

# .Net Interface Guide

Version 13.1

**DYALOG** APL

The tool of thought for expert programming

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# Contents

<b>Chapter 1: Overview</b> .....	<b>1</b>
Classic and Unicode Versions.....	1
Introduction.....	1
Prerequisites.....	3
.NET Interface Support Files.....	3
Files Installed with Dyalog.....	4
Configuring the .Net Framework.....	4
<b>Chapter 2: Accessing .Net Classes</b> .....	<b>7</b>
Introduction.....	7
Locating .NET Classes and Assemblies.....	7
Using .NET Classes.....	10
Browsing .Net Classes.....	13
Advanced Techniques.....	21
More Examples.....	24
Enumerations.....	28
Handling Pointers with Dyalog.ByRef.....	29
<b>Chapter 3: Using Windows.Forms</b> .....	<b>33</b>
Introduction.....	33
Creating GUI Objects.....	33
Object Hierarchy.....	34
Positioning and Sizing Forms and Controls.....	34
Modal Dialog Boxes.....	34
Non-Modal Forms.....	39
<b>Chapter 4: Writing .Net Classes in Dyalog APL</b> .....	<b>41</b>
Introduction.....	41
Assemblies, Namespaces and Classes.....	41
Example 1.....	42
Example 2.....	47
Example 2a.....	50
Example 3.....	52
Example 4.....	55
Example 5.....	59
Interfaces.....	63

---

<b>Chapter 5: Dyalog APL and IIS</b> .....	<b>65</b>
Introduction.....	65
IIS Applications and Virtual Directories.....	66
Internet Services Manager.....	67
<b>Chapter 6: Writing Web Services</b> .....	<b>75</b>
Introduction.....	75
Web Service (.asmx) Scripts.....	76
Compilation.....	77
Exporting Methods.....	78
Web Service Data Types.....	79
Execution.....	79
Global.asax and Application and Session Objects.....	80
Sample Web Service: EG1.....	80
Sample Web Service: LoanService.....	83
Sample Web Service: GolfService.....	88
Sample Web Service: EG2.....	106
<b>Chapter 7: Calling Web Services</b> .....	<b>111</b>
Introduction.....	111
The MakeProxy function.....	111
Using LoanService from Dyalog APL.....	112
Using GolfService from Dyalog APL.....	113
Exploring Web Services.....	117
Asynchronous Use.....	119
<b>Chapter 8: Writing ASP.NET Web Pages</b> .....	<b>123</b>
Introduction.....	123
Your first APL Web Page.....	124
The Page_Load Event.....	129
Code Behind.....	132
Workspace Behind.....	135
<b>Chapter 9: Writing Custom Controls for ASP.NET</b> .....	<b>153</b>
Introduction.....	153
The SimpleCtl Control.....	154
The TemperatureConverterCtl1 Control.....	158
The TemperatureConverterCtl2 Control.....	163
The TemperatureConverterCtl3 Control.....	170
<b>Chapter 10: APLScript</b> .....	<b>175</b>

---

Introduction.....	175
The APLScript Compiler.....	176
Creating an APLScript File.....	178
Transferring code from the Dyalog APL Session.....	179
General principles of APLScript.....	180
Creating Programs (.exe) with APLScript.....	181
Creating .NET Classes with APLScript.....	184
Creating ASP.NET Classes with APLScript.....	191
<b>Chapter 11: Visual Studio Integration.....</b>	<b>195</b>
Introduction.....	195
Hello World Example.....	195
Using an Existing Workspace.....	200
<b>Chapter 12: Implementation Details.....</b>	<b>203</b>
Classic and Unicode Versions.....	203
Introduction.....	203
Isolation Mode.....	204
Structure of the Active Workspace.....	205
Threading.....	208
Debugging an APL.NET Class.....	210
<b>Index.....</b>	<b>213</b>



# Chapter 1:

## Overview

### Classic and Unicode Versions

Dyalog 13.0 exists in two versions, the Classic version, and the Unicode version. The Unicode version has full support for Unicode characters. The Classic version is less compatible with Unicode and is provided for compatibility with existing Dyalog applications.

There are a number of files that have different names depending on their Classic or Unicode flavour. For example the "Classic" `dyalog130.dll` has a `dyalog130_unicode.dll` counterpart; the "Classic" `dyalogc.exe` has a `dyalogc_unicode.exe` counterpart.

This document typically refers to the "Classic" variant but this should be read as meaning the Unicode variant where appropriate.

### Introduction

This manual describes the Dyalog APL interface to the Microsoft .NET Framework. This document does not attempt to explain the features of the .NET Framework, except in terms of their APL interfaces. For information concerning the .NET Framework, see the documentation, articles and help files, which are available from Microsoft and other sources.

The .NET interface features include:

- The ability to create and use objects that are instances of .NET Classes
- The ability to define new .NET Classes in Dyalog APL that can then be used from other .NET languages such as C# and VB.NET.
- The ability to write Web Services in Dyalog APL.
- The ability to write ASP.NET web pages in Dyalog APL

## .NET Classes

The .NET Framework defines a so-called Common Type System. This provides a set of data types, permitted values, and permitted operations. All cooperating languages are supposed to use these types so that operations and values can be checked (by the Common Language Runtime) at run time. The .NET Framework provides its own built-in class library that provides all the primitive data types, together with higher-level classes that perform useful operations.

Dyalog APL allows you to create and use instances of .NET Classes, thereby gaining access to a huge amount of component technology that is provided by the .NET Framework.

It is also possible to create Class Libraries (Assemblies) in Dyalog APL. This allows you to export APL technology packaged as .NET Classes, which can then be used from other .NET programming languages such as C# and Visual Basic.

The ability to create and use classes in Dyalog APL also provides you with the possibility to design APL applications built in terms of APL (and non-APL) components. Such an approach can provide benefits in terms of reliability, software management and re-usage, and maintenance.

## GUI Programming with System.Windows.Forms

One of the most important .NET class libraries is called `System.Windows.Forms`, which is designed to support traditional Windows GUI programming. Visual Studio .NET, which is used to develop GUI applications in Visual Basic and C#, produces code that uses `System.Windows.Forms`. Dyalog APL allows you to use `System.Windows.Forms`, instead of (and in some cases, in conjunction with) the built-in Dyalog APL GUI objects such as the Dyalog APL Grid, to program the Graphical User Interface.

## Web Services

Web Services are programmable components that can be called by different applications. Web Services have the same goal as COM, but are technically platform independent and use HTTP as the communications protocol with an application. A Web Service can be used either internally by a single application or exposed externally over the Internet for use by any number of applications.



## ASP.NET and WebForms

ASP.NET is a new version of Microsoft Active Server Page technology that makes it easier to develop and deploy dynamic Web applications. To supplement ASP.NET, there are some important new .NET class libraries, including WebForms which allow you to build browser-based user interfaces using the same object-oriented mechanism as you use Windows.Forms for the Windows GUI. The use of these component libraries replaces basic HTML programming.

ASP.NET pages are server-side scripts, that are usually written in C# or Visual Basic. However, you can also employ Dyalog APL directly as a scripting language (*APLScript*) to write ASP.NET web pages. In addition, you can call Dyalog APL workspaces directly from ASP.NET pages, and write custom server-side controls that can be incorporated into ASP.NET pages.

These features give you a wide range of possibilities for using Dyalog APL to build browser-based applications for the Internet, or for your corporate Intranet.

## Prerequisites

The Dyalog APL .NET interface requires a computer running a current version of Windows, from Windows 2000 up to and including Windows 7 and Windows Server 2008, with the following elements installed:

- The Microsoft .NET Framework SDK V2.0 with Service Pack 1 (Version 2.0.50727) or higher.
- Microsoft Internet Information Services (IIS) 5.0 or higher
- Microsoft Internet Explorer Version 6.00 (or higher)

## .NET Interface Support Files

The following files are used to support the .NET interface:

- `dyalogc.exe` and `dyalogc_unicode.exe`<sup>1</sup>; the *APLScript* compiler that is itself written in Dyalog APL and packaged as an executable.
- `dialogprovider.dll`; which performs the initial processing of an *APLScript* file.
- `bridge1301.dll` and `bridge130_unicode.dll`; the interface library to the .NET framework
- `dialognet.dll`; a subsidiary library

---

<sup>1</sup> Some files exist in two versions, a Classic version and a Unicode version.

## Files Installed with Dyalog

The following files are located in the directory where Dyalog is installed:

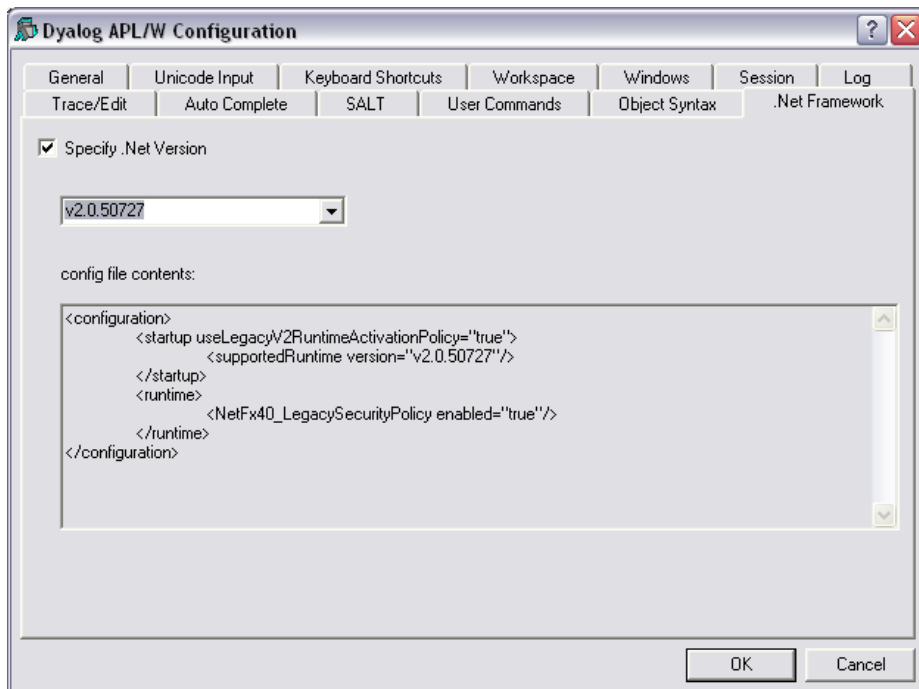
- `dyalog131.dll`; the developer/debug version of the dynamic link library that hosts the execution of Dyalog APL classes and COM objects.
- `dyalog131rt.dll`; the re-distributable run-time version of `dyalog131.dll`.

