Alessandro Del Sole

Foreword by Anthony D. Green,
Program Manager, Visual Basic, Microsoft

Visual Basic® 2015

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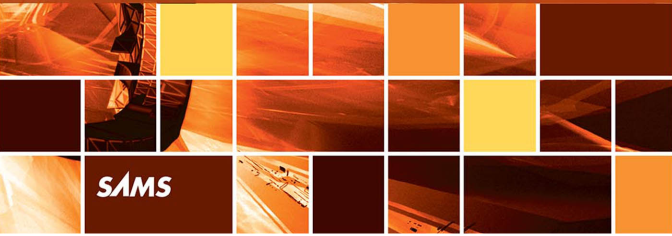

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Visual Basic® 2015 Unleashed

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Foreword

Back in 2013 Alessandro Del Sole reached out to the Visual Basic team to let us know that the VB Tips & Tricks user group in Italy had reached a 15-year milestone and that what would make it even more special would be to have a team member come out and celebrate with them. Being asked by the leader of one of our longest-running user groups boasting a membership of 40,000+ strong, it was a no-brainer. I knew I had to go. So I hopped on a 12-hour flight to Milan to give a 1-hour talk, a 10-minute speech, turned around, and flew back home (another 12 hours)—and it was totally worth it!

I joined the Visual Basic team in 2010 and in the entire time that I've known him since then, Alessandro has been an invaluable member of the VB community. He has consistently exemplified the qualities of an MVP, demonstrating technical leadership in the community, subject matter expertise, and receiving ongoing nominations and recognition by his peers as MVP of the Year.

Being familiar with Alessandro's VB books, I've always admired the comprehensiveness of his writing style. So many books approach development from just the language, or just a few libraries, but Alessandro covers the end-to-end—from language to library to IDE, in keeping with the Visual Basic spirit. And that style continues in this new edition. Here in Redmond, we're all very proud of the tremendous value we've added for VB developers in Visual Studio 2015, including a new ecosystem of Roslyn-powered diagnostic analyzers, refactoring (for the first time), great productivity language features, and a brand new experience for developing universal Windows 10 apps that run on PCs, Windows Phone, Xbox One, Microsoft Band, and HoloLens! True to form, Alessandro has taken the time to revisit everything new; each of his chapters in this edition highlights those enhancements, leaving nothing out. And personally, as the PM for the Roslyn APIs and a VB language designer for the last five years, I was especially thrilled to see him take up the topic of authoring code analysis tools with Roslyn (with his usual technical fervor) in the "Code Analysis" chapter.

So if you're looking for one-stop shopping to get the big picture (and get developing) in .NET and Visual Studio for VB developers in 2015, then this is the book for you. You'll be glued to it for a week integrating all the little enhancements into your day-to-day. And then after you've caught your breath, you'll keep coming back to it again and again as you explore whole new technologies over time. Much like those 24 hours of flying back in 2013, this book is totally worth it!

Anthony D. Green

Program Manager, Visual Basic, Microsoft

About the Author

Alessandro Del Sole, a Microsoft Most Valuable Professional (MVP) for .NET and Visual Basic since 2008, is well known throughout the global VB community. He is a community leader on the Italian Visual Basic Tips and Tricks website (http://www.visual-basic.it), which serves more than 46,000 VB developers, as well as a frequent contributor to the MSDN Visual Studio Developer Center. He has been awarded MVP of the Year five times (2009, 2010, 2011, 2012, 2014) and enjoys writing articles on .NET development both in English and Italian. He also writes blog posts and produces instructional videos as well as Windows Store apps. You can find him online in forums and you can follow him on Twitter at @progalex.

Dedication

To my mom: Life without you is not the same. You still live inside me through all of your lessons in life. I miss you.

To my dad, a brave great man. I am still learning from you what being a man means and I hope to be like you in my life.

To my girlfriend, Angelica, a wonderful ray of light in my life. Thanks for being there every day.

Acknowledgments

First, I would like to thank Joan Murray, Betsy Gratner, Kitty Wilson, Mark Renfrow, and everyone else at Sams Publishing for trusting me enough to write the third edition of this book about Visual Basic. Writing books like this is hard work not only for the author but also for all the people involved in the reviews and in the production process. Working with these guys made the process much more pleasant. Thank you!

Very special thanks to Lucian Wischik and Anthony D. Green from the Managed Languages Team at Microsoft, who have been the technical editors for this book. They did an incredible job walking through every single sentence and every single line of code. As the people who best know the Visual Basic language in the world, their suggestions and corrections were invaluable to me and definitely contributed to creating excellent and precise content. Thank you so much.

Great thanks also to the guys from the Italian subsidiary of Microsoft, Roberto Andreoli, Lorenzo Barbieri, Erica Barone, and Matteo Pagani, for their continuous support and encouragement for my activities. My deep thanks and appreciation for their passionate work with communities and with MVPs to Alessandro Teglia, Cristina Gonzalez Herrero (my MVP lead), and Marjorie di Clemente.

I would like to thank my everyday friends who are always ready to encourage me even if they are not developers and will never read my books. Most importantly, these people always support me when I need their help. So my deep thanks to Nadia Paloschi, Roberto Bianchi, Alessandro Ardovini, Michela Santini, Leonardo Amici, and Karin Meier. You are in my heart.

As a community leader in the Italian Visual Basic Tips and Tricks community (www.visual-basic.it), I would like to thank all those guys who are the stimulus for making things better every day; all those people who visited my blog at least once or who read even one article of mine; and all those people who visit our website and follow us on forums, videos, articles, and blogs. Special thanks to my MVP colleagues Diego Cattaruzza, Antonio Catucci, Renato Marzaro, and Raffaele Rialdi for their great support and valuable suggestions. Thanks to Marco Notari for his continuous support and encouragement.

We Want to Hear from You!

As the reader of this book, *you* are our most important critic and commentator. We value your opinion and want to know what we're doing right, what we could do better, what areas you'd like to see us publish in, and any other words of wisdom you're willing to pass our way.

We welcome your comments. You can email or write to let us know what you did or didn't like about this book—as well as what we can do to make our books better.

Please note that we cannot help you with technical problems related to the topic of this book.

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Introduction

A new era is coming for Microsoft. From Windows 10, to embracing open source, to opening to third-party platforms and operating systems, to the cloud first/mobile first vision, to the release of Visual Studio 2015, it is really an exciting time to be a software developer working with Microsoft products and technologies. From a developer perspective, Visual Studio 2015 marks a very important milestone because it is the state of the art in representing Redmond's new vision and because it is the most productive version ever. Both the Visual Basic and C# compilers have been open sourced, together with a tiny, modular subset of the .NET Framework called .NET Core, which is intended for cross-platform development. There are many new features, many new tools, and many new development opportunities with Visual Studio 2015 and the Visual Basic language that certainly open up amazing new scenarios but that also require some changes in how to approach building applications, especially with regard to mobile devices. As an experienced developer working with Visual Basic for many years and as a community person who daily connects with developers worldwide, I know very well what programmers using Visual Basic need to face in the real world, what they expect from developer tools and learning resources, and what they need to get the most out of their code and skills in order to build high-quality, rich applications and to get appropriate information to look at the future.

This book has two main goals: the first goal is to walk through the Visual Basic programming language deeply, explaining all the available language features, object-oriented programming, common patterns, and everything you need to know to really master the language. The second goal is to show what you can do with Visual Basic in practice; for instance, you can build Windows applications for the desktop, and you can also build apps for Windows 10 (which is a brand-new topic), as well as applications for the web, the cloud, and other platforms. Describing the VB language and what you can do with it is a tradition retaken from previous editions; but technology evolves, and so does the *Visual Basic Unleashed* book. With updated content and chapters that describe in details all the new language features, this new edition also focuses on the latest tools and platforms. As a couple of significant examples, *Visual Basic 2015 Unleashed* explains how to build universal Windows apps for Windows 10 and how to leverage the new compiler APIs from the .NET Compiler Platform to write custom domain-specific live code analysis rules. In addition, the book explains how to get the maximum out of the Visual Studio's development environment so that you can be more productive than ever. But there is a lot more; this book embraces all the possible development areas available to Visual Basic today. A new era is coming for Microsoft, and it's coming for you, too.

Code Samples and Software Requirements

Good explanations often require effective code examples. The companion source code for this book can be downloaded from www.informit.com/title/9780672334504. Code samples are organized by chapter so that it is easy to find the code you need. In order to load, compile, and test the source code, you need Microsoft Visual Studio 2015. If you are not an MSDN subscriber or you did not purchase one of the paid editions, you can download Visual Studio 2015 Community, which is available for free and is enough to run the sample code. You can download Visual Studio 2015 Community (as well as a trial of the Enterprise edition) from https://www.visualstudio.com/downloads/visual-studio-2015-downloads-vs. You are also encouraged to download and install the Visual Studio 2015 Software Development Kit (SDK), which is a requirement in some chapters and is available from the same location as the free download.

Code-Continuation Arrows

When a line of code is too long to fit on the page of the printed book, a code-continuation arrow (➥) appears to mark the continuation. Here is an example:

```
            somePeople.Add(New Person With {.FirstName = "First Name: " &
➥i.ToString,
```

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CHAPTER 42

Asynchronous Programming

IN THIS CHAPTER

- ▶ Overview of Asynchrony
- ▶ The Old-Fashioned Way: Event-Based Asynchrony
- ▶ The Old-Fashioned Way: The Asynchronous Programming Model
- ▶ The Modern Way: The `Async` Pattern
- ▶ Getting Started with `Async/Await`
- ▶ Exception Handling in `Async`
- ▶ Implementing Task-Based Asynchrony
- ▶ Cancellation and Progress
- ▶ Asynchronous Lambda Expressions
- ▶ Asynchronous I/O File Operations in .NET 4.6
- ▶ Debugging Tasks

When you go to the restaurant, there are waiters and waitresses ready to serve your table. A waiter takes your order, brings the order to the kitchen, goes to serve another table, and then comes back to your table to bring you your meals. While waiting for you to finish, the waiter does similar operations for other patrons. So, the waiter does not stand at your table from when you arrive until you finish your meal before going to serve another table; if he did, the restaurant would need to hire one waiter per table to avoid the block of their activity, which is not practical. If you compare this real-world description with computer programming, the waiter is some code in your application. If this code must perform a long-running operation and you write such a code in the user interface (UI) thread or, more generally, in one thread, your code will act like a waiter that waits from the start to the end of the meal on a table and cannot do anything else in the meantime, thereby blocking the application activity. This is what happens when you write code in a synchronous approach; synchronous code performs one task at a time and the next task starts only when the previous one completes. To avoid blocking the application, you can use multithreading and instances of the `Thread` class, described in Chapter 40, "Processes and Multithreading." With multithreading, you can write code that performs a long-running operation on a separate thread and keep the application responsive. Threading is a way to write asynchronous code that developers have been using for a long time, along with two patterns: the Event-based Asynchronous Pattern and the Asynchronous Programming Model. But actually, asynchrony does not necessarily mean running on a background thread. Instead, it means that a task is executed in different moments. Threading is one way to achieve asynchrony, but it is quite complex and not always the best choice. For this reason, back in .NET 4.5 Microsoft introduced new libraries and new keywords to the Visual Basic and Visual C# languages to make asynchronous calls easy. In this chapter, you get an overview of both the Event-based Asynchronous Pattern and the Asynchronous Programming Model; then you learn about the Asynchronous Pattern, which is without a doubt one of the most important features in Visual Basic language. You will see how easily you can now write modern and responsive applications via asynchronous code.

