialized variable produces undefined behavior, though the compiler may warn about it depending on settings. Always initialize variables before reading them.

Scope rules determine where identifiers are visible:

- **Global scope:** Variables and constants declared at unit level (outside any procedure, function, or class) are accessible throughout the unit from any routine.
- **Local scope:** Variables declared inside a procedure, function, or begin..end block are visible only within that block.
- **Nested scopes:** Inner blocks can declare variables with the same name as outer scopes; the inner declaration shadows the outer one within its scope.

```
var
  GlobalCount: Integer = 0;   // Visible throughout the unit

procedure DemoScope;
var
  LocalCount: Integer;        // Visible only in DemoScope
begin
  LocalCount := 10;
  GlobalCount := 20;          // Can access global variable

  if True then
  begin
    var BlockCount: Integer := 5;   // Visible only in this if block
    Writeln(BlockCount);            // OK: 5
  end;
  // Writeln(BlockCount);           // Error: BlockCount not visible here
end;
```

Modern Delphi (since version 10 Seattle) supports local variable declarations anywhere a statement is allowed, using the `var` keyword inline. This reduces the need to declare all variables at the top of a block and keeps declarations close to their usage:

```
procedure ProcessData;
begin
  var Input := ReadInput;      // Declared where first needed
  var Result := Transform(Input);
  WriteOutput(Result);
end;
```

This style improves readability by reducing distance between declaration and use while maintaining the same scoping semantics.

Primitive Types: Integers, Floats, Booleans, Characters

Delphi provides a rich set of primitive types with explicit sizes and ranges. Choosing the right type matters for correctness, performance, and cross-platform compatibility.

Integer types:

Type	Size (bits)	Range	Notes
ShortInt	8	-128..127	Signed byte
SmallInt	16	-32768..32767	Signed word
Integer	32 (Win32/Win64) or 64 (POSIX 64-bit)	Platform-dependent	Use NativeInt for cross-platform 32/64-bit code
LongInt	32 (Windows) or 64 (POSIX 64-bit)	Same as Integer on Windows	Historical type, prefer Integer or NativeInt
Int64	64	$-2^{63..2}63-1$	Always 64-bit regardless of platform
Byte	8	0..255	Unsigned byte
Word	16	0..65535	Unsigned word
Cardinal	32 (Windows) or 64 (POSIX 64-bit)	Same size as Integer	Use NativeUInt for cross-platform
LongWord	32 (Windows) or 64 (POSIX 64-bit)	Same as Cardinal on Windows	Historical type

Type	Size (bits)	Range	Notes
UInt64	64	0..2^64-1	Always 64-bit unsigned
NativeInt	32 or 64	Matches pointer size	Use for sizes, counts, and indices in cross-platform code
NativeUInt	32 or 64	Matches pointer size	Unsigned version of NativeInt

Critical note: On 64-bit POSIX platforms (macOS, Linux), `LongInt`, `LongWord`, `Integer`, and `Cardinal` are 64-bit types to match the C ABI. On Windows (both 32-bit and 64-bit), they remain 32-bit for backward compatibility [29]. For code that must work correctly across all platforms, use `NativeInt` and `NativeUInt` instead of `Integer` and `Cardinal` when you need a type matching the pointer width.

Floating-point types:

Type	Size (bits)	Notes
Single	32	IEEE 754 single precision
Double	64	IEEE 754 double precision, default float type
Extended	80 (x86) or 64 (x64/ARM)	Variable size; on Win64 and ARM platforms it maps to Double
Comp	64	Integer stored in extended format, legacy type
Currency	64	Fixed-point with 4 decimal places, good for financial calculations

For most applications, `Double` is the appropriate floating-point type. Avoid `Extended` in cross-platform code because its size and precision vary by plat-

form. Use `Currency` for monetary values to avoid floating-point rounding issues, or use integer arithmetic with explicit decimal scaling.

Boolean types:

Type	Size	Notes
Boolean	8 bits	Standard boolean, True/False
ByteBool	8 bits	Legacy Windows API compatibility
WordBool	16 bits	Legacy Windows API compatibility
LongBool	32 bits	Legacy compatibility

Use `Boolean` for all new code. The other types exist only for interoperability with older Windows APIs and should not appear in application logic.