The `samples` subdirectory contains several sub-directories relating to the .NET interface:

- `aplclasses`; a sub-directory that contains examples of .NET classes written in APL.
- `aplscript`; a sub-directory that contains APLScript examples.
- `asp.net`; a sub-directory that is mapped to the IIS Virtual Directory `dyalog.net`, and contains various sample APL Web applications.
- `winforms`; a sub-directory that contains sample applications that use the `System.Windows.Forms` GUI classes.

## Configuring the .Net Framework

If you have more than one version of the .Net Framework installed, you may select which version APL uses from the .Net Framework tab of the Configuration dialog.



---

This dialog box allows you to specify which version of the .Net Framework you want to use with Dyalog APL. It is only necessary to do this if you have more than one version of the .Net Framework installed.

If *Specify .Net Version* is selected, APL will display the versions of the .Net Framework that are installed in the combo box below.

Choose the version you require and click *OK*.

Unlike the other configuration dialogs, which typically set values in the Registry, this dialog creates a configuration file `dyalog.exe.config` in the same directory as the Dyalog APL program. Note the following:

- Version 13.1 does not read the contents of an existing `dyalog.exe.config` file.
- For .Net Version 2, no configuration file is required; if you select Version 2 having previously selected Version 4, the file will be deleted.
- You will need suitable permissions to write the configuration file, or delete it – you may wish to start APL by right clicking on the Dyalog shortcut and selecting *Run as administrator*.

The dialog box shows the contents of this file as illustrated above.



# Chapter 2:

## Accessing .Net Classes

### Introduction

.NET classes are implemented as part of the Common Type System. The Type System provides the rules by which different languages can interact with one another. *Types* include interfaces, value types and classes. The .NET Framework provides built-in primitive types plus higher-level types that are useful in building applications.

A *Class* is a kind of *Type* (as distinct from interfaces and value types) that encapsulates a particular set of methods, events and properties. The word *object* is usually used to refer to an *instance* of a class. An object is typically created by calling the system function `NEW`, with the class as the first element of the argument.

Classes support inheritance in the sense that every class (but one) is based upon another so-called *Base Class*.

An assembly is a file that contains all of the code and metadata for one or more classes. Assemblies can be dynamic (created in memory on-the-fly) or static (files on disk). For the purposes of this document, the term Assembly refers to a file (usually with a .DLL extension) on disk.

### Locating .NET Classes and Assemblies

Unlike COM objects, which are referenced via the Windows Registry, .NET assemblies and the classes they contain, are generally self-contained independent entities (they can be based upon classes in other assemblies). In simple terms, you can install a class on your system by copying the assembly file onto your hard disk and you can de-install it by erasing the file.

Although classes are arranged physically into assemblies, they are also arranged logically into namespaces. These have nothing to do with Dyalog APL namespaces and, to avoid confusion, are henceforth referred to in this document as .NET namespaces.

Often, a single .NET namespace maps onto a single assembly and usually, the name of the .NET namespace and the name of its assembly file are the same; for example, the .NET namespace `System.Windows.Forms` is contained in an assembly named `System.Windows.Forms.dll`.

However, it is possible for a .NET Namespace to be implemented by more than one assembly; there is not a one-to-one-mapping between .NET Namespaces and assemblies. Indeed, the main top-level .NET Namespace, `System`, is spread over a number of different assembly files.

Within a single .NET Namespace there can be any number of classes, but each has its own unique name. The full name of a class is the name of the class itself, prefixed by the name of the .NET namespace and a dot. For example, the full name of the `DateTime` class in the .NET namespace `System` is `System.DateTime`.

There can be any number of different versions of an assembly installed on your computer, and there can be several .NET namespaces with the same name, implemented in different sets of assembly files; for example, written by different authors.

To use a .NET Class, it is necessary to tell the system to load the assembly (`dll`) in which it is defined. In many languages (including C#) this is done by supplying the *names* of the assemblies or the *pathnames* of the assembly files as a compiler directive.

Secondly, to avoid the verbosity of programmers having to always refer to full class names, the C# and Visual Basic languages allow the .NET namespace prefix to be elided. In this case, the programmer must declare a list of .NET namespaces with `Using` (C#) and `Imports` (Visual Basic) declaration statements. This list is then used to resolve unqualified class names referred to in the code.

In either language, when the compiler encounters the unqualified name of a class, it searches the specified .NET namespaces for that class.

In Dyalog APL, this mechanism is implemented by the `⎕USING` system variable. `⎕USING` performs the same two tasks that `Using/Imports` declarations and compiler directives provide in C# and Visual Basic; namely to give a list of .NET namespaces to be searched for unqualified class names, and to specify the assemblies which are to be loaded.

`⎕USING` is a vector of character vectors each element of which contains 1 or 2 comma-delimited strings. The first string specifies the name of a .NET namespace; the second specifies the *pathname* of an assembly file. This may be a full pathname or a relative one, but must include the file extension (`.dll`). If just the file name is specified, it is assumed to be located in the standard .NET Framework directory that was specified when the .NET Framework was installed (e.g. `C:\windows\Microsoft.NET\Framework\v2.0.50727`)

It is convenient to treat .NET namespaces and assemblies in pairs. For example:

```
⊠USING←'System,mcorlib.dll'
```

```
⊠USING,←c'System.Windows.Forms,System.Windows.Forms.dll'
⊠USING,←c'System.Drawing,System.Drawing.dll'
```

Note that because Dyalog APL automatically loads `mscorlib.dll` (which contains the most commonly used classes in the `System` Namespace), it is not actually necessary to specify it explicitly in `⊠USING`.

Note that `⊠USING` has Namespace scope, i.e. each Dyalog APL Namespace, Class or Instance has its own value of `⊠USING` that is initially inherited from its parent space but which may be separately modified. `⊠USING` may also be localised in a function header, so that different functions can declare different search paths for .NET namespaces/assemblies.

Within a Class script, you may instead employ one or more `:Using` statements to specify the .NET search path. Each of these statements is equivalent to appending an enclosed character vector to `⊠USING`.

```
:Using System,mscorlib.dll
:Using System.Windows.Forms,System.Windows.Forms.dll
:Using System.Drawing,System.Drawing.dll
```

Classes also inherit from the namespace they are contained in. The statement

```
:Using
```

Is equivalent to

```
⊠USING←0ρc''
```

...and allows a class to clear the inherited value before appending to `⊠USING`, or to state that no .Net assemblies should be loaded. If `⊠USING` is empty, APL will not search for .Net classes in order to resolve names which would otherwise give a **VALUE ERROR**.

Note that assigning a simple character vector to `⊠USING` is equivalent to setting it to the enclose of that vector. The statement (`⊠USING←''`) does not empty `⊠USING`, it sets it to a single empty element, which gives access to `mscorlib.dll` and `bridge130.dll` without a namespace prefix. The equivalent is a `:Using` statement followed by a comma separator but no namespace prefix and no assembly name:

```
:Using ,
```

## Using .NET Classes

To create a Dyalog APL object as an instance of a .NET class, you use the `⎕NEW` system function. The `⎕NEW` system function is monadic. It takes a 1 or 2-element argument, the first element being a *class*.

If the argument is a scalar or a 1-element vector, an instance of the class is created using the *constructor* that takes NO argument.

If the argument is a 2-element vector, an instance of the class is created using the *constructor* whose argument matches the disclosed second element.

For example, to create a `DateTime` object whose value is the 30<sup>th</sup> April 2008:

```
⎕USING←'System'
mydt←⎕NEW DateTime (2008 4 30)
```

The result of `⎕NEW` is an reference to the newly created instance:

```
⎕NC c'mydt'
9.2
```

If you format a reference to a .NET Object, APL calls its `ToString` method to obtain a useful description or identification of the object. This topic is discussed in more detail later in this chapter.

```
mydt
30/04/2008 00:00:00
```

If you want to use fully qualified class names instead, one of the elements of `⎕USING` must be an empty vector. For example:

```
⎕USING←,c''
mydt←⎕NEW System.DateTime (2008 4 30)
```

When creating an instance of the `DateTime` class, you are required to provide an argument with two elements: (the class and the *constructor argument*, in our case a 3-element vector representing the date). Many classes provide a default constructor which takes no arguments. From Dyalog APL, the *default constructor* is called by calling `⎕NEW` with only a reference to the class in the argument. For example, to obtain a default `Button` object, we only need to write:

```
mybtn←⎕NEW Button
```



The above statement assumes that you have defined `USING` correctly; there must be a reference to `System.Windows.Forms.dll`, and a namespace prefix which allows the name `Button` to be recognised as `System.Windows.Forms.Button`.

The mechanism by which APL associates the class name with a class in a .NET namespace is described below.