Overview of Asynchrony

Modern applications often need to perform complex computations or access resources through a network. Complex computations can become very long, a network resource might not be available, or the application might not scale well on the server. If the code that performs this kind of operation is running in the same thread as the caller, the thread gets blocked until all operations complete. If such a thread is the UI thread, the user interface becomes unresponsive and can no longer accept the user input until all operations have been completed. This type of approach is called *synchronous* because only one operation at a time is executed until all the processes are completed.

Having an unresponsive user interface is not acceptable in modern applications, so this is the place where asynchrony comes in. Asynchrony enables you to execute some pieces of code in a different thread or context, so that the caller thread never blocks. If this is the UI thread, the user interface remains responsive even if other operations are running. The other thread (or context) then tells the caller thread that an operation completed, regardless of the successful or unsuccessful result. The .NET Framework has been offering, for a long time, two thread-based approaches to asynchrony called *Event-based Asynchrony* and *Asynchronous Programming Model* in which you launch operations in a different thread and get notification of their completion via delegates. As you saw in Chapter 41, "Parallel Programming and Parallel LINQ," the .NET Framework 4.0 introduced the Task Parallel Library and the concept of parallelism. TPL makes it easier to create applications capable of scaling long-running operations across all the available processors. TPL also makes applications faster and more responsive while executing complex tasks concurrently, but this all about concurrency, which is not the same as asynchrony. In this chapter, you first learn about the Event-based Asynchrony and the Asynchronous Programming Model to get started with the important concepts; then you start putting your hands on the possibilities offered by the .NET Framework 4.6. By doing so, it will be easier for you to compare the old way to the new way and understand why you should migrate your exiting code to use the new patterns.

The Old-Fashioned Way: Event-Based Asynchrony

More often than not, applications need to perform multiple tasks at one time, while still remaining responsive to user interaction. One of the possibilities offered by the .NET Framework since the early days is the *Event-based Asynchronous Pattern* (*EAP*). A class that adheres to this pattern implements a number of methods whose names terminate with the

Async suffix and that execute some work on a different thread. Such methods mirror their synchronous counterparts, which instead block the caller thread. Also, for each of these asynchronous methods, there is an event whose name terminates with the Completed suffix and that is raised when the asynchronous operation completes. This way, the caller gets notification of the completion. Because the user might want to cancel an asynchronous operation at a certain point, classes adhering to the EAP must also implement methods whose names terminate with CancelAsync, each related to one of the asynchronous methods that actually performs the requested work. When such work is completed, a delegate will handle the operation result before control is sent back to the caller; this delegate is also known as *callback*. This pattern also requires classes to support cancellation and progress reporting. To understand how EAP works, let's consider a simple example based on the System.Net.WebClient class, which enables you to access networks from client applications. Consider the following code:

```
Sub Main()
    Dim client As New System.Net.WebClient
    AddHandler client.DownloadStringCompleted,
               AddressOf client_DownloadStringCompleted

    client.DownloadStringAsync(New Uri("http://msdn.microsoft.com"))
End Sub
```

A new instance of the WebClient class is created. To receive notification of completion, you must subscribe the DownloadStringCompleted event (assuming you will download a string, but other methods and related events are available) and supply a delegate that will be invoked when the event is raised. After you have subscribed the event, you can then invoke the desired method; in the current example, it's the WebClient.DownloadStringAsync method that downloads contents from the specified URL as a string. If you write other lines of code after the invocation of DownloadStringAsync, these are not necessarily executed after the download operation has completed as it would instead happen in synchronous code. So, if you need to manipulate the result of an asynchronous operation, you must do it inside the callback, which is the delegate invoked after the completion event is raised. The following code provides an example:

```
Private Sub client_DownloadStringCompleted(sender As Object,
                                           e As DownloadStringCompletedEventArgs)
    If e.Error Is Nothing Then
        Console.WriteLine(XDocument.Parse(e.Result).ToString)
        Console.WriteLine("Done")
    End If
End Sub
```

As you can see, the DownloadStringCompletedEventArgs class contains information about the result of the asynchronous operation. Usually, a specific class inherits from System.EventArgs and stores the result of an asynchronous operation, one per asynchronous method. You can check for errors, and if everything is successful, you can then work with the e.Result property that contains the actual result of the task. Classes that adhere to the EAP also enable you to report the progress of an asynchronous operation by exposing a `ProgressChanged` event. Continuing the previous example, the `WebClient` class exposes an event called `ProgressChanged` and a class called `DownloadProgressChangedEventArgs` that stores information about the operation progress. To handle such an event, you must first subscribe it like this:

```
AddHandler client.DownloadProgressChanged,
           AddressOf client_DownloadProgressChanged
```

You then handle the `ProgressChanged` event to report progress:

```
Private Sub client_DownloadProgressChanged(sender As Object,
                                           e As DownloadProgressChangedEventArgs)
    Console.WriteLine(e.ProgressPercentage)
    'Use e.BytesReceived for the number of bytes received in progress
    'Use e.TotalBytesToReceive to get the total bytes to be downloaded
End Sub
```

You can eventually use lambda expressions and statement lambdas as anonymous delegates, as demonstrated in the following code:

```
Private Sub Download()
    Dim client As New WebClient
    AddHandler client.DownloadStringCompleted,
               Sub(sender, e)
                   If e.Error Is Nothing Then
                       Console.WriteLine(XDocument.
                                         Parse(e.Result).
                                         ToString)
                   End If
               End Sub

    client.DownloadStringAsync(New Uri("http://msdn.microsoft.com"))
End Sub
```

The EAP has been very popular among developers for years because the way you write code is similar to how you handle events of the user interface. This certainly makes the asynchronous approach simpler. Later in this chapter, when comparing EAP to the new `Async` pattern, you will better understand why the old way can lead to confusion and become very complex to handle.

The Old-Fashioned Way: The Asynchronous Programming Model

The Asynchronous Programming Model (APM) is still based on threading. In this model, an operation is launched on a separated thread via a method whose name starts with `Begin` (e.g., `BeginWrite`). A method like this must accept, among its parameters, an argument of type IAsyncResult. This is a special type used to store the result and the state of an asynchronous operation. The most important members of this interface are two properties: AsyncState (of type Object), which represents the result of the operation under the form of either a primitive or a composite type, and IsCompleted (of type Boolean), which returns if the operation actually completed. As another parameter, these methods must receive a delegate that will be executed when the asynchronous operation is completed. Within this delegate, you will be able to analyze the result of the asynchronous operation, but you will also need to explicitly end the asynchronous operation by invoking a method whose name starts with End (e.g., EndWrite). Some classes in the .NET Framework are built to be APM-ready, such as Stream and its derived classes. So, to demonstrate how APM works, a good example can be based on the FileStream class. The following code demonstrates how to write some bytes to a stream asynchronously and how the callback receives information from the caller with IAsyncResult.

```
Private Sub OpenStreamAsync()
    Dim someBytes(1000) As Byte
    Dim randomGenerator As New Random()
   'Generate a random sequence of bytes
    randomGenerator.NextBytes(someBytes)

    Using fs As New FileStream("Somedata.dat", FileMode.Create, FileAccess.Write)
        Dim result As IAsyncResult =
            fs.BeginWrite(someBytes, 0, someBytes.Length,
                          AddressOf fs_EndWrite, fs)
    End Using

End Sub

Private Sub fs_EndWrite(result As IAsyncResult)
    Dim stream As FileStream = CType(result.AsyncState, FileStream)
    stream.EndWrite(result)
    'Additional work goes here...
End Sub
```

The IAsyncResult.AsyncState property contains the actual data sent from the caller and must be explicitly converted into the type that you need to work with; in this case, the stream. The reason is that you also must explicitly invoke the EndWrite method that finalizes the asynchronous operation. You can also pass custom objects as the IAsyncResult argument for the callback, to pass more complex and detailed information that you might need to elaborate when the task completes.

The Modern Way: The Async Pattern

Visual Basic 2012 introduced a new pattern that solves some problems related to threading and enables you to write better and cleaner code. It does this with two keywords: Async and Await. Async is a modifier you use to mark methods that run asynchronous operations. `Await` is an operator that gets a placeholder for the result of an asynchronous operation and waits for the result, which will be sent back at a later time while other operations are executed. This enables you to keep the caller thread responsive. For a first understanding of how this pattern works, let's take a look at the following function that downloads the content of a website as a string, returning the result as an `XDocument` that can be manipulated with LINQ:

```
Function DownloadSite() As XDocument
    Dim client As New System.Net.WebClient
    Dim content As String =
        client.DownloadString("http://www.microsoft.com")

    Dim document As XDocument = XDocument.Parse(content)
    Return document
End Function
```

This code is pretty easy because it creates an instance of the `WebClient` class, then downloads the content of the specified website, and finally returns the XML document converted through `XDocument.Parse`. This code is synchronous, meaning that the caller thread will remain blocked until all the operations in the method body are completed. If the caller thread is the UI thread, the user interface will remain blocked. Figure 42.1 shows a graphical representation of how a synchronous call works.

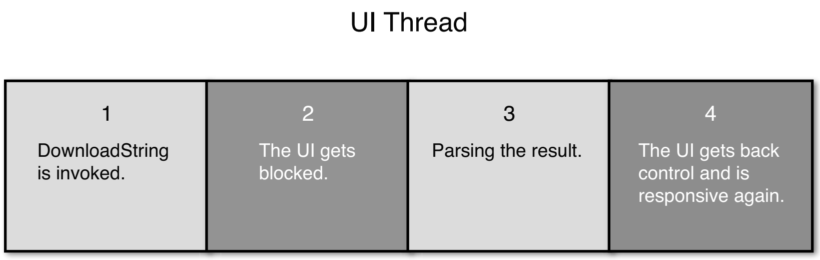

UI Thread
1
DownloadString is invoked.
2
The UI gets blocked.
3
Parsing the result.
4
The UI gets back control and is responsive again.

FIGURE 42.1 Representation of a synchronous call.

This is how you can rewrite the previous code using the `Async` pattern:

```
Async Function DownloadSiteAsync() As Task(Of XDocument)
    Dim client As New System.Net.WebClient
    Dim content As String =
        Await client.DownloadStringTaskAsync("http://www.microsoft.com")

    Dim document As XDocument = XDocument.Parse(content)

    Return document
End Function
```

Await AS A RESERVED KEYWORD

The Await keyword is not a reserved word everywhere in the code. It is a reserved word when it appears inside a method or lambda marked with the Async modifier and only if it appears after that modifier. In all other cases, it is not a reserved word.

This code is asynchronous, so it will never block the caller thread because not all the code is executed at the same time. Figure 42.2 shows a representation of an asynchronous call.

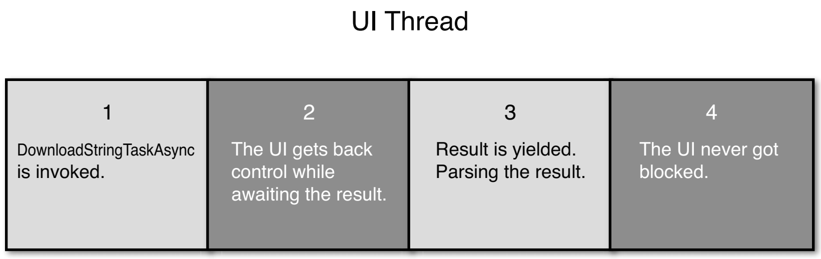

UI Thread
1
DownloadStringTaskAsync is invoked.
2
The UI gets back control while awaiting the result.
3
Result is yielded. Parsing the result.
4
The UI never got blocked.