Character type:

The `Char` type in modern Delphi (since version 2009) is a 16-bit Unicode character (UTF-16 code unit), equivalent to the Windows `WCHAR` type [30]. A single `Char` represents one UTF-16 code unit, which may be half of a surrogate pair for characters outside the Basic Multilingual Plane.

```
var
  C: Char;
begin
  C := 'A';           // ASCII character
  C := #65;           // Same character via ordinal value
  C := #$0041;        // Hex notation, same result
  C := #$03B1;        // Greek letter alpha
end;
```

For byte-oriented character data (such as reading binary files or working with specific encodings), use `AnsiChar` (8-bit) or explicit byte arrays rather than `Char`.

Strings and Unicode: AnsiString vs UnicodeString

Understanding string types in modern Delphi is essential because the language underwent a fundamental change with version 2009 when strings became Unicode by default.

UnicodeString (the default `string` type):

Since Delphi 2009, the unqualified type name `string` refers to `UnicodeString`, a reference-counted, dynamically allocated string of UTF-16 characters [31]. Key properties:

- Each character is 2 bytes (one UTF-16 code unit).
- Strings are reference-counted: assigning a string to another variable increments the reference count; when the count reaches zero, memory is freed automatically.
- Copy-on-write semantics: when a string with multiple references is modified, the runtime creates a private copy for the modifying reference.
- `Length(S)` returns the number of characters (UTF-16 code units), not bytes.
- Indexing starts at 1, not 0: `S[1]` is the first character.

```
var
  S1, S2: string;
begin
  S1 := 'Hello';
  S2 := S1;           // Reference count of underlying data becomes 2
  S2 := S2 + ' World';// Copy-on-write: S2 gets its own copy, S1 unchanged
  Writeln(S1);        // 'Hello'
  Writeln(S2);        // 'Hello World'
end;
```

AnsiString:

`AnsiString` is an 8-bit string using the system default code page (or a specified code page for typed AnsiString variants like `ANSISTRING`). It exists primarily for:

- Interoperability with APIs that expect ANSI strings.
- Processing data in specific encodings where byte-level control matters.
- Legacy code migration scenarios.

```
var
  AS: AnsiString;
begin
  AS := 'Hello';      // Stored as ANSI bytes in system code page
  Writeln(Length(AS)); // Number of bytes, which equals characters for ASCII
end;
```

UTF8String:

`UTF8String` is a UTF-8 encoded string type. It is less commonly used directly because `string` (UnicodeString) is the standard internal representation and conversion utilities handle UTF-8 encoding at boundaries:

```
uses
  System.SysUtils, System.Classes;

var
  UnicodeS: string;
  Utf8Bytes: TBytes;
begin
  UnicodeS := 'Hello World';
  Utf8Bytes := TEncoding.UTF8.GetBytes(UnicodeS);   // Convert to UTF-8 bytes
  UnicodeS := TEncoding.UTF8.GetString(Utf8Bytes);  // Convert back
end;
```

Best practices for strings:

1. Use `string` (UnicodeString) as the default string type for all application logic [32].
2. Convert to/from specific encodings explicitly at system boundaries: file I/O, network communication, database access, and external API calls.
3. Avoid using `string` as a byte buffer; use `TBytes` or `AnsiString` when you need raw byte manipulation.
4. Be aware that `Length` on a UnicodeString returns character count (UTF-16 code units), which may differ from visual grapheme count for emoji and other composed characters.

Enumerations and Subranges

Enumerations define named integer constants representing a fixed set of values:

```
type
  TDayOfWeek = (moMonday, tuTuesday, weWednesday, thThursday,
                frFriday, saSaturday, suSunday);

  TColor = (clRed, clGreen, clBlue, clYellow);

  TLogLevel = (llDebug, llInfo, llWarning, llError, llFatal);
```

Enumeration values are ordinally typed: each successive value has an ordinal one greater than the previous, starting at 0 by default. You can specify explicit ordinals:

```
type
  HTTPStatusCode = (
    scOK = 200,
    scNotFound = 404,
    scServerError = 500
  );
```

Enumerations support ordinal operations:

```
var
  Day: TDayOfWeek;
begin
  Day := moMonday;
  Writeln(Ord(Day));           // 0
  Writeln(Succ(Day));          // tuTuesday
  Writeln(Pred(suSunday));     // saSaturday
  Writeln(Day < frFriday);     // True
end;
```

Modern Delphi allows methods on enumerations via type helpers (covered in Chapter 4), enabling extension without modifying the original type.