## Constructors and Overloading

Each .NET Class has one or more *constructor* methods. A constructor is a method which is called to initialise an instance of the Class. Typically, a Class will support several constructor methods - each with a different set of parameters. For example, `System.DateTime` supports a constructor that takes three `Int32` parameters (year, month, day), another that takes six `Int32` parameters (year, month, day, hour, minute, second), and so forth. These different constructor methods are not distinguished by having different names but by the different sets of parameters they accept.

This concept, which is known as *overloading*, may seem somewhat alien to the APL programmer. After all, we are used to defining functions that accept a whole range of different arguments. However, type checking, which is fundamental to the .NET Framework, requires that a method is called with the correct number of parameters, and that each parameter is of a predefined type. Overloading solves this issue.

When you create an instance of a class in C#, you do so using the `new` operator. This is automatically mapped to the appropriate constructor method by matching the parameters you supply to the various forms of the constructor. A similar mechanism is implemented in Dyalog APL using the `NEW` system function.

## How the `NEW` System Function is implemented

When APL executes an expression such as:

```
mydt←NEW DateTime (2008 4 30)
```

the following logic is used to resolve the reference to `DateTime` correctly.

The first time that APL encounters a reference to a non-existent name (i.e. a name that would otherwise generate a `VALUE ERROR`), it searches the .NET namespaces/assemblies specified by `USING` for a .NET class of that name. If found, the name (in this case `DateTime`) is recorded in the APL symbol table with a name class of 9.6 and is associated with the corresponding .NET namespace. If not, `VALUE ERROR` is reported as usual. Note that this search *ONLY* takes place if `USING` has been assigned a value.

Subsequent references to that symbol (in this case `DateTime`) are resolved directly and do not involve any assembly searching.

If you use `⎕NEW` with only a class as argument, APL will attempt to call the version of its constructor that is defined to take no arguments. If no such version of the constructor exists, the call will fail with a `LENGTH ERROR`.

Otherwise, if you use `⎕NEW` with a class as argument and a second element, APL will call the version of the constructor whose parameters match the second element you have supplied to `⎕NEW`. If no such version of the constructor exists, the call will fail with a `LENGTH ERROR`.

## Displaying a .NET Object

When you display a reference to a .NET object, APL calls the object's `ToString` method and displays the result. All objects provide a `ToString` method because all objects ultimately inherit from the .NET class `System.Object`. Many .NET classes will provide their own `ToString` that overrides the one inherited from `System.Object`, and return a useful description or identifier for the object in question. `ToString` usually supports a range of calling parameters, but APL always calls the version of `ToString` that is defined to take no calling parameters. Monadic format (`⌘`) and monadic `⎕FMT` have been extended to provide the same result, and provides a quick shorthand method to call `ToString` in this way. The default `ToString` supplied by `System.Object` returns the name of the object's `Type`. This can be changed using the system function `⎕DF`. For example,

```
z←⎕NEW DateTime ⎕TS
z.(⎕DF(⌘DayOfWeek),,'G< 99:99>'⎕FMT 100⌊Hour Minute)
z
Saturday 09:17
```

Note that if you want to check the type of an object, this can be obtained using the `GetType` method, which is supported by all .Net objects.

---

## Browsing .Net Classes

Microsoft supplies a tool for browsing .NET Class libraries called `ILDASM.EXE`<sup>1</sup>.

As a convenience, the Dyalog APL Workspace Explorer has been extended to perform a similar task as `ILDASM` so that you can gain access to the information within the context of the APL environment.

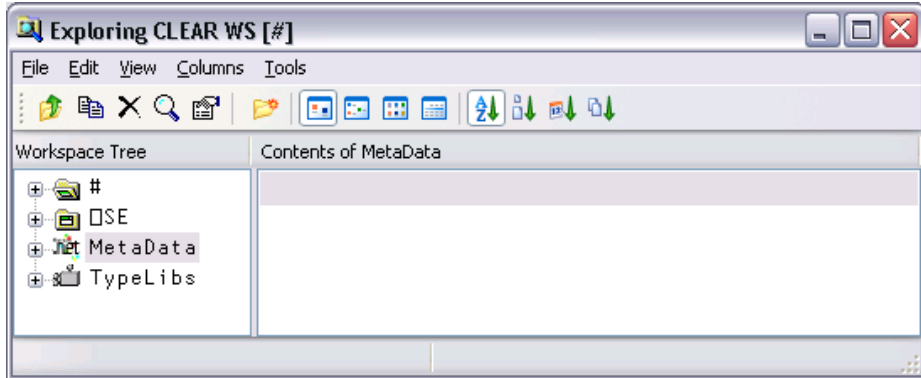
The information that describes .NET classes, which is known as its *Metadata*, is part of the definition of the class and is stored with it. This Metadata corresponds to Type Information in COM, which is typically stored in a separate Type Library.

To enable the display of Metadata in the Workspace Explorer, you must have the *Type Libraries* option of the *View* menu checked.

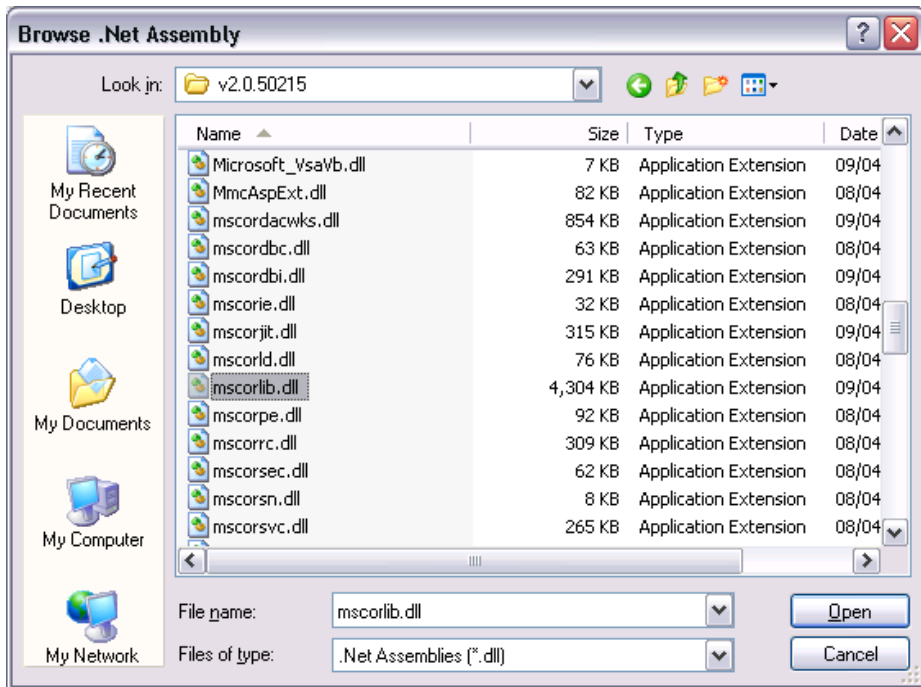
---

<sup>1</sup> `ILDASM.EXE` can be found in the .NET SDK and is distributed with Visual Studio

To gain information about one or more Net Classes, open the Workspace Explorer, right click the *Metadata* folder, and choose *Load*.



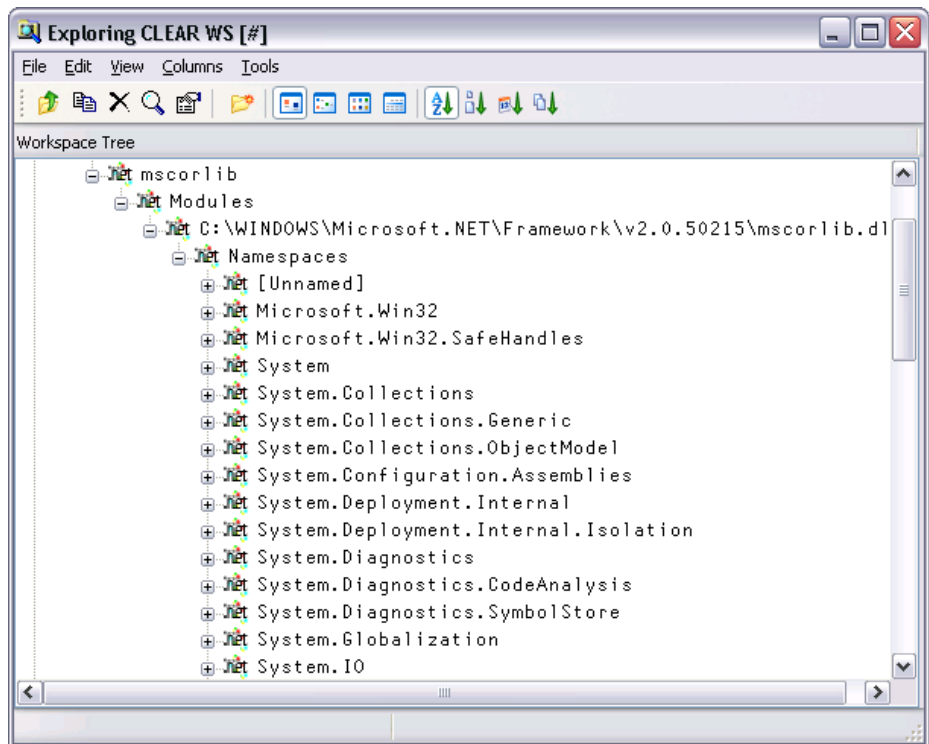
This brings up the *Browse .Net Assembly* dialog box as shown below. Navigate to the .NET assembly of your choice, and click *Open*.