FIGURE 42.2 Representation of an asynchronous call.

THE STORY OF THREADS WITH Async/Await

The Async pattern relies on the concept of Task described in the previous chapter. For this reason, asynchronous code written with Async/Await does not necessarily run on a separate thread. In fact, it is represented by an instance of the Task class. Because one thread can run multiple Task instances, it is normal that asynchronous code can run in the same caller thread, such as the UI thread.

The following is a list of important considerations that will be discussed in the next section:

- A method that runs asynchronous code must be marked with the Async modifier. When the compiler encounters this modifier, it expects an Await expression inside the method body.
- Methods marked with Async are also referred to as *asynchronous methods*.
- By convention, names of asynchronous methods must end with the Async suffix.
- Asynchronous methods must return a Task (if they return no value) or a Task(Of T), where T is the type that you would return with synchronous methods. See the previous XDocument example.
- Asynchronous methods support the standard access modifiers (such as Private, Public, and so on), but they cannot be iterator methods at the same time, so the Iterator modifier cannot be used along with Async.

- The `Main` method of an application can never be asynchronous. Notice that if you mark the `Main` method as asynchronous and write asynchronous calls in its body, the background compiler will not report any warnings or exceptions. It will report an error when you compile or try to run the code.
- Any method that returns a `Task` or `Task(Of T)` can be used along with `Await` ("awaitable").
- The `Await` expression puts a placeholder for the result of the invoked task. The result will be returned later at some time, making the application remain responsive. However, the next code will actually run when the result has been returned. This is because the compiler ideally splits the method into two parts; the second part is nothing but a callback that is executed when the awaited task notifies the caller of its completion.
- Although you should return a `Task` or `Task(Of T)`, the compiler automatically infers the task-based type even if you return the original type. The second code snippet in the previous example demonstrates how the `Return` statement returns `XDocument` but the compiler automatically returns `Task(Of XDocument)`.

Although these first important considerations might sound confusing, you will soon appreciate the benefits of using the `Async` pattern. It enables you to avoid multithreading and explicit callbacks, enabling you to write much easier and cleaner code. In the next section, you get started with the `Async` pattern with a practical example so that all the concepts described so far will be explained better.

Where Do I Use `Async`?

The `Async` libraries are in the .NET Framework 4.6, so you can use the pattern in whatever technology uses .NET 4.6. WPF, Windows Forms, ASP.NET, and even Windows Store apps. These are all technologies that can leverage the power of these libraries.

In other words, you have no limits in using the new pattern and should always use this new way to asynchrony.

`Async` AND WINDOWS 8.X STORE APPS

There is another important reason beyond the availability of the `Async` pattern in .NET languages now: developing Windows 8.x Store Apps. Windows 8.x Apps require you to write most of the code asynchronously, and using old techniques would make developing apps really difficult. Instead, with the `Async` pattern, coding for Windows 8.x is much faster, easier, and cleaner. Because the user interface of Windows 8.x apps must always be responsive with no exceptions, using the `Async` pattern is very common. Also, the unification of the programming model with the Windows Phone 8.1 platform made the `Async` pattern natively available in these kinds of apps. This is another reason to read this chapter with particular attention.

When and Why to Use Async/Await and Comparisons with the TPL

Using the Async pattern enables you to write applications that are more responsive and that perform better, but you will not use it everywhere. In fact, there are specific situations in which Async has benefits. As a general rule, Async's main purpose is to keep the UI responsive while tasks running in the UI thread might become potentially blocking. You use Async in the following scenarios:

- Potentially blocking tasks running in the user interface thread
- Image processing
- I/O operations (disk, networking, web access)
- Working with sockets

Using Async and Await differs from parallel programming because the purpose is not to have pieces of code that run concurrently; instead, the purpose is keeping the user interface responsive. In parallel programming, you have code that is CPU-consuming, so you use Task instances to split the execution of your code into multiple units of work. Thus, most of the code is executed at the same time by using a multicore architecture. In Async, instead, you do not have CPU-consuming code. You might have potentially blocking tasks, though, so your goal is to keep the UI thread free. This is possible because the result of an Await expression is delayed and control is yielded to the caller while waiting.

Getting Started with Async/Await

In this section you see the Async pattern with an example based on retrieving information from the Internet. You will build a WPF application that downloads RSS feeds information from the Web, simulating a long-running process over a network. You first, though, create an application that works synchronously; then you see how to implement the Event-based Asynchronous Pattern described at the beginning of this chapter. Finally, you learn how things change in a third example built using the new Async and Await keywords.

The Synchronous Approach

Create a new WPF project with Visual Basic 2015 and .NET Framework 4.6. The application will consume the Visual Basic RSS feed exposed by the Microsoft's Channel9 website, with particular regard to the list of published videos. Each item in the feed has a large number of properties, but for the sake of simplicity only the most important will be presented in the application's UI. So, the first thing you need to do is create a class that represents a single video described in the feed. Listing 42.1 demonstrates how to implement a class called Video.

LISTING 42.1 Representing a Single Video

```
Public Class Video
    Public Property Title As String
    Public Property Url As String
    Public Property Thumbnail As String
    Public Property DateRecorded As String
    Public Property Speaker As String

    Public Shared FeedUrl As String = _
           "http://channel9.msdn.com/Tags/visual+basic/RSS"
End Class
```

Notice that all the properties are of type `String` just to represent values as they exactly come from the feed. Also, a shared field contains the feed URL. Now open the MainWindow.xaml file, to prepare the application's user interface. The goal is to show the videos' thumbnails and summary information and to provide the ability to click a thumbnail to open the video in its original location. The `ListBox` control is a good choice to display a collection of items. This will be placed inside the default `Grid` panel. Each item in the `ListBox` will be presented via a custom template made of a Border and a `StackPanel` that contains an `Image` control (for the video thumbnail) and a number of `TextBlock` controls that are bound to properties of the `Video` class. Listing 42.2 shows the full code for the main window.

LISTING 42.2 Implementing the Application's User Interface

```
<Window x:Class="MainWindow"
    xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
    xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
    Title="MainWindow" Height="350" Width="525">
    <Grid>
        <ListBox Name="VideoBox" ItemsSource="{Binding}"
                 ScrollViewer.HorizontalScrollBarVisibility="Disabled">
            <ListBox.ItemsPanel>
                <ItemsPanelTemplate>
                    <WrapPanel VirtualizingPanel.IsVirtualizing="True"/>
                </ItemsPanelTemplate>
            </ListBox.ItemsPanel>
            <ListBox.ItemTemplate>
                <DataTemplate>
                    <Border BorderBrush="Black" Margin="5"
                            BorderThickness="2" Tag={Binding Url}
                            MouseLeftButtonUp="Border_MouseLeftButtonUp_1"
                            Width="200" Height="220">
                        <StackPanel>
                            <Image Source="{Binding Thumbnail}"
                                   Width="160" Height="120" />
                            <TextBlock Text="{Binding Title}" TextWrapping="Wrap"
                                       Grid.Row="1"/>
                            <TextBlock Text="{Binding DateRecorded}" Grid.Row="2"/>
                            <TextBlock Text="{Binding Speaker}" Grid.Row="3"/>
                        </StackPanel>
                    </Border>
                </DataTemplate>
            </ListBox.ItemTemplate>
        </ListBox>
    </Grid>
</Window>
```

It is worth mentioning that the code replaces the default items container (a `VirtualizingStackPanel`) with a `WrapPanel` container so that items are not forced to be presented on one line horizontally. This requires disabling the horizontal scrollbar on the `ListBox` (`ScrollViewer.HorizontalScrollBarVisibility="Disabled"`) and changing the `ListBox.ItemsPanel` content with the `WrapPanel`. Also notice how the `Border.Tag` property is bound to the `Url` property of the `Video` class. This enables you to store the video's URL and click the Border at runtime to open the video in its original location. Now switch to the code-behind file. The first thing you must do is add a number of `Imports` directives, some for importing XML namespaces needed to map information from the RSS feed and some for working with additional .NET classes:

```
Imports System.Net
Imports <xmlns:media="http://search.yahoo.com/mrss/">
Imports <xmlns:dc="http://purl.org/dc/elements/1.1/">
```

The next step is implementing a method that queries the RSS feed returning the list of videos. In this first implementation, you will use a synchronous approach, which will block the user interface when the application is running:

```
Private Function QueryVideos() As IEnumerable(Of Video)
    Dim client As New WebClient

    Dim data As String = client.DownloadString(New Uri(Video.FeedUrl))

    Dim doc As XDocument = XDocument.Parse(data)
        Dim query = From video In doc...<item>
                    Select New Video With {
                        .Title = video.<title>.Value,
                        .Speaker = video.<dc:creator>.Value,
                        .Url = video.<link>.Value,
                        .Thumbnail = video...<media:thumbnail>.
                        FirstOrDefault?.@url,
                        .DateRecorded = String.Concat("Recorded on ",
                         Date.Parse(video.<pubDate>.Value,
                         Globalization.CultureInfo.InvariantCulture).
                         ToShortDateString)}
    Return query
End Function
```

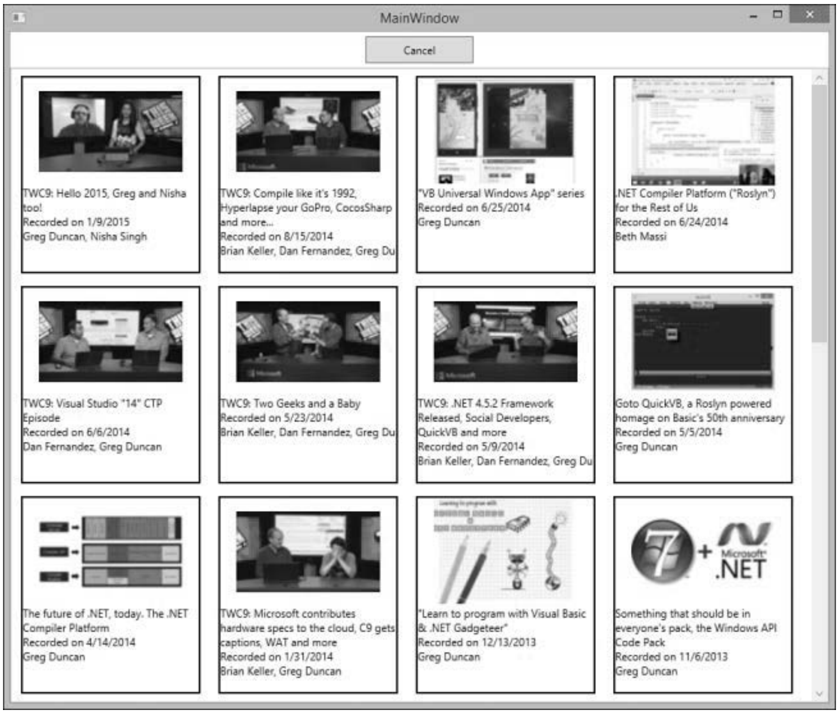
The code is simple. An instance of the `WebClient` class, which provides simplified access to networked resources, is created and the invocation of its `DownloadString` method downloads the entire content of the feed under the form of a `String` object. Notice that this is the point at which the user interface gets blocked. In fact, it will need to wait for `DownloadString` to complete the operation before returning to be responsive. After the feed has been downloaded, it is converted into an object of type `XDocument` and a LINQ query enables you to retrieve all the needed information (refer to Chapter 27, "Manipulating XML Documents with LINQ and XML Literals," for further information on LINQ to XML). Finally, a method called `LoadVideos` will run the query and assign the result to the Window's `DataContext`; such a method will be invoked at startup. You can change this type of implementation, but it will be more useful later when making comparisons with the asynchronous implementation. The following code demonstrates this, plus the event handler for the `MouseLeftButtonUp` event of the `Border` control, where you launch the video in its original web page:

```
Private Sub LoadVideos()
    Me.DataContext = QueryVideos()
End Sub

Private Sub MainWindow_Loaded(sender As Object,
                              e As RoutedEventArgs) Handles Me.Loaded
    LoadVideos()
End Sub

Private Sub Border_MouseLeftButtonUp_1(sender As Object,
                                        e As MouseButtonEventArgs)
    'Tag is of type Object so an explicit conversion to String is required
    Dim instance = CType(sender, Border)
    Process.Start(CStr(instance.Tag))
End Sub
```

You can now run the application. Figure 42.3 shows the result of the query over the video feed.