Subranges define a restricted range of an ordinal type:

```
type
  TDigit = 0..9;
  TLetterGrade = 'A'..'F';
  TMonth = 1..12;
```

Subrange types provide compile-time safety: the compiler warns or errors if you assign a value outside the declared range (depending on range-checking settings):

```
var
  Month: TMonth;
begin
  Month := 6;      // OK
  Month := 13;     // Error or runtime range check violation
end;
```

Use subrange types when a variable should only hold values within a specific range. They document intent and enable the compiler to catch errors that would otherwise manifest as subtle bugs at runtime.

Arrays: Static, Dynamic, Open Array Parameters

Delphi supports several array types with different semantics and use cases.

Static arrays have a fixed size known at compile time:

```
var
  DaysInMonth: array[1..12] of Integer = (31, 28, 31, 30, 31, 30,
                                          31, 31, 30, 31, 30, 31);
  Buffer: array[0..255] of Byte;
  Matrix: array[0..9, 0..9] of Double;   // Multi-dimensional
begin
  Writeln(DaysInMonth[1]);    // 31 (January)
  Buffer[0] := 42;
  Matrix[3][5] := 3.14;
end;
```

Static arrays are value types: assigning one to another copies all elements. They are appropriate when the size is truly fixed and small, such as lookup tables or fixed-size buffers. For larger or variable-sized collections, prefer dynamic arrays or generic collections from `System.Generics.Collections`.

Dynamic arrays allocate memory at runtime and can change size:

```
var
  Numbers: array of Integer;
begin
  SetLength(Numbers, 10);    // Allocate 10 elements (indices 0..9)
  Numbers[0] := 42;
  Numbers[9] := 99;

  SetLength(Numbers, 20);    // Resize to 20 elements, preserving existing data
  Numbers[15] := 77;

  // Multi-dimensional dynamic arrays
  var Grid: array of array of Double;
  SetLength(Grid, 5, 5);     // 5x5 grid
  Grid[2][3] := 1.23;
end;
```

Dynamic arrays are reference types with reference counting and copy-on-write semantics similar to strings. `SetLength` reallocates the underlying memory when needed. When all references go out of scope, memory is freed automatically.

Key considerations:

- Dynamic arrays are zero-based by default.
- Resizing a large dynamic array repeatedly in a loop is inefficient because each resize may reallocate and copy data. Pre-allocate to the expected final size when possible.
- For collections of objects or records where you need sorting, searching, or other operations, prefer generic collections (`TList<T>`, `TDictionary<K,V>`) from `System.Generics.Collections` over raw dynamic arrays.

Open array parameters allow routines to accept arrays of any size:

```
function SumIntegers(const Values: array of Integer): Int64;
var
  I: Integer;
begin
  Result := 0;
  for I := Low(Values) to High(Values) do
    Result := Result + Values[I];
end;

procedure PrintArray(const Items: array of string);
var
  I: Integer;
begin
  for I := Low(Items) to High(Items) do
    Writeln(Items[I]);
end;

var
  StaticArr: array[1..5] of Integer = (10, 20, 30, 40, 50);
  DynamicArr: array of Integer;
begin
  SetLength(DynamicArr, 4);
  DynamicArr[0] := 1;
  DynamicArr[1] := 2;
  DynamicArr[2] = 3;
  DynamicArr[3] := 4;

  Writeln(SumIntegers(StaticArr));    // 150
  Writeln(SumIntegers(DynamicArr));   // 10
  Writeln(SumIntegers([5, 10, 15]));  // 30 (array constructor)
end;
```

Open array parameters are declared with `array of Type` in the parameter list (without a size specifier). They can accept static arrays, dynamic arrays, or array constructors (`[a, b, c]`). Inside the routine, use `Low` and `High` to determine bounds rather than assuming zero-based indexing.