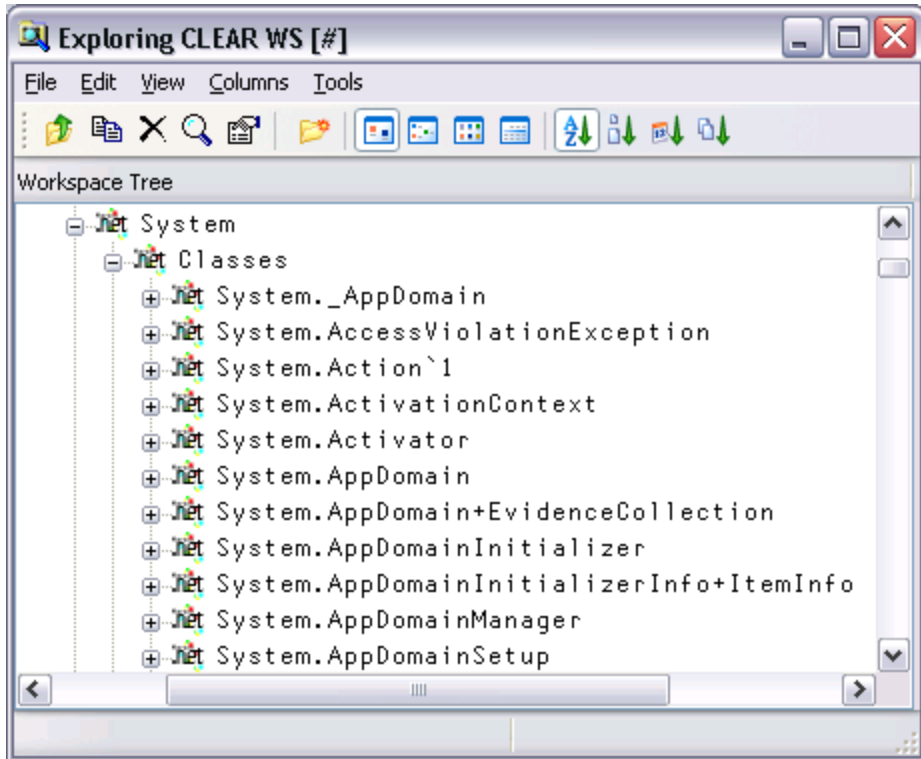
Note that the .NET Classes provided with the .NET Framework are typically located in `C:\WINDOWS\Microsoft.NET\Framework\v2.0.50215`. The last named folder is the Version number.

The most commonly used classes of the .NET Namespace System are stored in this directory in an Assembly named `mscorlib.dll`, along with a number of other fundamental .NET Namespaces.

The result of opening this Assembly is illustrated in the following screen shot. The somewhat complex tree structure that is shown in the Workspace Explorer merely reflects the structure of the Metadata itself.

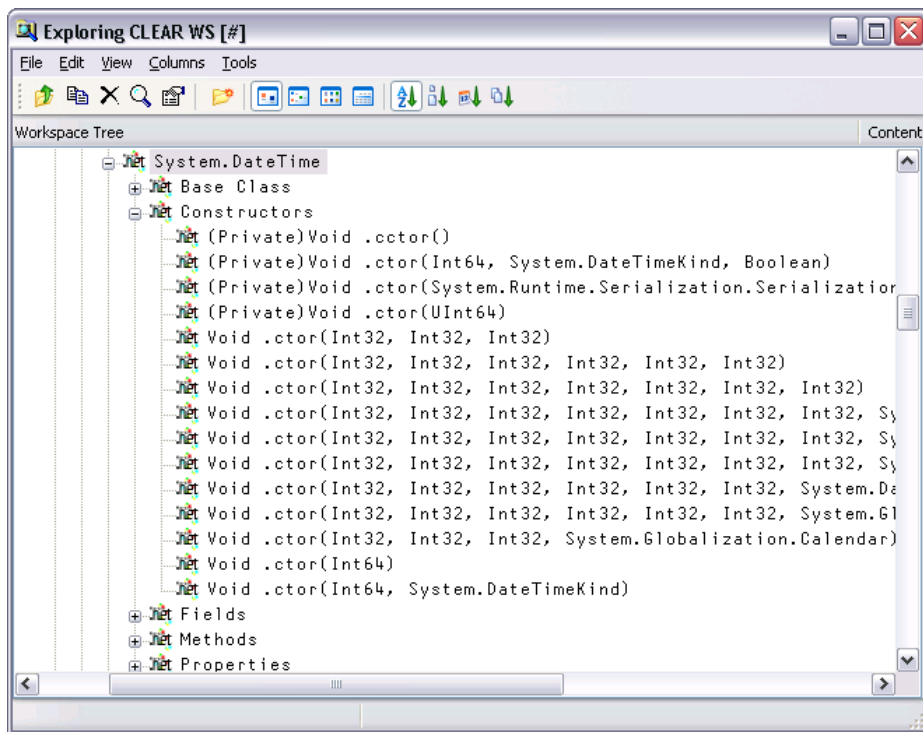


Opening the *System/Classes* sub-folder causes the Explorer to display the list of classes contained in the .NET Namespace *System* as shown in the picture below.



The *Constructors* folder shows you the list of all of the valid constructors and their parameter sets with which you may create a new instance of the Class by calling **New**. The constructors are those named *.ctor*; you may ignore the one named *.ctor*, (the class constructor) and any labelled as *Private*.

For example, you can deduce that **DateTime.New** may be called with three numeric (Int32) parameters, or six numeric (Int32) parameters, and so forth. There are in fact seven different ways that you can create an instance of a DateTime.

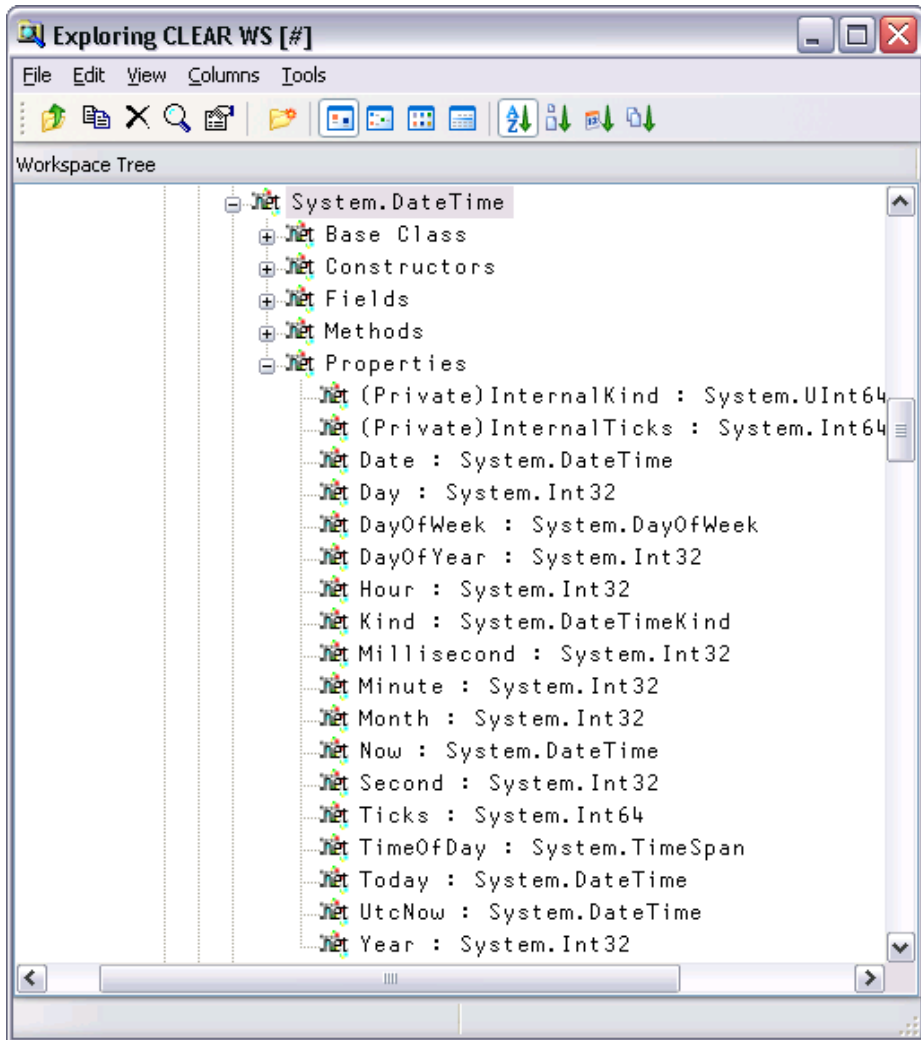


For example, the following statement may be used to create a new instance of DateTime (09:30 in the morning on 30<sup>th</sup> April 2001):

```
mydt ← NEW DateTime (2001 4 30 9 30 0)

mydt
30/04/2001 09:30:00
```

The *Properties* folder provides a list of the properties supported by the Class. It shows the name of the property followed by its data type. For example, the `DayOfYear` property is defined to be of type `Int32`.