TWC9: Hello 2015, Greg and Nisha too!
Recorded on 1/9/2015
Greg Duncan, Nisha Singh

TWC9: Compile like it's 1992, Hyperlapse your GoPro, CocosSharp and more...
Recorded on 8/15/2014
Brian Keller, Dan Fernandez, Greg Du

"VB Universal Windows App" series
Recorded on 6/25/2014
Greg Duncan

.NET Compiler Platform ("Roslyn") for the Rest of Us
Recorded on 6/24/2014
Beth Massi

TWC9: Visual Studio "14" CTP Episode
Recorded on 6/6/2014
Dan Fernandez, Greg Duncan

TWC9: Two Geeks and a Baby
Recorded on 5/23/2014
Brian Keller, Dan Fernandez, Greg Du

TWC9: .NET 4.5.2 Framework Released, Social Developers, QuickVB and more
Recorded on 5/9/2014
Brian Keller, Dan Fernandez, Greg Du

Goto QuickVB, a Roslyn powered homage on Basic's 50th anniversary
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Greg Duncan

The future of .NET, today. The .NET Compiler Platform
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Greg Duncan

TWC9: Microsoft contributes hardware specs to the cloud, C9 gets captions, WAT and more
Recorded on 1/31/2014
Brian Keller, Greg Duncan

"Learn to program with Visual Basic & .NET Gadgeteer"
Recorded on 12/13/2013
Greg Duncan

Something that should be in everyone's pack, the Windows API Code Pack
Recorded on 11/6/2013
Greg Duncan

FIGURE 42.3 Loading an RSS feed the synchronous way.

The application works as expected, but the real problem with this approach is that the user cannot interact with the interface while the query is running. The reason is that the query's code is running in the UI thread, so the user interface is busy with the query and does not accept any interaction. This can be easily demonstrated by attempting to move the window while the query is running because you will not be able to move it elsewhere. This has other implications: you cannot refresh controls that display the status of the task because they would be refreshed only when the query completes. Also, you cannot enable users to cancel the operation because you would need a button that the user would never be able to click.

Event-Based Asynchrony and Callbacks

A much better approach is moving the long-running operation into a separate thread, so that the UI can remain responsive while the other thread executes the operation. Lots of classes in the .NET Framework, especially those whose job is interacting with the Web and with networks-expose event-based asynchrony through methods that launch and execute an operation on a separate thread and raise an event when it is completed, passing the result to the caller via a callback. The `WebClient` class has an asynchronous counterpart of `DownloadString`, called `DownloadStringAsync`, that you can use to execute the code on a separate thread and wait for the query result via a callback. The following code demonstrates how to accomplish this (do not worry if you notice something wrong because an explanation is provided in moments):

```
Private Function QueryVideos() As IEnumerable(Of Video)
    Dim client As New WebClient
    Dim query As IEnumerable(Of Video)

    AddHandler client.DownloadStringCompleted, Sub(sender, e)
                                                   If e.Error IsNot Nothing Then
                                                       'Error handling logic here..
                                                   End If

                                                   Dim doc = _
                                                       XDocument.Parse(e.Result)
                                                   Dim query = From video
                                                               In doc...<item>
                                                               Select _
                                                               New Video With {
                                                     .Title =
                                                     video.<title>.Value,
                                                     .Speaker =
                                                     video.<dc:creator>.
                                                     Value,
                                                     .Url = video.<link>.Value,
                                                     .Thumbnail =
                                                     video...<media:thumbnail>.
                                                     FirstOrDefault?.@url,
                                                     .DateRecorded =
                                                     String.Concat("Recorded on ",
                                                     Date.Parse(video.
                                                     <pubDate>.Value,
                                                     Globalization.CultureInfo.
                                                    InvariantCulture).
                                                    ToShortDateString)}
                                               End Sub

    client.DownloadStringAsync(New Uri(Video.FeedUrl))
    Return query
End Function
```

The code specifies a statement lambda as an event handler for the `DownloadString-Completed` event, instead of declaring a separate delegate and pointing to this via an `AddressOf` clause. The `e` object is of type `DownloadStringCompletedEventArgs` and contains the result of the operation. The problem in this code is that the `Return` statement does not work because it is attempting to return a result that has not been produced yet. On the other side, you cannot write something like this:

```
Private Function QueryVideos() As IEnumerable(Of Video)
    Dim client As New WebClient
    Dim query As IEnumerable(Of Video)

    AddHandler client.DownloadStringCompleted, Sub(sender, e)
                                                   If e.Error IsNot Nothing Then
                                                       'Error handling logic here..
                                                   End If

                                                   Dim doc = _
                                                       XDocument.Parse(e.Result)
                                                   Dim query = From ...
                                                   Return query

                                               End Sub

    client.DownloadStringAsync(New Uri(Video.FeedUrl))
End Function
```

This code does not work because you cannot return a result from a `Sub` and because it should be returned from the outer method, not the inner. In conclusion, `Return` statements do not work well with event-based asynchrony. The solution at this point is returning the result via a callback and an `Action(Of T)` object. So the appropriate implementation of the `QueryVideos` method in this approach is the following:

```
Private Sub QueryVideos(listOfVideos As Action(Of IEnumerable(Of Video),
                                        Exception))
    Dim client As New WebClient
    AddHandler client.DownloadStringCompleted, Sub(sender, e)
                                                   If e.Error IsNot Nothing Then
                                                       listOfVideos(Nothing,
                                                                    e.Error)
                                                       Return
                                                   End If

                                                   Dim doc = _
                                                       XDocument.Parse(e.Result)
                                                   Dim query =
                                                       From video In doc...<item>
                                                       Select New Video With {
                                                       .Title =
                                                       video.<title>.Value,
                                                       .Speaker =
                                                       video.<dc:creator>.
                                                       Value,
                                                       .Url = video.<link>.Value,
                                                       .Thumbnail =
                                                       video...<media:thumbnail>.
                                                       FirstOrDefault?.@url,
                                                       .DateRecorded =
                                                       String.Concat("Recorded on ",
                                                       Date.Parse(video.
                                                       <pubDate>.Value,
                                                       Globalization.CultureInfo.
                                                       InvariantCulture).
                                                       ToShortDateString)}
                                                   listOfVideos(query, Nothing)
                                               End Sub

    Try
        client.DownloadStringAsync(New Uri(Video.FeedUrl))
    Catch ex As Exception
        listOfVideos(Nothing, ex)
    End Try
End Sub
```

The previous code does the following:

1. Holds the list of videos from the RSS feed in an `Action(Of IEnumerable(Of Video), Exception)` object. The `Exception` instance here is useful to determine whether an error occurred during the query execution.
2. If the query completes successfully, the query result is passed to the `Action` object (that is, the callback).
3. If an exception occurs during the query execution (see the first `If` block inside the statement lambda), the callback receives `Nothing` as the first parameter because the collection of items was not retrieved successfully and the exception instance as the second parameter.
4. If an exception occurs immediately when the web request is made, the callback still receives `Nothing` and the exception instance. This is at the `Try..Catch` block level.

So using a callback here has been necessary for two reasons: sending the query result back to the caller correctly and handling two exception scenarios. But you are not done yet. In fact, you have to completely rewrite the `LoadVideos` method to hold the result of the callback and determine whether the operation completed successfully before assigning the query result to the Window's `DataContext`. The following code demonstrates this:

```
Private Sub LoadVideos()
    Dim action As Action(Of IEnumerable(Of Video),
                         Exception) = Nothing
    action =
        Sub(videos, ex)
```

```
            If ex IsNot Nothing Then
                MessageBox.Show(ex.Message)
                Return
            End If

            If (videos.Any) Then
                Me.DataContext = videos
            Else
                QueryVideos(action)
            End If
        End Sub
    QueryVideos(action)
End Sub
```

As you can see, the code is not easy, unless you are an expert. There is an invocation to the previous implementation of `QueryVideos`, passing the instance of the callback. When the result is sent back, the statement lambda first checks for exceptions and, if not, takes the query result as the data source. If you now run the application again, you will get the same result shown in Figure 42.3; however, this time the user interface is responsive and the user can interact with it. But reaching this objective had costs. You had to completely rewrite method implementations and write code that is complex and difficult to read and to extend. So, the multithreading in this situation has not been very helpful. This is the point in which the `Async`/`Await` pattern comes in to make things simple.

Asynchrony with `Async/Await`

The `Async`/`Await` pattern has the goal of simplifying the way developers write asynchronous code. You will learn a lot about the underlying infrastructure, but before digging into that, it is important for you to see how your code can be much cleaner and readable. Let's start by modifying the `QueryVideos` method to make some important considerations:

```
Private Async Function QueryVideosAsync() As  _
        Task(Of IEnumerable(Of Video))
    Dim client As New WebClient

    Dim data = Await client.DownloadStringTaskAsync(New Uri(Video.FeedUrl))

    Dim doc = XDocument.Parse(data)

    Dim query = From video In doc...<item>
                Select New Video With {
                    .Title = video.<title>.Value,
                    .Speaker = video.<dc:creator>.Value,
                    .Url = video.<link>.Value,
                    .Thumbnail = video...<media:thumbnail>.
                    FirstOrDefault?.@url,
                    .DateRecorded = String.Concat("Recorded on ",
                    Date.Parse(video.<pubDate>.Value,
                        Globalization.CultureInfo.InvariantCulture).
                    ToShortDateString)}

    Return query
End Function
```

Asynchronous methods must be decorated with the `Async` modifier. When the compiler encounters this modifier, it expects that the method body contains one or more `Await` statements. If not, it reports a warning saying that the method will be treated as synchronous, suggesting that the `Async` modifier should be removed. `Async` methods must return an object of type `Task`. If the method returns a value (`Function`), then it must return a `Task(Of T)` where `T` is the actual result type. Otherwise, if the method returns no value, both following syntaxes are allowed:

```
Async Function TestAsync() As Task
   'You can avoid Return statements, the compiler assumes returning no values
End Function

Async Sub TestAsync()
'...
End Sub
```

The difference between the two implementations is that the first one can be called inside another method with `Await`, but the second one cannot (because it does not need to be awaited). A typical example of the second syntax is about event handlers: they can be asynchronous and can use `Await`, but no other method will wait for their result. By convention, the suffix of asynchronous methods is the `Async` literal. This is why `QueryVideos` has been renamed into `QueryVideosAsync`. An exception is represented by asynchronous methods already existing in previous versions of the .NET Framework, based on the EAP, whose name already ends with `Async`. In this case `Async` is replaced with `TaskAsync`. For instance (as you discover in moments), the `DownloadStringAsync` method in the `WebClient` class has a new counterpart called `DownloadStringTaskAsync`. Any method that returns a `Task` or `Task(Of T)` can be used with `Await`. With `Await`, a task is started but the control flow is immediately returned to the caller. The result of the task will not be returned immediately, but later and only when the task completes. But because the control flow immediately returns to the caller, the caller remains responsive. `Await` can be thought as of a placeholder for the task's result, which will be available after the awaited task completes. In the previous `QueryVideosAsync` method, `Await` starts the `WebClient.DownloadStringTaskAsync` method and literally waits for its result but, while waiting, the control flow does not move to `DownloadStringAsyncTask`, while it remains in the caller. Because in the current example the code is running in the UI thread, the user interface remains responsive because the requested task is being executed asynchronously.