Records: Basic Syntax, Methods, and Operators

Records group related fields into a single composite type. They are value types (copied on assignment) and traditionally had no methods, but modern Delphi extends records significantly.

Basic record syntax:

```
type
  TPoint = record
    X, Y: Integer;
  end;

  TPerson = record
    Name: string;
    Age: Integer;
    IsActive: Boolean;
  end;

var
  P: TPoint;
  Person: TPerson;
begin
  P.X := 10;
  P.Y := 20;

  Person.Name := 'Alice';
  Person.Age := 30;
  Person.IsActive := True;
end;
```

Records can be initialized using record constructors (special class functions named `Create`):

```
type
  TPoint = record
    X, Y: Integer;

    class function Create(const AX, AY: Integer): TPoint; static;
  end;

class function TPoint.Create(const AX, AY: Integer): TPoint;
begin
  Result.X := AX;
  Result.Y := AY;
end;

var
  P: TPoint;
begin
  P := TPoint.Create(10, 20);
end;
```

Record methods (available since Delphi 2005) allow behavior encapsulation with data:

```
type
  TRectangle = record
    Left, Top, Right, Bottom: Integer;

    function Width: Integer; inline;
    function Height: Integer; inline;
    function Contains(const Point: TPoint): Boolean;
    procedure Inflate(const ADelta: Integer);
  end;

function TRectangle.Width: Integer;
begin
  Result := Right - Left;
end;

function TRectangle.Height: Integer;
begin
  Result := Bottom - Top;
end;

function TRectangle.Contains(const Point: TPoint): Boolean;
begin
  Result := (Point.X >= Left) and (Point.X < Right) and
            (Point.Y >= Top) and (Point.Y < Bottom);
end;

procedure TRectangle.Inflate(const ADelta: Integer);
begin
  Dec(Left, ADelta);
  Dec(Top, ADelta);
  Inc(Right, ADelta);
  Inc(Bottom, ADelta);
end;
```

The `inline` directive hints to the compiler that it should expand the method call inline rather than generating a function call, improving performance for small methods. The compiler may ignore this hint.

Record operators (available since Delphi 2009) allow overloading operators for record types:

```
type
  TVector2D = record
    X, Y: Double;

    class operator Add(const A, B: TVector2D): TVector2D; static;
    class operator Subtract(const A, B: TVector2D): TVector2D; static;
    class operator Multiply(const A: TVector2D; const B: Double): TVector2D;
    ↪  static;
    class operator Equal(const A, B: TVector2D): Boolean; static;
    class operator NotEqual(const A, B: TVector2D): Boolean; static;
  end;

class operator TVector2D.Add(const A, B: TVector2D): TVector2D;
begin
  Result.X := A.X + B.X;
  Result.Y := A.Y + B.Y;
end;

class operator TVector2D.Subtract(const A, B: TVector2D): TVector2D;
begin
  Result.X := A.X - B.X;
  Result.Y := A.Y - B.Y;
end;

class operator TVector2D.Multiply(const A: TVector2D; const B: Double):
↪  TVector2D;
begin
  Result.X := A.X * B;
  Result.Y := A.Y * B;
end;

class operator TVector2D.Equal(const A, B: TVector2D): Boolean;
begin
  Result := (A.X = B.X) and (A.Y = B.Y);
end;

class operator TVector2D.NotEqual(const A, B: TVector2D): Boolean;
begin
  Result := not (A = B);
end;

var
  V1, V2, V3: TVector2D;
begin
  V1.X := 1.0; V1.Y := 2.0;
  V2.X := 3.0; V2.Y := 4.0;
  V3 := V1 + V2;              // Uses class operator Add
  Writeln(V3.X, ', ', V3.Y);  // 4, 6
  V3 := V1 * 2.0;             // Uses class operator Multiply
end;
```

Class operators are declared with the `class operator` keyword and must be `static`. They enable records to behave like built-in types with natural syntax for common operations.