You can query a property by direct reference:

```
mydt.DayOfWeek
Monday
```

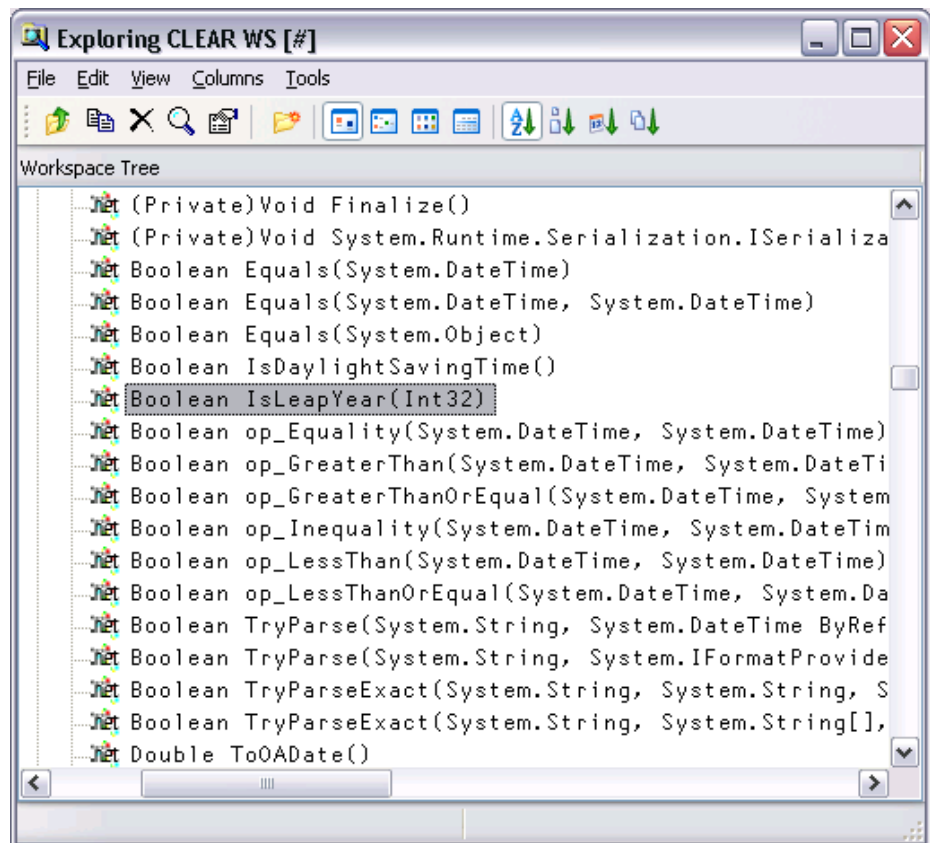


Notice too that the data types of some properties are not simple data types, but Classes in their own right. For example, the data type of the `Now` property is itself `System.DateTime`. This means that when you reference the `Now` property, you get back an object that represents an instance of the `System.DateTime` object:

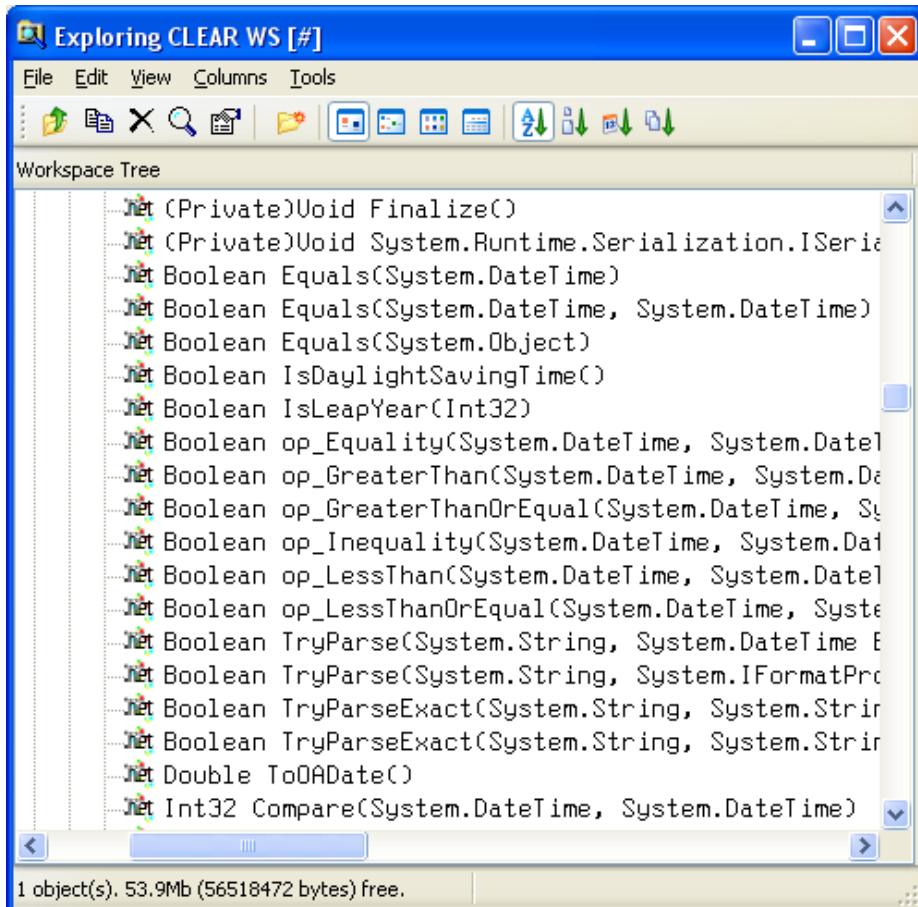
```
mydt.Now
07/11/2001 11:30:48
    TS
2001 11 7 11 30 48 0
```

The *Methods* folder lists the methods supported by the Class. The Explorer shows the data type of the result of the method, followed by the name of the method and the types of its arguments. For example, the `IsLeapYear` method takes an `Int32` parameter (`year`) and returns a `Boolean` result.

```
mydt.IsLeapYear 2000
1
```



Many of the reported objects are listed as *Private*, which means they are inaccessible to users of the class – you are not able to call them or inspect their value. For more information about classes, see the chapter on *Object Oriented Programming* in the *Dyalog APL Language Reference Manual*.



# Advanced Techniques

## Shared Members

Certain .NET Classes provide

`methods`, fields and properties, that can be called directly without the need to create an instance of the Class first. These *members* are known as shared, because they have the same definition for the class and for any instance of the class.

The methods `Now` and `IsLeapYear` exported by `System.DateTime` fall into this category. For example:

```

    USING←, c' System'

    DateTime.Now
07/11/2008 11:30:48

    DateTime.IsLeapYear 2000
1
  
```

## APL language extensions for .NET objects

The .NET Framework provides a set of standard operators (methods) that are supported by certain classes. These operators include methods to compare two .NET objects and methods to add and subtract objects.

In the case of the `DateTime` Class, there are operators to compare two `DateTime` objects. For example:

```

    DT1←NEW DateTime (2008 4 30)
    DT2←NEW DateTime (2008 1 1)

    A Is DT1 equal to DT2 ?
    DateTime.op_Equality DT1 DT2
0
  
```

The `op_Addition` and `op_Subtraction` operators add and subtract `TimeSpan` objects to `DateTime` objects. For example:

```

    DT3←DateTime.Now
    DT3
07/11/2008 11:33:45

    TS←NEW TimeSpan (1 1 1)
    TS
01:01:01
  
```

```

      DateTime.op_Addition DT3 TS
07/11/2008 12:34:46

```

```

      DateTime.op_Subtraction DT3 TS
07/11/2008 10:32:44

```

The corresponding APL primitive functions have been extended to accept .NET objects as arguments and simply call these standard .NET methods internally. The methods and the corresponding APL primitives are shown in the table below.

.NET Method	APL Primitive Function
op_Addition	+
op_Subtraction	-
op_Multiply	×
op_Division	÷
op_Equality	=
op_Inequality	≠
op_LessThan	<
op_LessThanOrEqual	≤
op_GreaterThan	>
op_GreaterThanOrEqual	≥

So instead of calling the appropriate .NET method to compare two objects, you can use the familiar APL primitive instead. For example:

```

      DT1=DT2
0
      DT1>DT2
1
      DT3+TS
07/11/2008 12:34:46
      DT3-TS
07/11/2008 10:32:44

```

Apart from being easier to use, the primitive functions automatically handle arrays and support scalar extension; for example:

```

      DT1>DT2 DT3
1 0

```

In addition, the monadic form of Grade Up ( $\Delta$ ) and Grade Down ( $\Psi$ ), and the Minimum ( $\perp$ ) and Maximum ( $\Gamma$ ) primitive functions have been extended to work on arrays of references to .NET objects. Note that the argument(s) must be a homogeneous set of references to objects of the same .NET class, and in the case of Grade Up and Grade Down, the argument must be a vector. For example:

```

      ΔDT1 DT2 DT3
2 1 3
      ⊔/DT1 DT2 DT3
01/01/2008 00:00:00

```

## Exceptions

When a .Net object generates an error, it does so by *throwing an exception*. An exception is in fact a .Net class whose ultimate base class is `System.Exception`.

The system constant `⊔EXCEPTION` returns a reference to the most recently generated exception object.