In other words, what `Await` actually does is sign up the rest of the method as a callback on the task, returning immediately. When the task that is being awaited completes, it will invoke the callback and will resume the execution from the exact point it was left.

After the operation has been completed, the rest of the code can elaborate the result. With this kind of approach, your method looks much simpler, like the first synchronous version, but it is running asynchronously with only three edits (the `Async` modifier, `Task(Of T)` as the return type, and the `Await` operator).

WHY THE `Task` TYPE?

In Chapter 41 you learned a lot about the `Task` class and saw how this can run CPU-intensive work on a separate thread, but it also can represent an I/O operation such as a network request. For this reason, the `Task` class is the natural choice as the result type for asynchronous operations using `Async/Await`.

Continuing considerations on the previous method, take a look at the final `Return` statement. It is returning an `IEnumerable(Of Video)`, but actually the method's signature requires returning a `Task(Of IEnumerable(Of Video))`. This is possible because the compiler automatically makes `Return` statements to return a `Task`-based version of their result even if they do not. As a result, you will not get confused because you will write the same code but the compiler will take care of converting the return type into the appropriate type. This also makes migration of synchronous code to asynchronous easier. Technically speaking, the compiler synthesizes a new `Task(Of T)` object at the first `Await` in the method. This `Task(Of T)` object is returned to the caller at the first `Await`. Later on, when it encounters a `Return` statement, the compiler causes that already-existing `Task(Of T)` object to transition from a "not yet completed" state into the "completed with result" state. Continuing the migration of the code example to the `Async/Await` pattern, you now need a few edits to the `LoadVideos` method. The following code demonstrates this:

```
Private Async Function LoadVideosAsync() As Task
    Me.DataContext = Await QueryVideosAsync()
End Sub
```

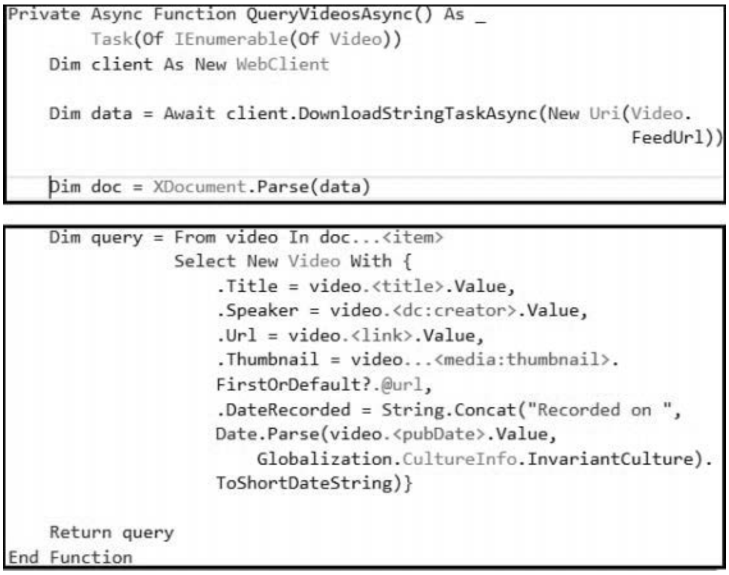
The method is now called `LoadVideoAsync` and marked with the `Async` modifier. The reason is that it contains an `Await` expression that invokes the `QueryVideosAsync` method. The result of this invocation is taken as the main window's data source. Finally, you have to edit the `MainWindow_Loaded` event handler and make it asynchronous like this:

```
Private Async Sub MainWindow_Loaded(sender As Object,
                                    e As RoutedEventArgs) Handles Me.Loaded
    Await LoadVideosAsync()
End Sub
```

If you now run the application, you will still get a responsive user interface that you can interact with while the long-running task (the query) is executing, but you have achieved this by modifying existing code with very few edits.

How `Async` and `Await` Work Behind the Scenes

Behind the scenes of the ease of the `Async` pattern, the compiler does incredible work to make the magic possible. When you make an asynchronous call by using `Await`, that invocation starts a new instance of the `Task` class. As you know from Chapter 41, one thread can contain multiple `Task` instances. So you might have the asynchronous operation running in the same thread but on a new `Task`. Internally, it's as if the compiler could split an asynchronous method in two parts, a method and its callback. If you consider the `QueryVideosAsync` shown previously, you could imagine a method defined until the invocation of `Await`. The next part of the method is moved into a callback that is invoked after the awaited operation is completed. This has two benefits. The first benefit is that it ensures that code that needs to manipulate the result of an awaited operation will work with the actual result, which has been returned after completion of the task (this is in fact the moment in which the callback is invoked). Second, such callback is invoked in the same calling thread, which avoids the need of managing threads manually or using the `Dispatcher` class in technologies like WPF or Silverlight. Figure 42.4 gives you an ideal representation of how the asynchronous method has been split.

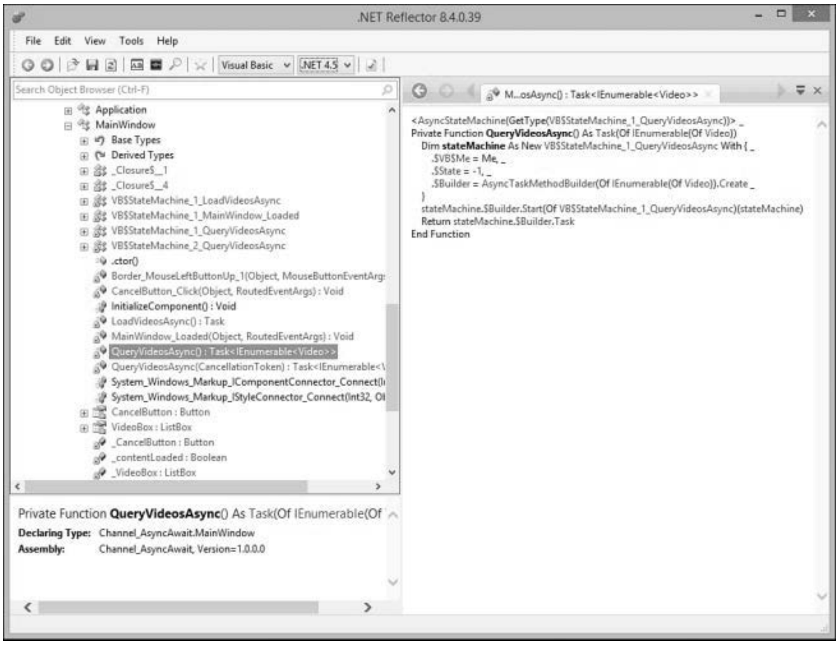


```
Private Async Function QueryVideosAsync() As _
        Task(Of IEnumerable(Of Video))
    Dim client As New WebClient

    Dim data = Await client.DownloadStringTaskAsync(New Uri(Video.
                                                    FeedUrl))

    Dim doc = XDocument.Parse(data)
```

```
    Dim query = From video In doc...<item>
                Select New Video With {
                    .Title = video.<title>.Value,
                    .Speaker = video.<dc:creator>.Value,
                    .Url = video.<link>.Value,
                    .Thumbnail = video...<media:thumbnail>.
                    FirstOrDefault?.@url,
                    .DateRecorded = String.Concat("Recorded on ",
                    Date.Parse(video.<pubDate>.Value,
                        Globalization.CultureInfo.InvariantCulture).
                    ToShortDateString)}

    Return query
End Function
```

FIGURE 42.4 An asynchronous method is split into two ideal parts; the second is a callback.

Beyond considerations like the ones about threading, it is interesting to analyze the code the compiler generated to make asynchrony so efficient in Visual Basic 2015. For this exercise, you need a decompiler tool such as .NET Reflector from Red-Gate, which is available as a free trial from https://www.red-gate.com/products/dotnet-development/reflector/. If you open the compiled .exe file with a tool like this, you can see that the implementation of asynchronous methods is completely different from the one you wrote and that the compiler generated several structures that implement a state machine that supports asynchrony. Figure 42.5 shows the `QueryVideosAsync` real implementation.


.NET Reflector 8.4.0.39
File Edit View Tools Help
Visual Basic
.NET 4.5
Search Object Browser (Ctrl-F)
M...osAsync() : Task<IEnumerable<Video>>

```
Application
MainWindow
  Base Types
  Derived Types
  _Closure$__1
  _Closure$__4
  VB$StateMachine_1_LoadVideosAsync
  VB$StateMachine_1_MainWindow_Loaded
  VB$StateMachine_1_QueryVideosAsync
  VB$StateMachine_2_QueryVideosAsync
  .ctor()
  Border_MouseLeftButtonUp_1(Object, MouseButtonEventArg:
  CancelButton_Click(Object, RoutedEventArgs) : Void
  InitializeComponent() : Void
  LoadVideosAsync() : Task
  MainWindow_Loaded(Object, RoutedEventArgs) : Void
  QueryVideosAsync() : Task<IEnumerable<Video>>
  QueryVideosAsync(CancellationToken) : Task<IEnumerable<\
  System_Windows_Markup_IComponentConnector_Connect(I
  System_Windows_Markup_IStyleConnector_Connect(Int32, Ol
  CancelButton : Button
  VideoBox : ListBox
  _CancelButton : Button
  _contentLoaded : Boolean
  _VideoBox : ListBox
```

```
Private Function QueryVideosAsync() As Task(Of IEnumerable(Of
Declaring Type:  Channel_AsyncAwait.MainWindow
Assembly:        Channel_AsyncAwait, Version=1.0.0.0
```

```
<AsyncStateMachine(GetType(VB$StateMachine_1_QueryVideosAsync))> _
Private Function QueryVideosAsync() As Task(Of IEnumerable(Of Video))
   Dim stateMachine As New VB$StateMachine_1_QueryVideosAsync With { _
      .$VB$Me = Me, _
      .$State = -1, _
      .$Builder = AsyncTaskMethodBuilder(Of IEnumerable(Of Video)).Create _
   }
   stateMachine.$Builder.Start(Of VB$StateMachine_1_QueryVideosAsync)(stateMachine)
   Return stateMachine.$Builder.Task
End Function
```

FIGURE 42.5 Investigating the actual generated code with .NET Reflector.

For your convenience, the following is the auto-generated code for `QueryVideosAsync`:

```
<AsyncStateMachine(GetType(VB$StateMachine_1_QueryVideosAsync))> _
Private Function QueryVideosAsync() As Task(Of IEnumerable(Of Video))
    Dim stateMachine As New VB$StateMachine_1_QueryVideosAsync With { _
        .$VB$Me = Me, _
        .$State = -1, _
        .$Builder = AsyncTaskMethodBuilder(Of IEnumerable(Of Video)).Create _
    }
    stateMachine.$Builder.
    Start(Of VB$StateMachine_1_QueryVideosAsync)(stateMachine)
    Return stateMachine.$Builder.Task
End Function
```

You do not need to know the code in detail because this implementation is purely internal; however, the real code relies on the `AsyncTaskMethodBuilder` class, which creates an instance of an asynchronous method and requires specifying a state machine that controls the execution of the asynchronous task (which is returned once completed). For each asynchronous method, the compiler generated an object representing the state machine. For instance, the compiler generated an object called `VB$StateMachine_1_QueryVideosAsync` that represents the state machine that controls the execution of the `QueryVideosAsync` method. Listing 42.3 contains the code of the aforementioned structure.