Records are appropriate when:

- You need a lightweight, value-type container for related data.
- Copy semantics are desirable (modifying a copy does not affect the original).
- Performance matters and you want to avoid heap allocation overhead of classes.

Classes are more appropriate when:

- You need polymorphism through inheritance or interfaces.
- Reference semantics are desired (multiple variables sharing the same instance).
- The type requires complex lifetime management or integration with Delphi's object ownership model.

Sets and Their Practical Uses and Limits

Sets in Object Pascal represent collections of values from an ordinal type where each value can appear at most once. They support efficient membership testing, union, intersection, and difference operations.

```
type
  TDayOfWeek = (moMonday, tuTuesday, weWednesday, thThursday,
                frFriday, saSaturday, suSunday);

  TWorkDays = set of TDayOfWeek;

var
  WorkWeek: TWorkDays;
begin
  WorkWeek := [moMonday, tuTuesday, weWednesday, thThursday, frFriday];

  Writeln(moMonday in WorkWeek);   // True
  Writeln(saSaturday in WorkWeek); // False

```

```
  var Weekends: TWorkDays = [saSaturday, suSunday];
  var AllDays: TWorkDays = WorkWeek + Weekends;      // Union
  var Common: TWorkDays = WorkWeek * Weekends;       // Intersection (empty)
  var NonWork: TWorkDays = Weekends - WorkWeek;      // Difference
end;
```

Set operations:

- `+` : Union (elements in either set)
- `-` : Difference (elements in left set but not right)
- `*` : Intersection (elements in both sets)
- `in` : Membership test
- `=` : Equality comparison
- `<>`, `<`, `>`, `<=`, `>=` : Set comparison operators

Critical limitation: Sets can only contain ordinal types with a maximum of 256 distinct values (0..255). This means you cannot create sets of strings, floats, or large enumeration types. The underlying representation is a bit vector, which makes operations extremely fast but limits the element type range.

Sets are ideal for:

- Flags representing combinations of options from a small fixed set.
- Tracking membership in small categories (days of week, months, small enums).
- Bitmask-style operations where performance matters.

For larger or more flexible collections, use generic collections instead.

Type Aliases and Strong Typing

Type aliases create alternative names for existing types:

```
type
  TAge = Integer;
  TTemperature = Double;
  TUserName = string;
```

A type alias is fully compatible with the original type. You can assign an `Integer` to a variable of type `TAge` without casting, and vice versa:

```
var
  Age: TAge;
  N: Integer;
begin
  Age := 30;      // OK
  N := Age;       // Also OK, fully compatible
end;
```

Use type aliases to document intent: `TAge` communicates meaning that raw `Integer` does not, even though they are the same type at runtime.

Strong typing (distinct types) creates types that are not interchangeable with their base type, even if they share the same underlying representation:

```
type
  TCustomerId = type Integer;
  TOrderId = type Integer;

var
  CustomerID: TCustomerId;
  OrderID: TOrderId;
begin
  CustomerID := 123;
  // OrderID := CustomerID;    // Error: incompatible types
  OrderID := TOrderId(CustomerID);  // OK: explicit cast
end;
```

Strong typing prevents accidental mixing of semantically different values that happen to share a representation. The compiler enforces type safety, catching errors like passing a customer ID where an order ID is expected.

Use strong typing when:

- Multiple types share the same underlying representation but have distinct meanings.

- You want compile-time protection against confusing similar values.
- The cost of explicit casts is acceptable (it is usually minimal).

Type aliases and strong typing are simple techniques that significantly improve code clarity and safety with zero runtime overhead.

Chapter Summary

This chapter covered Object Pascal fundamentals: unit structure with interface/implementation sections, constants and variables with scope rules, primitive types including platform-dependent integer sizes, Unicode strings and encoding considerations, enumerations and subranges for constrained value sets, static and dynamic arrays plus open array parameters, records with methods and operators, sets for small ordinal collections, and type aliases versus strong typing for documentation and safety.

These building blocks form the vocabulary of every Delphi program. The next chapter continues language fundamentals with procedures, functions, advanced parameter passing, anonymous methods, closures, pointers, attributes, RTTI, and other features that distinguish modern Delphi from its historical roots.

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