For example, if you attempt to create an instance of a `DateTime` object with a year that is outside its range, the constructor throws an exception. This causes APL to report a (trappable) `EXCEPTION` error (error number 90) and access to the exception object is provided by `⊔EXCEPTION`.

```

      ⊔USING←'System'
      DT←⊔NEW DateTime (100000 0 0)
EXCEPTION
      DT←⊔NEW DateTime (100000 0 0)

      ⊔EN
90
      ⊔EXCEPTION.Message
Year, Month, and Day parameters describe
an unrepresentable DateTime.

      ⊔EXCEPTION.Source
mscorlib

      ⊔EXCEPTION.StackTrace
at System.DateTime.DateToTicks(Int32 year,
                                Int32 month,
                                Int32 day)

at System.DateTime..ctor(Int32 year,
                          Int32 month,
                          Int32 day)

```

## More Examples

### Directory and File Manipulation

The .NET Namespace `System.IO` (also in the Assembly `mscorlib.dll`) provides some useful facilities for manipulating files. For example, you can create a `DirectoryInfo` object associated with a particular directory on your computer, call its `GetFiles` method to obtain a list of files, and then get their `Name` and `CreationTime` properties.

```
⊞USING←,c'System.IO'
d←⊞NEW DirectoryInfo (c'C:\Dyalog')
```

`d` is an instance of the `Directory` Class, corresponding to the directory `c:\Dyalog`.

```
      d
C:\Dyalog1
```

The `GetFiles` method returns a list of files; actually, `FileInfo` objects, that represent each of the files in the directory: Its optional argument specifies a filter; for example:

```
      d.GetFiles c'*.exe'
evalstub.exe  exestub.exe  dyalog.exe  dyalogrt.exe
```

The `Name` property returns the name of the file associated with the `File` object:

```
      (d.GetFiles c'*.exe').Name
evalstub.exe  exestub.exe  dyalog.exe  dyalogrt.exe
```

And the `CreationTime` property returns its creation time, which is a `DateTime` object:

```
      (d.GetFiles c'*.exe').CreationTime
```

```
01/04/2004 09:37:01 01/04/2004 09:37:01 08/06/2004 ...
```

If you call `GetFiles` without an argument (in APL, with an argument of  $\theta$ ), it returns a complete list of files:

```
files←d.GetFiles θ
```

---

<sup>1</sup>In this document, we will refer to the location where Dyalog APL Version 13.1 resides as `C:\Dyalog`. Your installation of Dyalog APL may be in a different folder or even on a different drive but the examples should work just the same if you replace `C:\Dyalog` by your folder name

Taking advantage of namespace reference array expansion, an expression to display file names and their creation times is as follows.

```

files,[1.5]files.CreationTime
relnotes.hlp      03/02/2004 11:47:02
relnotes.cnt     03/02/2004 11:47:02
def_uk.dse      22/03/2004 12:13:31
DIALOGS.HLP    22/03/2004 12:13:31
dyares32.dll    22/03/2004 12:13:40
...

```

## Sending an email

The .NET Namespace `System.Web.Mail` provides objects for handling email.

You can create a new email message as an instance of the `MailMessage` class, set its various properties, and then send it using the `SmtMail` class.

Please note that these examples will only work if your computer is configured to allow you to send email in this way.

```

using System.Web.Mail, System.Web.dll
m=new MailMessage
m.From='tony.blair@uk.gov'
m.To='sales@dialog.com'
m.Subject='order'
m.Body='Send me 100 copies of Dyalog APL now'

SmtMail.Send m

```

However, note that the `Send` method of the `SmtMail` object is overloaded and may be called with a single parameter of type `System.Web.Mail.MailMessage` as above, or four parameters of type `System.String`:

So instead, you can just say:

```

SmtMail.Send 'tony.blair@uk.gov'
             'sales@dialog.com'
             'order'
             'Send me the goods'

```

## Web Scraping

The .NET Framework provides a whole range of classes for accessing the internet from a program. The following example illustrates how you can read the contents of a web page. It is complicated, but realistic, in that it includes code to cater for a fire-wall/proxy connection to the internet. It is only 9 lines of APL code, but each line requires careful explanation.

First we need to define `⎕USING` so that it specifies all of the .NET Namespaces and Assemblies that we require.

```
⎕USING←'System, System.dll' 'System.Net' 'System.IO'
```

The `WebRequest` class in the .NET Namespace `System.Net` implements the .NET Framework's request/response model for accessing data from the Internet. In this example we create a `WebRequest` object associated with the URI `http://www.cdnnow.com`. Note that `WebRequest` is an example of a static class. You don't make instances of it; you just use its methods.

```
wrq←WebRequest.Create 'http://www.cdnnow.com'
```

In fact (and somewhat confusingly) if the URI specifies a scheme of "http://" or "https://", you get back an object of type `HttpWebRequest` rather than a plain and simple `WebRequest`. So, at this stage, `wrq` is an `HttpWebRequest` object.

```
wrq
System.Net.HttpWebRequest
```

This class has a `Proxy` property through which you specify the proxy information for a request made through a firewall. The value assigned to the `Proxy` property has to be an object of type `System.Net.WebProxy`. So first we must create a new `WebProxy` object specifying the hostname and port number for the firewall. You will need to change this statement to suit your own internet configuration (it may even not be necessary to do this).

```
PX←NEW WebProxy('http://dyagate.dyadic.com:8080')
PX
System.Net.WebProxy
```

Having set up the `WebProxy` object as required, we then assign it to the `Proxy` property of the `HttpRequest` object `wrq`.

```
wrq.Proxy←PX
```



The `HttpRequest` class has a `GetResponse` method that returns a response from an internet resource. No it's not HTML (yet), the result is an object of type `System.Net.HttpWebResponse`.

```
wr←wrq.GetResponse  
wr  
System.Net.HttpWebResponse
```

The `HttpWebResponse` class has a `GetResponseStream` method whose result is of type `System.Net.ConnectStream`. This object, whose base class is `System.IO.Stream`, provides methods to read and write data both synchronously and asynchronously from a data source, which in this case is physically connected to a TCP/IP socket.

```
str←wr.GetResponseStream  
str  
System.Net.ConnectStream
```

However, there is yet another step to consider. The `Stream` class is designed for byte input and output; what we need is a class that reads characters in a byte stream using a particular encoding. This is a job for the `System.IO.StreamReader` class. Given a `Stream` object, you can create a new instance of a `StreamReader` by passing it the `Stream` as a parameter.

```
rdr←NEW StreamReader str  
rdr  
System.IO.StreamReader
```

Finally, we can use the `ReadToEnd` method of the `StreamReader` to get the contents of the page.

```
s←rdr.ReadToEnd  
ps  
45242
```

Note that to avoid running out of connections, it is necessary to close the `Stream`:

```
str.Close
```

## Enumerations

An enumeration is a set of named constants that may apply to a particular operation. For example, when you open a file you typically want to specify whether the file is to be opened for reading, for writing, or for both. A method that opens a file will take a parameter that allows you to specify this. If this is implemented using an enumerated constant, the parameter may be one of a specific set of (typically) integer values; for example, 1=read, 2=write, 3=both read and write. However, to avoid using meaningless numbers in code, it is conventional to use names to represent particular values. These are known as *enumerated constants* or, more simply, as *enums*.

In the .NET Framework, *enums* are implemented as classes that inherit from the base class `System.Enum`. The class as a whole represents a set of enumerated constants; each of the constants themselves is represented by a static field within the class.

The next chapter deals with the use of `System.Windows.Forms` to create and manipulate the user interface. The classes in this .NET Namespace use *enums* extensively.

For example, there is a class named `System.Windows.Forms.FormBorderStyleStyle` that contains a set of static fields named `None`, `FixedDialog`, `Sizeable`, and so forth. These fields have specific integer values, but the values themselves are of no interest to the programmer.

Typically, you use an enumerated constant as a parameter to a method or to specify the value of a property. For example, to create a `Form` with a particular border style, you would set its `BorderStyle` property to one of the members of the `BorderStyle` class, viz.

```

□USING←' System '

□USING,←c 'System.Windows.Forms,system.windows.forms.dll '
f1←□NEW Form
f1.BorderStyle←FormBorderStyle.FixedDialog
FormBorderStyle.□NL ~2 a List enum members
Fixed3D FixedDialog FixedSingle FixedToolWindow None
Sizeable SizeableToolWindow

```

An enum has a value, which you may use in place of the enum itself when such usage is unambiguous. For example, the `FormBorderStyle.Fixed3D` enum has an underlying value is 2:

```
Convert.ToInt32 FormBorderStyle.Fixed3D
2
```

You could set the border style of the Form `f1` to `FormBorderStyle.Fixed3D` with the expression:

```
f1.BorderStyle←2
```

However, this practice is not recommended. Not only does it make your code less clear, but also if a value for a property or a parameter to a method may be one of several different enum types, APL cannot tell which is expected and the call will fail.

For example, when the constructor for `System.Drawing.Font` is called with 3 parameters, the 3<sup>rd</sup> parameter may be either a `FontStyle` enum or a `GraphicsUnit` enum. If you were to call `Font` with a 3<sup>rd</sup> parameter of 1, APL cannot tell whether this refers to a `FontStyle` enum, or a `GraphicsUnit` enum, and the call will fail.

## Handling Pointers with `Dyalog.ByRef`

Certain .NET methods take parameters that are pointers.

An example is the `DivRem` method that is provided by the `System.Math` class. This method performs an integer division, returning the quotient as its result, and the remainder in an address specified as a pointer by the calling program.

APL does not have a mechanism for dealing with pointers, so `Dyalog` provides a .NET class for this purpose. This is the `Dyalog.ByRef` class, which is provided by an Assembly that is loaded automatically by the `Dyalog` APL program.

Firstly, to gain access to the `Dyalog.Net` Namespace, it must be specified by `⎕USING`. Note that you need not specify the Assembly (DLL) from which it is obtained (`bridge130.dll`, because (like `mscorlib.dll`) it is automatically loaded by when APL starts.

```
⎕USING←'System' 'Dyalog'
```

The `Dyalog.ByRef` class represents a pointer to an object of type `System.Object`. It has a number of constructors, some of which are used internally by APL itself. You only need to be concerned about two of them; the one that takes no parameters, and the one that takes a single parameter of type `System.Object`. The former is used to create an empty pointer; the latter to create a pointer to an object or some data.

For example, to create an empty pointer:

```
ptr1←[]NEW ByRef
```

Or, to create pointers to specific values,

```
ptr2←[]NEW ByRef 0
ptr3←[]NEW ByRef (c110)
ptr4←[]NEW ByRef ([]NEW DateTime (2000 4 30))
```

Notice that a single parameter is required, so you must enclose it if it is an array with several elements. Alternatively, the parameter may be a .NET object.