LISTING 42.3 Internal Implementation of a State Machine for `Async` Methods

```
<CompilerGenerated> _
Private NotInheritable Class VB$StateMachine_1_QueryVideosAsync
    Implements IAsyncStateMachine
    ' Methods
    Public Sub New()
    <CompilerGenerated> _
    Friend Sub MoveNext() Implements IAsyncStateMachine.MoveNext
    <DebuggerNonUserCode> _
    Private Sub SetStateMachine(stateMachine As IAsyncStateMachine) _
            Implements IAsyncStateMachine.SetStateMachine

    ' Fields
    Friend $A0 As TaskAwaiter(Of String)
    Public $Builder As AsyncTaskMethodBuilder(Of IEnumerable(Of Video))
    Public $State As Integer
    Friend $VB$Me As MainWindow
    Friend $VB$ResumableLocal_client$0 As WebClient
    Friend $VB$ResumableLocal_data$1 As String
    Friend $VB$ResumableLocal_doc$2 As XDocument
    Friend $VB$ResumableLocal_query$3 As IEnumerable(Of Video)
End Class
```

The code in Listing 42.3 is certainly complex, and you are not required to know how it works under the hood, but focus for a moment on the `MoveNext` method. This method is responsible of the asynchronous execution of tasks; depending on the state of the task, it resumes the execution at the appropriate point. You can see how the compiler translates the `Await` keyword into an instance of the `TaskAwaiter` structure, which is assigned with the result of the invocation to the `Task.GetAwaiter` method (both are for compiler-use only). If you compare the result of this analysis with the ease of usage of the `Async` pattern, it is obvious that the compiler does tremendous work to translate that simplicity into a very efficient asynchronous mechanism.

Documentation and Examples of the `Async` Pattern

Microsoft offers a lot of useful resources to developers who want to start coding the new way. The following list summarizes several resources that you are strongly encouraged to visit to make your learning of `Async` complete:

- **Visual Studio Asynchronous Programming:** The official developer center for `Async`. Here you can find documentation, downloads, instructional videos, and more on language specifications. It is available at http://msdn.microsoft.com/en-us/vstudio/async.aspx.

- **101 Async Samples:** An online page that contains a huge number of code examples based on Async for both Visual Basic and Visual C#. You can find samples at http://www.wischik.com/lu/AsyncSilverlight/AsyncSamples.html.
- **Sample code:** Available on the MSDN Code Gallery (http://code.msdn.microsoft.com).

Do not leave out of your bookmarks the root page of the .NET Framework 4.5 and 4.6 documentation (http://msdn.microsoft.com/en-us/library/w0x726c2).

Exception Handling in `Async`

Another great benefit of using the `Async` pattern is that exception handling is done the usual way. In fact, if an awaited method throws an exception, this can be naturally handled within a `Try..Catch..Finally` block. The following code provides an example:

```
Private Async Sub DownloadSomethingAsync()
    Dim client As New System.Net.WebClient
    Try
        Dim result = Await client.
            DownloadStringTaskAsync("http://msdn.com/vbasic")
    Catch ex As Exception
        Console.WriteLine(ex.Message)
    Finally
        Console.WriteLine("Operation completed.")
    End Try
End Sub
```

As you can see, there is no difference in handling exceptions inside asynchronous methods compared to classic synchronous methods. This makes code migration easier.

Implementing Task-Based Asynchrony

As you remember from Chapter 41, the `Task` class provides methods and other members that enable you to execute CPU-intensive work, by splitting code across all the available processors so that most of the code is executed concurrently, when possible. Such members of the `Task` class return instances of the `Task` class itself, and therefore can be used along with `Await`. This possibility has some advantages:

- You can execute synchronous code on a separate thread more easily.
- You can run multiple tasks concurrently and wait for them to complete before making further manipulations.
- You can use `Await` with CPU-consuming code.

This approach is known as Task-Based Asynchrony, and in this section you learn how to get the most out of it.

Switching Threads

In Chapter 40 you learned how to write code that can run on a separate thread, how to create new threads manually, and how to use the Thread Pool managed by the .NET Framework. With this approach, you run a portion of synchronous code in a separate thread, thus keeping the caller thread-free from an intensive and potentially blocking work. In the .NET Framework 4.6, you have additional alternatives to reach the same objective but writing simpler code. The `Task.Run` method enables you to run a new task asynchronously, queuing such a task into a thread in the Thread Pool. The result is returned as `Task` handle for the intensive work, so that you can use `Await` to wait for the result. `Task.Run` takes as the first argument a delegate that defines the work that will be executed in the background thread. Such a delegate can be represented either by a method that you point to via the `AddressOf` clause or by lambdas. In the latter case, the delegate can be a `System.Action` represented by a statement lambda or a `System.Func(Of T)` represented by a lambda expression. The following example demonstrates how synchronous code is easily executed in a separate thread by invoking `Task.Run`:

```
Private Async Sub RunIntensiveWorkAsync()
    'This runs on the UI thread
    Console.WriteLine("Starting...")

    'This runs on a Thread Pool thread
    Dim result As Integer = Await Task.Run(Function()
                                               Dim workResult As Integer = _
                                                   SimulateIntensiveWork()
                                               Return workResult
                                           End Function)


    'This runs again on the UI thread
    Console.WriteLine("Finished")
    Console.ReadLine()
End Sub

Private Function SimulateIntensiveWork() As Integer
    Dim delay As Integer = 5000
    Threading.Thread.Sleep(delay)
    Return delay
End Function
```

While the result of `Task.Run` is being awaited, the control is immediately returned to the user interface, which remains responsive in the Console window. All the `Console.WriteLine` and `Console.ReadLine` statements are executed on the UI thread, whereas the simulated CPU-consuming code runs on the separate thread. `Task.Run` schedules a new task exactly as `Task.Factory.StartNew` does; you saw this method in Chapter 41. So, this code has the same effect as using `Task.Run`:

```
Dim result As Integer = Await Task.Factory.StartNew(Function()
                                                       Dim workResult _
                                                       As Integer = _
                                                           SimulateIntensiveWork()
                                                       Return workResult
                                                   End Function)
```

In summary, `Task.Run` lets you easily execute intensive computations on a separate thread, taking all the benefits of `Await`.

Using Combinators

The `Task` class has other interesting usages, such as managing concurrent operations. This is possible because of two methods, `Task.WhenAll` and `Task.WhenAny`, also known as *combinators*. `Task.WhenAll` creates a task that will complete when all the supplied tasks complete; `Task.WhenAny` creates a task that will complete when at least one of the supplied tasks completes. For example, imagine you want to download multiple RSS feeds information from a website. Instead of using `Await` against individual tasks to complete, you can use `Task.WhenAll` to continue only after all tasks have completed. The following code provides an example of concurrent download of RSS feeds from the Microsoft Channel 9 feed used previously:

```
Private Async Sub DownloadAllFeedsAsync()
    Dim feeds As New List(Of Uri) From
        {New Uri("http://channel9.msdn.com/Tags/windows+8/RSS"),
        New Uri("http://channel9.msdn.com/Tags/windows+phone"),
        New Uri("http://channel9.msdn.com/Tags/visual+basic/RSS")}

    'This task completes when all of the requests complete
    Dim feedCompleted As IEnumerable(Of String) = _
                                           Await Task.
                                           WhenAll(From feed In feeds
                                           Select New System.Net.WebClient().
                                           DownloadStringTaskAsync(feed))

    'Additional work here...
End Sub
```

This code creates a collection of tasks by sending a `DownloadStringTaskAsync` request for each feed address in the list of feeds. The task completes (and thus the result of awaiting `WhenAll` is returned) only when all three feeds have been downloaded, meaning that the complete download result will not be available if only one or two feeds have been downloaded. `WhenAny` works differently because it creates a task that completes when any of the tasks in a collection of tasks completes. The following code demonstrates how to rewrite the previous example using `WhenAny`:

```
Private Async Sub DownloadFeedsAsync()
    Dim feeds As New List(Of Uri) From
        {New Uri("http://channel9.msdn.com/Tags/windows+8/RSS"),
        New Uri("http://channel9.msdn.com/Tags/windows+phone"),
        New Uri("http://channel9.msdn.com/Tags/visual+basic/RSS")}

    'This task completes when any of the requests complete
    Dim feedCompleted As Task(Of String) = Await Task.WhenAny(From feed In feeds
                                                 Select New System.Net.WebClient().
                                                 DownloadStringTaskAsync(feed))
    'Additional work here...
End Sub
```

In this case a single result will be yielded because the task will be completed when any of the tasks completes. You can also wait for a list of tasks defined as explicit asynchronous methods, like in the following example:

```
Public Async Sub WhenAnyRedundancyAsync()

    Dim messages As New List(Of Task(Of String)) From
        {
            GetMessage1Async(),
            GetMessage2Async(),
            GetMessage3Async()
        }
    Dim message = Await Task.WhenAny(messages)
    Console.WriteLine(message.Result)
    Console.ReadLine()
End Sub

Public Async Function GetMessage1Async() As Task(Of String)
    Await Task.Delay(700)
    Return "Hi VB guys!"
End Function

Public Async Function GetMessage2Async() As Task(Of String)
    Await Task.Delay(600)
    Return "Hi C# guys!"
End Function

Public Async Function GetMessage3Async() As Task(Of String)
    Await Task.Delay(500)
    Return "Hi F# guys!"
End Function
```

Here you have three asynchronous methods, each returning a string. The code builds a list of tasks including each asynchronous method in the list. `Task.WhenAny` receives the instance of the collection of tasks as an argument and completes when one of the three methods completes. In this example, you are also seeing for the first time the `Task.Delay` method. This is the asynchronous equivalent of `Thread.Sleep`, but while the latter blocks the thread for the specified number of milliseconds, with `Task.Delay` the thread remains responsive.

ADDITIONAL SAMPLES ON `WhenAny`

The 101 `Async` Samples include a couple of interesting examples of different usages of `WhenAny`, such as interleaving one request at a time and limiting the number of concurrent downloads. You find them under the Combinators node of the samples page mentioned at the beginning of the chapter.

Cancellation and Progress

Because the `Async` pattern relies on the `Task` class, implementing cancellation is something similar to what you have already studied back in Chapter 41, thus the `CancellationTokenSource` and `CancellationToken` classes are used. In this section you see how to implement cancellation both for asynchronous methods and for `Task.Run` operations. Next, you learn how to report the progress of an operation, which is common in asynchronous programming and improves the user experience.