The ByRef class has a single property called Value.

```
ptr2.Value
0
ptr3.Value
1 2 3 4 5 6 7 8 9 10
ptr4.Value
30/04/2000 00:00:00
```

Note that if you reference the Value property without first setting it, you get a VALUE ERROR.

```
ptr1.Value
VALUE ERROR
ptr1.Value
^
```

Returning to the example, we recall that the DivRem method takes 3 parameters:

1. the numerator
2. the denominator
3. a pointer to an address into which the method will write the remainder after performing the division.

```
remptr←[]NEW ByRef
remptr.Value
VALUE ERROR
remptr.Value
^
Math.DivRem 311 99 remptr
3
remptr.Value
14
```

In some cases a .NET method may take a parameter that is an Array and the method expects to fill in the array with appropriate values. In APL there is no syntax to allow a parameter to a function to be modified in this way. However, we can use the `Dyalog.ByRef` class to call this method. For example, the `System.IO.FileStream` class contains a `Read` method that populates its first argument with the bytes in the file.

```
⎕using←'System.IO' 'Dyalog' 'System'  
fs←⎕NEW FileStream ('c:\tmp\jd.txt' FileMode.Open)  
fs.Length  
25  
fs.Read(arg←⎕NEW ByRef,⊢25)0 25  
25  
arg.Value  
104 101 108 108 111 32 102 114 111 109 32 106 111 104 110  
32 100 97 105 110 116 114 101 101 10
```



# Chapter 3:

## Using Windows.Forms

### Introduction

`System.Windows.Forms` is a .NET namespace that provides a set of classes for creating the Graphical User Interface for Windows applications. For languages such as C# and Visual Basic, this mechanism is intended to replace the Windows API as the means to write the GUI. For Dyalog APL developers, `System.Windows.Forms` is an *alternative* to the Dyalog APL built-in GUI, which will continue to be maintained for the foreseeable future.

One advantage of using `System.Windows.Forms` is that it provides immediate access to the latest Microsoft GUI components. Whenever Microsoft develops a new `Windows.Forms` component, it can immediately be incorporated into a Dyalog APL application; you do not need to wait for Dyalog to provide a specific interface to it. The same applies to GUI components developed by third parties.

Unless otherwise specified, all the examples described in this Chapter may be found in the `samples\winforms\winforms.dws` workspace.

### Creating GUI Objects

GUI objects are represented by .NET classes in the .NET Namespace `System.Windows.Forms`. In general, these classes correspond closely to the GUI objects provided by Dyalog APL, which are themselves based upon the Windows API.

For example, to create a form containing a button and an edit field, you would create instances of the `Form`, `Button` and `TextBox` classes.

## Object Hierarchy

The most striking difference between the `Windows.Forms` GUI and the Dyalog GUI is that in `Windows.Forms` the container hierarchy represented by forms, group boxes, and controls is not represented by an object hierarchy. Instead, objects that represent GUI controls are created stand-alone (i.e. without a parent) and then associated with a container, such as a `Form`, by calling the `Add` method of the parent's `Controls` collection. Notice too that `Windows.Forms` objects are associated with APL symbols that are namespace references, but `Windows.Forms` objects do not have implicit names.

## Positioning and Sizing Forms and Controls

The position of a form or a control is specified by its `Location` property, which is measured relative to the top left corner of the client area of its container.

`Location` has a data type of `System.Drawing.Point`. To set `Location`, you must first create an object of type `System.Drawing.Point` then assign that object to `Location`.

Similarly, the size of an object is determined by its `Size` property, which has a data type of `System.Drawing.Size`. This time, you must create a `System.Drawing.Size` object before assigning it to the `Size` property of the control or form.

Objects also have `Top (Y)` and `Left (X)` properties that may be specified or referenced independently. These accept simple numeric values.

The position of a `Form` may instead be determined by its `DesktopLocation` property, which is specified relative to the taskbar. Another alternative is to set the `StartPosition` property whose default setting is `WindowsDefaultLocation`, which represents a computed best location.

## Modal Dialog Boxes

Dialog Boxes are displayed modally to prevent the user from performing tasks outside of the dialog box.

To create a modal dialog box, you create a `Form`, set its `BorderStyle` property to `FixedDialog`, set its `ControlBox`, `MinimizeBox` and `MaximizeBox` properties to `false`, and display it using `ShowDialog`.



A modal dialog box has a `DialogResult` property that is set when the `Form` is closed, or when the user presses `OK` or `Cancel`. The value of this property is returned by the `ShowDialog` method, so the simplest way to handle user actions is to check the result of `ShowDialog` and proceed accordingly. Example 1 illustrates a simple modal dialog box.

## Example 1

Function `EG1` illustrates how to create and use a simple modal dialog box. Much of the function is self explanatory, but the following points are noteworthy.

`EG1 [1-2]` set `USING` to include the .NET Namespaces `System.Windows.Forms` and `System.Drawing`.

`EG1 [6, 8, 9]` create a `Form` and two `Button` objects. As yet, they are unconnected. The constructor for both classes is defined to take no arguments, so the `NEW` system function is only called with a class argument.

`EG1 [14]` shows how the `Location` property is set by first creating a new `Point` object with a specific pair of (x and y) values.

`EG1 [18]` computes the values for the `Point` object for `button2.Location`, from the values of the `Left`, `Height` and `Top` properties of `button1`; thus positioning `button2` relative to `button1`.

```

    ▽ EG1;form1;button1;button2;true;false;USING;Z
[1]   USING←,c'System.Windows.Forms,
        System.Windows.Forms.dll'
[2]   USING←,c'System.Drawing,System.Drawing.dll'
[3]   true false←1 0
[4]
[5]   A Create a new instance of the form.
[6]   form1←NEW Form
[7]   A Create two buttons to use as the accept and cancel btns
[8]   button1←NEW Button
[9]   button2←NEW Button
[10]
[11]  A Set the text of button1 to "OK".
[12]  button1.Text←'OK'
[13]  A Set the position of the button on the form.
[14]  button1.Location←NEW Point,c10 10
[15]  A Set the text of button2 to "Cancel".
[16]  button2.Text←'Cancel'
[17]  A Set the position of the button relative to button1.
[18]  button2.Location←NEW Point,
        cbutton1.Left button1.(Height+Top+10)
[19]

```

EG1[21, 23] sets the DialogResult property of `button1` and `button2` to `DialogResult.OK` and `DialogResult.Cancel` respectively. Note that `DialogResult` is an enumeration with a predefined set of member values.

Similarly, EG1[32] defines the `BorderStyle` property of the form using the `FormBorderStyle` enumeration.

EG1[38 40] defines the `AcceptButton` and `CancelButton` properties of the Form to `button1` and `button2` respectively. These have the same effect as the Dyalog GUI Default and Cancel properties.

EG1[42] sets the `StartPosition` of the Form to be centre screen. Once again this is specified using an enumeration; `FormStartPosition`.

```
[20]  A Make button1's dialog result OK.
[21]  button1.DialogResult←DialogResult.OK
[22]  A Make button2's dialog result Cancel.
[23]  button2.DialogResult←DialogResult.Cancel
[24]
[25]
[26]  A Set the title bar text of the form.
[27]  form1.Text←'My Dialog Box'
[28]  A Display a help button on the form.
[29]  form1.HelpButton←true
[30]
[31]  A Define the border style of the form to that of a
      dialog box.
[32]  form1.BorderStyle←FormBorderStyle.FixedDialog
[33]  A Set the MaximizeBox to false to remove the
      maximize box.
[34]  form1.MaximizeBox←false
[35]  A Set the MinimizeBox to false to remove the
      minimize box.
[36]  form1.MinimizeBox←false
[37]  A Set the accept button of the form to button1.
[38]  form1.AcceptButton←button1
[39]  A Set the cancel button of the form to button2.
[40]  form1.CancelButton←button2
[41]  A Set the start position of the form to the center
      of the screen.
[42]  form1.StartPosition←FormStartPosition.CenterScreen
[43]
```

EG1[45 46] associate the buttons with the Form. The `Controls` property of the Form returns an object of type `Form.ControlCollection`. This class has an `Add` method that is used to add a control to the collection of controls that are owned by the Form.

EG1[50] calls the `ShowDialog` method (with no argument; hence the  $\Theta$ ). The result is an object of type `Form.DialogResult`, which is an enumeration.