Implementing Cancellation

Let's look at the WPF sample application created in the section "Getting Started with `Async`/`Await`." Imagine you want to give users the ability of cancelling the download of the RSS feed from the Microsoft Channel9 website. First, make a slight modification to the user interface so that the main `Grid` is divided into two rows, and in the first row add a `Button` like this:

```
<Grid.RowDefinitions>
    <RowDefinition Height="40"/>
    <RowDefinition/>
</Grid.RowDefinitions>
<Button Width="120" Height="30" Name="CancelButton"
        Content="Cancel"/>
```

Do not forget to add the `Grid.Row="1"` property assignment for the `ListBox` control. Double-click the new button so that you can quickly access the code editor. Declare a new `CancellationTokenSource` object that will listen for cancellation requests. The event handler for the new button's `Click` event will invoke the `Cancel` method on the instance of the `CancellationTokenSource`:

```
Private tokenSource As CancellationTokenSource

Private Sub CancelButton_Click(sender As Object, e As RoutedEventArgs) _
    Handles CancelButton.Click
    'If Me.tokenSource IsNot Nothing Then
    '    Me.tokenSource.Cancel()
    'End If
    Me.tokenSource?.Cancel()
End Sub
```

The user can now request cancellation by clicking this button. Next, you need to make a couple of edits to the `QueryVideosAsync` method created previously. The first edit is making this method receive a `CancellationToken` object as an argument. This object will handle cancellation requests during the method execution. The second edit requires replacing the `WebClient` class with a new class called `HttpClient`. The reason for this change is that the `WebClient`'s asynchronous methods no longer support cancellation as in the first previews of the `Async` library, although asynchronous methods in `System.Net.Http.HttpClient` do. Among the others, this class exposes a method called `GetAsync` that retrieves contents from the specified URL and receives the cancellation token as the second argument. The result is returned under the form of a `System.Net.Http.HttpResponseMessage` class. As the name implies, this class represents an HTTP response message including the status of the operation and the retrieved data. The data is represented by a property called `Content`, which exposes methods to convert data into a stream (`ReadAsStreamAsync`), into an array of bytes (`ReadAsByteArrayAsync`), and into a string (`ReadAsStringAsync`). Other than changing the code to use `HttpClient` and to receive the cancellation token, you only need to handle the `OperationCanceledException`, which is raised after the cancellation request is received by the asynchronous method. The following code demonstrates the `QueryVideosAsync` method:

```
'The following implementation with HttpClient supports Cancellation
Private Async Function QueryVideosAsync(token As CancellationToken) As  _
        Task(Of IEnumerable(Of Video))
    Try
        Dim client As New HttpClient

        'Get the feed content as an HttpResponseMessage
        Dim data = Await client.GetAsync(New Uri(Video.FeedUrl), token)

        'Parse the content into a String
        Dim actualData = Await data.Content.ReadAsStringAsync

        Dim doc = XDocument.Parse(actualData)

        Dim query = From video In doc...<item>
                    Select New Video With {
                    .Title = video.<title>.Value,
                    .Speaker = video.<dc:creator>.Value,
                    .Url = video.<link>.Value,
                        .Thumbnail = video...<media:thumbnail>.
                            FirstOrDefault?.@url,
                        .DateRecorded = String.Concat("Recorded on ",
                            Date.Parse(video.<pubDate>.Value,
                            Globalization.CultureInfo.InvariantCulture).
                            ToShortDateString)}

        Return query
    Catch ex As OperationCanceledException
        MessageBox.Show("Operation was canceled by the user.")
        Return Nothing
    Catch ex As Exception
        MessageBox.Show(ex.Message)
        Return Nothing
    End Try
End Function
```

The very last edit to the application is changing the `LoadVideosAsync` method to launch the query passing a cancellation token:

```
Private Async Function LoadVideosAsync() As Task
    Me.tokenSource = New CancellationTokenSource

    Me.DataContext = Await QueryVideosAsync(Me.tokenSource.Token)
End Function
```

If you now run the application, not only will the user interface remain responsive, but you will be also able to click the Cancel button to stop the query execution. Notice that in a synchronous approach, implementing cancellation has no benefits. In fact, if on one side writing code to support cancellation is legal, on the other side the user would never have a chance to click a button because the UI thread would be blocked until the completion of the task. Similarly, you can add cancellation to tasks running in a separate thread and started with `Task.Run`. By continuing the example shown previously about this method, you can first rewrite the `SimulateIntensiveWork` method as follows:

```
Private Function SimulateIntensiveWork(token As CancellationToken) _
         As Integer
    Dim delay As Integer = 5000
    Threading.Thread.Sleep(delay)

        token.ThrowIfCancellationRequested()

    Return delay
End Function
```

You should be familiar with this approach because it has been discussed in Chapter 41. The method receives the cancellation token and checks for cancellation requests. If any exist, it throws an `OperationCanceledException`. Next, you add support for cancellation by passing an instance of the `CancellationTokenSource` class to the method invocation inside `Task.Run`:

```
Private cancellationToken As CancellationTokenSource

Private Async Sub RunIntensiveWorkAsync()
    cancellationToken = New CancellationTokenSource
    'This runs on the UI thread
    Console.WriteLine("Starting...")

    Try
        'This runs on a Thread Pool thread
        Dim result As Integer = Await Task.Run(Function()
                                                   Dim workResult As Integer = _
                                                   SimulateIntensiveWork( _
                                                   cancellationToken.Token)
                                                   Return workResult
                                               End Function)

        'This runs again on the UI thread
        Console.WriteLine("Finished")
    Catch ex As OperationCanceledException
        Console.WriteLine("Canceled by the user.")
    Catch ex As Exception

    End Try
    Console.ReadLine()
End Sub
```

To request cancellation, you should call the `cancellationToken.Cancel` method. At that point, the request is intercepted and an `OperationCanceledException` is thrown.

Reporting Progress

Reporting the progress of an asynchronous method execution is a common requirement. There is a pattern that you can use and that makes things easier. This pattern relies on the `System.IProgress(Of T)` interface and the `System.Progress(Of T)` class, which expose a `ProgressChanged` event that must be raised when the asynchronous operation is in progress. To provide an example that is easy to understand, imagine you still want to download the content of some feeds from the Microsoft Channel9 website and refresh the progress every time a site has been downloaded completely. The current example is based on a Console application. Consider the following code:

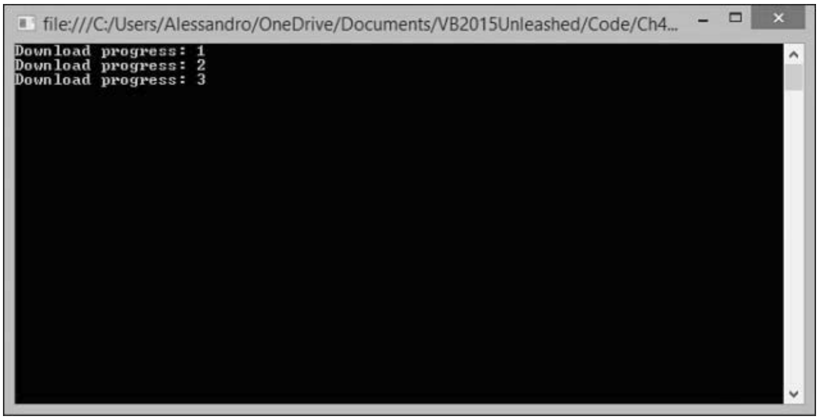
```
Private progress As Progress(Of Integer)
Private counter As Integer = 0
```

```
Sub Main()
    Try
        progress = New Progress(Of Integer)
        AddHandler progress.ProgressChanged, Sub(sender, e)
                                                 Console.
                                                 WriteLine _
                                                 ("Download progress: " & _
                                                 CStr(e))
                                             End Sub

        DownloadAllFeedsAsync(progress)

    Catch ex As Exception
        Console.WriteLine(ex.Message)
    Finally
        Console.ReadLine()
    End Try
End Sub
```

You first declare an object of type `Progress(Of Integer)` and a counter. The first object will receive the progress value when the `ProgressChanged` event is raised. In this case, the code uses the `Integer` type to pass a simple number, but you can pass more complex information with a different or custom type. Then the code specifies a handler for the `ProgressChanged` event, with type inference for the lambda's parameters. `Sender` is always `Object`, whereas `e` is of the same type as the generic type you assigned to `Progress`. So, in this case it is of type `Integer`. Here you are working in a Console application and are thus displaying the value as a text message. But in real-world applications, this is the value that you could assign to a `ProgressBar` control to report the progress in the user interface. The instance of the `Progress` class must be passed to the asynchronous method that performs the required tasks. The `Progress` class has just one method called `Report`; you invoke it after an `Await` invocation. The following code demonstrates how to report the progress of downloading a number of feeds:

```
Private Async Sub DownloadAllFeedsAsync(currentProgress As IProgress(Of Integer))
    Dim client As New System.Net.WebClient

    Dim feeds As New List(Of Uri) From
        {New Uri("http://channel9.msdn.com/Tags/windows+8/RSS"),
         New Uri("http://channel9.msdn.com/Tags/windows+phone"),
         New Uri("http://channel9.msdn.com/Tags/visual+basic/RSS")}
    For Each URL In feeds
        Await client.DownloadStringTaskAsync(URL)
        counter += 1
        If currentProgress IsNot Nothing Then currentProgress.Report(counter)
    Next
End Sub
```

`Report` receives as an argument an object of the same type that you assigned as the generic argument of the `Progress` class declaration in this case a counter of type `Integer` that is incremented every time a feed is downloaded. If you run this code, every time a feed is returned, the progress is also shown in the user interface, as demonstrated in Figure 42.6.


file:///C:/Users/Alessandro/OneDrive/Documents/VB2015Unleashed/Code/Ch4...

```
Download progress: 1
Download progress: 2
Download progress: 3
```

FIGURE 42.6 Reporting the progress of an asynchronous method.

This pattern makes reporting the progress of a task and in real-world applications, such as WPF and Windows apps, easy. It also makes updating controls like the `ProgressBar` incredibly simple by assigning to such controls the value stored in the instance of the `Progress` class.

Asynchronous Lambda Expressions

Methods can be asynchronous, but so can lambda expressions. To be asynchronous, a lambda must have the `Async` modifier and must return `Task` or `Task(Of T)`, but it cannot accept `ByRef` arguments and cannot be an iterator function. A lambda can be asynchronous when its code uses the `Await` operator to wait for a `Task` result. An example of asynchronous lambdas is with event handlers. For instance, you might need to wait for the result of a task when an event is raised, as in the following code snippet that handles a button's `Click`:

```
AddHandler Me.Button1.Click, Async Sub(sender, e)
                                 Await DoSomeWorkAsync
                             End Sub
```

You do not need an asynchronous lambda if the work you are going to execute does not return a `Task`. Another typical usage of asynchronous lambdas is with `Task.Run`. The following code shows the same example described when introducing `Task.Run`, but now the lambda that starts the intensive work is marked with `Async` and the method that actually performs intensive computations returns a `Task` so that it can be awaited:

```
Private Async Sub RunIntensiveWorkAsync()
    cancellationToken = New CancellationTokenSource
    'This runs on the UI thread
    Console.WriteLine("Starting...")

    Try
        'This runs on a Thread Pool thread
        Dim result As Integer = Await Task.Run(Async Function()
                                                   Dim workResult As Integer = _
                                                    Await _
                                                    SimulateIntensiveWorkAsync()
                                                   Return workResult
                                               End Function)
        'This runs again on the UI thread
        Console.WriteLine("Finished")
    Catch ex As OperationCanceledException
        Console.WriteLine("Canceled by the user.")
    Catch ex As Exception

    End Try
    Console.ReadLine()
End Sub

Private Async Function SimulateIntensiveWorkAsync() As Task(Of Integer)
    Dim delay As Integer = 1000
    Await Task.Delay(delay)
    Return delay
End Function
```

This code simulates CPU-intensive work inside an asynchronous method. However, this is not best practice and should be avoided when possible. Here it is shown for demonstration purposes only. For additional tips about asynchronous methods, visit http://channel9.msdn.com/Series/Three-Essential-Tips-for-Async/Async-Library-Methods-Shouldn-t-Lie.

Asynchronous I/O File Operations in .NET 4.6

Before .NET Framework 4.5, you could perform asynchronous operations over files and streams by using the Asynchronous Programming Model and methods such as `Stream.BeginRead` and `Stream.EndRead`. This kind of approach can be good, but it has the limitations described in the section "Getting Started with `Async`/`Await`" in this chapter. With .NET Framework 4.5 and after, asynchronous I/O operations can be simplified by using the `Async` pattern and by implementing asynchronous versions of methods that work with files and stream to avoid blocking the main thread. Such methods are exposed by the

`Stream`, `FileStream`, `MemoryStream`, `TextReader`, and `TextWriter` classes that you saw in action back in Chapter 18, "Manipulating Files and Streams." Table 42.1 summarizes the available asynchronous methods.

TABLE 42.1 Asynchronous Methods for Stream Classes

Method	Description	Return Type
`ReadAsync`	Reads a sequence of bytes from a stream and advances the position by the number of bytes read, with an asynchronous approach	`Task(Of Integer)`
`WriteAsync`	Writes a sequence of bytes to a stream, with an asynchronous approach	`Task`
`FlushAsync`	Clears buffers associated with the stream sending buffered data to the stream, using asynchrony	`Task`
`CopyToAsync`	Asynchronously copies a number of bytes from a stream to another	`Task`
`ReadLineAsync`	Reads a line of characters using asynchrony and returns a string	`Task(Of String)`
`ReadToEndAsync`	Asynchronously reads all characters from the current position to the end of the stream, and returns one string	`Task(Of String)`

To see some of these methods in action, create a new WPF project. The user interface of this sample application will have to look like Figure 42.7.

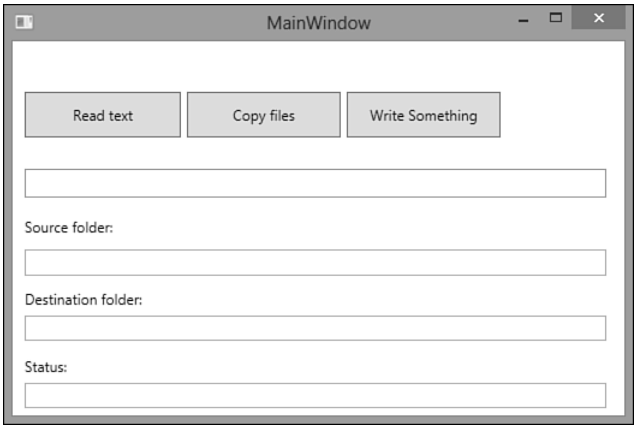


FIGURE 42.7 The user interface of the new sample application.

That said, add the following controls in the designer:

1. Three buttons, named `ReadTextButton`, `CopyButton`, and `WriteButton`. Then, set their `Content` properties with `Read text`, `Copy files`, and `Write Something`, respectively.
2. Four `TextBox` controls, named `ReadTextBox`, `SourceTextBox`, `DestinationTextBox`, and `StatusTextBox`.
3. Three `TextBlock` controls. You do not need to specify a name, but make sure their `Text` property is set with Source folder, Destination folder, and Status, respectively.

The first example uses the `StreamReader` class to read a text file asynchronously. The event handler for the `ReadTextButton.Click` event looks like this:

```
Private Async Sub ReadTextButton_Click(sender As Object,
                                       e As RoutedEventArgs) _
                                       Handles ReadTextButton.Click
    Using reader As New StreamReader("TextFile1.txt")
        Me.ReadTextBox.Text = Await reader.ReadToEndAsync
    End Using

End Sub
```

You mark the event handler with `Async`, and because this method will not be awaited by any other methods, it does not need to return a `Task`. Therefore, it can be defined as a `Sub`. Notice how you use `Await` together with the `ReadToEndAsync` method, while the rest of the implementation is made the usual way. The next example is about copying streams asynchronously. The following code shows the implementation of the `CopyButton.Click` event handler:

```
Private Async Sub CopyButton_Click(sender As Object,
                                   e As RoutedEventArgs) _
                                   Handles CopyButton.Click
    If Me.SourceTextBox.Text = "" Then
        MessageBox.Show("Please specify the source folder")
        Exit Sub
    End If

    If Me.DestinationTextBox.Text = "" Then
        MessageBox.Show("Please specify the target folder")
        Exit Sub
    End If

    For Each fileName As String In Directory.
        EnumerateFiles(Me.SourceTextBox.Text)
        Using SourceStream As FileStream = File.Open(fileName, FileMode.Open)
            Using DestinationStream As FileStream =
                File.Create(String.Concat(Me.DestinationTextBox.Text,
                                          fileName.
                                          Substring(fileName.LastIndexOf("\"c))))
                Await SourceStream.CopyToAsync(DestinationStream)
                Me.StatusTextBox.Text = "Copied " + DestinationStream.Name
            End Using
        End Using
    Next

End Sub
```

In particular, the code enumerates the content of the source folder and for each file it opens a stream for reading and another one for writing into the target folder. `Await` enables you to execute asynchronously the operation with the asynchronous method called `CopyToAsync`. It is worth mentioning that, with this approach, you can refresh the user interface with useful information, like showing the name of the last copied file. In a synchronous approach, this would not be possible because the UI would be blocked until the completion of the operation. The last example demonstrates how to write some text into a file asynchronously. This is the event handler for the `WriteButton.Click` event:

```
Private Async Sub WriteButton_Click(sender As Object,
                              e As RoutedEventArgs) Handles WriteButton.Click
    Dim uniencoding As UnicodeEncoding = New UnicodeEncoding()
    Dim filename As String =
        "c:\temp\AsyncWriteDemo.txt"

    Dim result As Byte() = uniencoding.GetBytes("Demo for Async I/O")

    Using SourceStream As FileStream = File.Open(filename, FileMode.OpenOrCreate)
        SourceStream.Seek(0, SeekOrigin.End)
        Await SourceStream.WriteAsync(result, 0, result.Length)
    End Using

End Sub
```

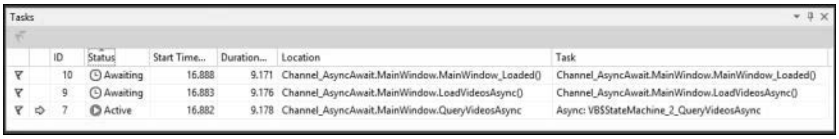
In this particular example, the code is written exactly like in the synchronous counterpart, except for the `Async` modifier and the `Await` statement that invokes the `WriteAsync` method (instead of running `Write`). By using the `Async` pattern, writing applications that work with streams and remain responsive has become dramatically simpler.

IMPLEMENTING CUSTOM AWAITERS

By using the Task-based asynchrony, you can work with instances of the `Task` class and use `Await` when waiting for their results. Using `Task.Run` and combinators will usually avoid the need to create custom types that can be used along with `Await`. However, in some situations you might want to define your own awaitable types. Reasons for making this can be various for example, performing some work over a control in the user interface from within a background thread. To accomplish this, you define a `Structure` or `Class` that implements the `INotifyCompletion` interface to expose a method called `OnCompleted`; then you need a method called `GetAwaiter`. The MSDN documentation does not provide enough information about building custom types that can be used with Await, but fortunately a blog post series by Lucian Wischik from Microsoft shows how to create one. You can find it at http://blogs.msdn.com/b/lucian/archive/2012/11/28/how-to-await-a-storyboard-and-other-things.aspx. There is also another blog post from the Stephen Toub, in which he discusses how to implement a custom awaitable type to perform asynchronous operations with sockets; you can find it at http://blogs.msdn.com/b/pfxteam/archive/2011/12/15/10248293.aspx.

Debugging Tasks

Visual Studio 2015 allows you to collect information about asynchronous tasks with the Tasks window. This is not a new tool; it has been available since Visual Studio 2012, but only for the Task Parallel Library. It now provides support for the `Async`/`Await` pattern in Visual Studio 2013 and requires Windows 8 or higher. To understand how it works, place a breakpoint on the `QueryVideosAsync` method in the sample WPF application and press **F5**. When the breakpoint is hit, select **Debug**, **Windows**, **Tasks** and press **F11** to step into the code. As you step into asynchronous method calls, the Tasks window shows information on each task, as shown in Figure 42.8.



Tasks

		ID	Status	Start Time...	Duration...	Location	Task
		10	Awaiting	16.888	9.171	Channel_AsyncAwait.MainWindow.MainWindow_Loaded()	Channel_AsyncAwait.MainWindow.MainWindow_Loaded()
		9	Awaiting	16.883	9.176	Channel_AsyncAwait.MainWindow.LoadVideosAsync()	Channel_AsyncAwait.MainWindow.LoadVideosAsync()
	➪	7	Active	16.882	9.178	Channel_AsyncAwait.MainWindow.QueryVideosAsync	Async: VB$StateMachine_2_QueryVideosAsync

FIGURE 42.8 The Tasks window.

As you can see, the Tasks window shows what task is active and what other tasks are awaiting the completion of the active task. It shows the duration, the method that started the asynchronous task (in the Location column), and the actual running task, such as a state machine (in the Task column). If you hover over the values in the ID column, you will also get additional information about the task execution order. This very useful tool helps you understand the execution flow of your asynchronous code.

Summary

Building applications that remain responsive whatever task they are executing is something that developers must take care of, especially from the user interface perspective. This chapter explained how to use asynchrony to build responsive applications by first discussing old-style programming models such as the Event-based Asynchronous Pattern and the Asynchronous Programming Model. Both provide techniques to write asynchronous code that runs on separate threads. However, both have some limitations, such as code complexity, issues in returning information to caller threads or functions, and managing errors effectively. Visual Basic 2015 offers the asynchronous pattern based on the `Async` and `Await` keywords, which enable you to keep the UI thread free and write code that is similar to the synchronous approach and is much easier to read and maintain. You invoke an asynchronous task, and then its result is returned some time later, but the control is immediately returned to the caller. When the result is available, an implicit callback enables you to consume the result of the asynchronous operation effectively. The `Async` pattern relies on the concept of task and on the `Task` class, which means that asynchrony easily includes support for cancellation, progress, anonymous delegates, and concurrent operations. The .NET Framework 4.6 itself exposes built-in classes that use the new `Async` pattern for making asynchronous I/O operations much easier with particular regard to streams and network requests. The `Async` pattern and the `Async`/`Await` keywords can be used across multiple platforms and presentation technologies.

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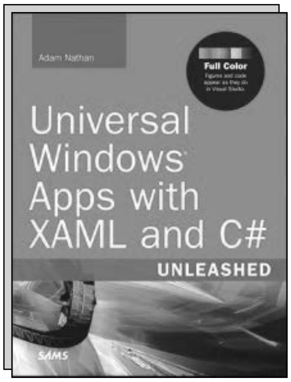
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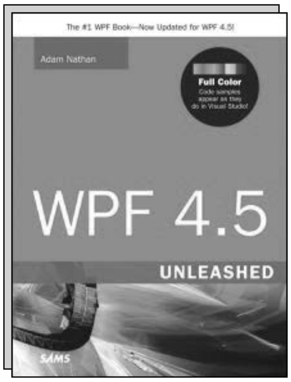
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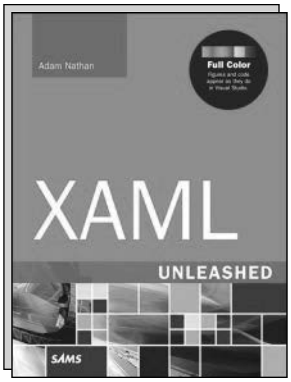
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