EG1[52] compares the result returned by `ShowDialog` with the enumeration member `DialogResult.OK` (note that the primitive function `=` has been extended to compare objects).

```
[44]  A Add button1 to the form.
[45]  form1.Controls.Add button1
[46]  A Add button2 to the form.
[47]  form1.Controls.Add button2
[48]
[49]  A Display the form as a modal dialog box.
[50]  Z←form1.ShowDialog  $\Theta$ 
[51]  A Determine if the OK button was clicked on the
                                     dialog box.
[52]  :If Z=DialogResult.OK
[53]    A Display a message box saying that the OK
                                     button was clicked.
[54]    Z←MessageBox.Show='The OK button on the form
                                     was clicked.'
[55]  :Else
[56]    A Display a message box saying that the Cancel
                                     button was clicked.
[57]    Z←MessageBox.Show='The Cancel button on the
                                     form was clicked.'
[58]  :EndIf
      ▽
```

**Warning:** The use of modal forms in .NET can lead to problematic situations while debugging. As the control is passed to .NET the APL interpreter cannot regain control in the event of an unforeseen error. It is advisable to change the code to something like the following until the code is fully tested:

```
[52]  form1.Visible←1
[53]  :While form1.Visible  $\diamond$  :endwhile
```

## Example 2

Functions EG2 and EG2A illustrate how the Each operator (⍷) and the extended namespace reference syntax in Dyalog APL may be used to produce more succinct, and no less readable, code.

```

    ▽ EG2;form1;label1;textBox1>true;false;⍷USING;Z
[1]   ⍷USING←,c'System.Windows.Forms,
      System.Windows.Forms.dll'
[2]   ⍷USING←c'System.Drawing,System.Drawing.dll'
[3]   true false←1 0
[4]
[5]   A Create a new instance of the form.
[6]   form1←⍷NEW Form
[7]
[8]   textBox1←⍷NEW TextBox
[9]   label1←⍷NEW Label
[10]
[11]  A Initialize the controls and their bounds.
[12]  label1.Text←'First Name'
[13]  label1.Location←⍷NEW Point (48 48)
[14]  label1.Size←⍷NEW Size (104 16)
[15]  textBox1.Text←''
[16]  textBox1.Location←⍷NEW Point (48 64)
[17]  textBox1.Size←⍷NEW Size (104 16)
[18]
[19]  A Add the TextBox control to the form's control
      collection.
[20]  form1.Controls.Add textBox1
[21]  A Add the Label control to the form's control
      collection.
[22]  form1.Controls.Add label1
[23]
[24]  A Display the form as a modal dialog box.
[25]  Z←form1.ShowDialog ⍷
    ▽

```

EG2A[7] takes advantage of the fact that .NET classes are namespaces, so the expression `Form TextBox Label` is a vector of namespace refs, and the expression `⍷NEW Form TextBox Label` runs the `⍷NEW` system function on each of them.

Similarly, EG2A[10 11 12] combine the use of extended namespace reference and the *Each* operator to set the `Text`, `Location` and `Size` properties in several objects together.

```

▽ EG2A;form1;label1;textBox1>true>false;□USING;Z
[1]  A Compact version of EG2 taking advantage of ref
      syntax and ""
[2]  □USING←'System.Windows.Forms,System.Windows.Forms.dll'
[3]  □USING,←c'System.Drawing,System.Drawing.dll'
[4]  true false←1 0
[5]
[6]  A Create a new instance of the form, TextBox and Label.
[7]  (form1 textBox1 label1)←□NEW"Form TextBox Label
[8]
[9]  A Initialize the controls and their bounds.
[10] (label1 textBox1).Text←'First Name' ''
[11] (label1 textBox1).Location←□NEW"Point,"c"(48 48)(48 64)
[12] (label1 textBox1).Size←□NEW"Size,"c"(104 16)(104 16)
[13]
[14] A Add the Label and TextBox controls to the form's
      control collection.
[15] form1.Controls.AddRange←label1 textBox1
[16]
[17] A Display the form as a modal dialog box.
[18] Z←form1.ShowDialog 0
▽

```

## Non-Modal Forms

Non-modal Forms are displayed using the `Run` method of the `System.Windows.Forms.Application` object. This method is designed to be called once, and only once, during the life of an application and this poses problems during APL development. Fortunately, it turns out that, in practice, the restriction is that `Application.Run` may only be run once on a single system thread. However, it may be run successively on different system threads. During development, you may therefore test a function that calls `Application.Run`, by running it on a new APL thread using `Spawn (&)`. See Chapter 13 for further details.

### DataGrid Examples

Three functions in the `samples\winforms\winforms.dws` workspace provide examples of non-modal Forms. These examples also illustrate the use of the `WinForms.DataGrid` class.

Function `Grid1` is an APL translation of the example given in the help file for the `DataGrid` class in the .NET SDK Beta1. The original code has been slightly modified to work with the current version of the SDK.

Function `Grid2` is an APL translation of the example given in the help file for the `DataGrid` class in the .NET SDK Beta2.

Function `Grid` is an APL translation of the example given in the file:

```
C:\Program Files\Microsoft.Net\SDK\v1.1\...  
QuickStart\winforms\samples\Data\Grid\vb\Grid.vb
```

This example uses Microsoft SQL Server 2000 to extract sample data from the sample NorthWind database. To run this example, you must have SQL Server running and you must modify function `Grid_Load` to specify the name of your server.

## GDIPLUS Workspace

The `samples\winforms\gdiplus.dws` workspace contains a sample that demonstrates the use of non-rectangular Forms. It is a direct translation into APL from a C# sample (WinForms-Graphics-GDIPlusShape) that was distributed on the Visual Studio .NET Beta 2 Resource CD.

## TETRIS Workspace

The `samples\winforms\tetris.dws` workspace contains a sample that demonstrates the use of graphics. It is a direct translation into APL from a C# sample (WinForms-Graphics-Tetris) that was distributed on the Visual Studio .NET Beta 2 Resource CD.

## WEBSERVICES Workspace

An example of a non-modal Form is provided by the `WFGOLF` function in the `samples\asp.net\webservices\webservices.dws` workspace. This function performs exactly the same task as the `GOLF` function in the same workspace, but it uses `Windows.Forms` instead of the built-in Dyalog GUI.

`WFGOLF`, and its callback functions `WFBOOK` and `WFSS` perform exactly the same task, with almost identical dialog box appearance, of `GOLF` and its callbacks `BOOK` and `SS` that are described in Chapter 7.

Note that when you run `WFGOLF` or `GOLF` for the first time, you must supply an argument of 1 to force the creation of the proxy class for the `GolfService` web service.

---

## Chapter 4:

# Writing .Net Classes in Dyalog APL

## Introduction

Dyalog APL allows you to build new .NET Classes, components and controls. A component is a class with emphasis on cleanup and containment and implements specific interfaces. A control is a component with user interface capabilities.

With one exception, every .NET Class inherits from exactly one base class. This means that it begins with all of the behaviour of the base class, in terms of the base class properties, methods and events. You add functionality by defining new properties, methods and events on top of those inherited from the base class or by overriding base class methods with those of your own.

## Assemblies, Namespaces and Classes

To create a .NET class in Dyalog APL, you simply create a standard APL Class and export the workspace as a *Microsoft .Net Assembly (\*.dll)*. See *User Guide Chapter 2*.

.NET Classes are organised in .NET Namespaces. If you wrap your Class (or Classes) within an APL namespace, the name of that namespace will be used to identify the name of the corresponding .NET Namespace in your Assembly.

If a Class is to be based upon a specific .NET Class, the name of that .NET Class must be specified as the Base Class in the `:Class` statement, and the `:Using` statement(s) must correctly locate the base class. If not, the Class is assumed to be based upon `System.Object`. If you use any .NET Types within your Class, you must ensure that these too are located by `:Using`.

Once you have defined the functionality of your .NET classes, you are ready to save them in an assembly. This is simply achieved by selecting *Export* from the *Session File* menu.

You will be prompted to specify the directory and name of the assembly (DLL) and it will then be created and saved. Your .NET class is now ready for use by any .Net development environment, including APL itself.

When an APL .NET class is invoked by a client application, it automatically loads `dyalog130.dll` or `dyalog130rt.dll`, the developer/debug or run-time dynamic link library version of Dyalog APL. You decide which of these DLLs is to be used according to the setting of the *Runtime application* checkbox in the *Create bound file* dialog box. See the User Guide for further details.

If you want to repeat the most recent export after making changes to the class, you can click on the icon to the right of the save icon on the WS button bar at the top of the session. Note that the workspace itself is not saved when you do an export, so if you want the export options to be remembered you must **)SAVE** the workspace *after* you have exported it.

## Example 1

This example builds an Assembly called `APLClasses1.dll` in the sub-directory `samples\aplclasses`, which contains a .NET Namespace called `APLClasses`.

`APLClasses` contains a single .NET Class called `Primitives` that exports a single method called `IndexGen`.

First we create a container namespace `#.APLClasses` that will represent the .NET Namespace in the assembly:

```
clear ws
      )NS APLClasses
#.APLClasses
```

Next, using the editor, we create a class called `Primitives`. Note that the default base class for an exported .net class is `System.Object`.

```
      )ed oAPLClasses.Primitives1
```

and enter the following:

---

<sup>1</sup>The character before the name `APLClasses.Primitives`, `o`, is typically obtained with Ctrl-O. It is used to tell the editor to edit a class



```

:Class Primitives
:Using System
    ▽ r←IndexGen n
        :Access public
        :Signature Int32[]←IndexGen Int32 n
        r←!n
    ▽
:EndClass

```

The class `Primitives` has now been defined with one public function in it.

The public characteristics for the exported method are included in the definition of the class and its functions. Those are specified in the `:Signature` statement.

Its syntax is:

```

:Signature [return type←] fname [arg1type [arg1name]
                                [,argNtype [argNname]]*]

```

that is: The type of the result returned by the function - followed by arrow - if any, the exported name (it can be different from the APL function name but it must be provided), and, if any arguments are to be supplied, their types and optional names, each type-name pair separated from the next by a comma. In the example above the function returns an array of 32-bit integers and takes a single integer as its argument. For further details, see *Language Reference*.

Note that, when the class is fixed, APL will try to find the .Net data types you have specified for the result and for the parameters. If one or more of the data types are not recognised as available .NET Types, you will be informed in the status window and APL will refuse to fix the class. If you see such a warning you have either entered an incorrect data type name, or you have not set `:Using` correctly, or some other syntax problem has been detected (for example the function is missing a terminating `▽`). In the previous example, the only data type used is `System.Int32`. Since we have set `:Using System`, the name `Int32` is found in the right place and all is well.

It should be noted that in the previous release of Dyalog APL the statements `:Returns` and `:ParameterList` were used instead of `:Signature`. They are still accepted for backwards compatibility but are considered deprecated. Their syntax will not be documented here but a list can be found in Appendix A.

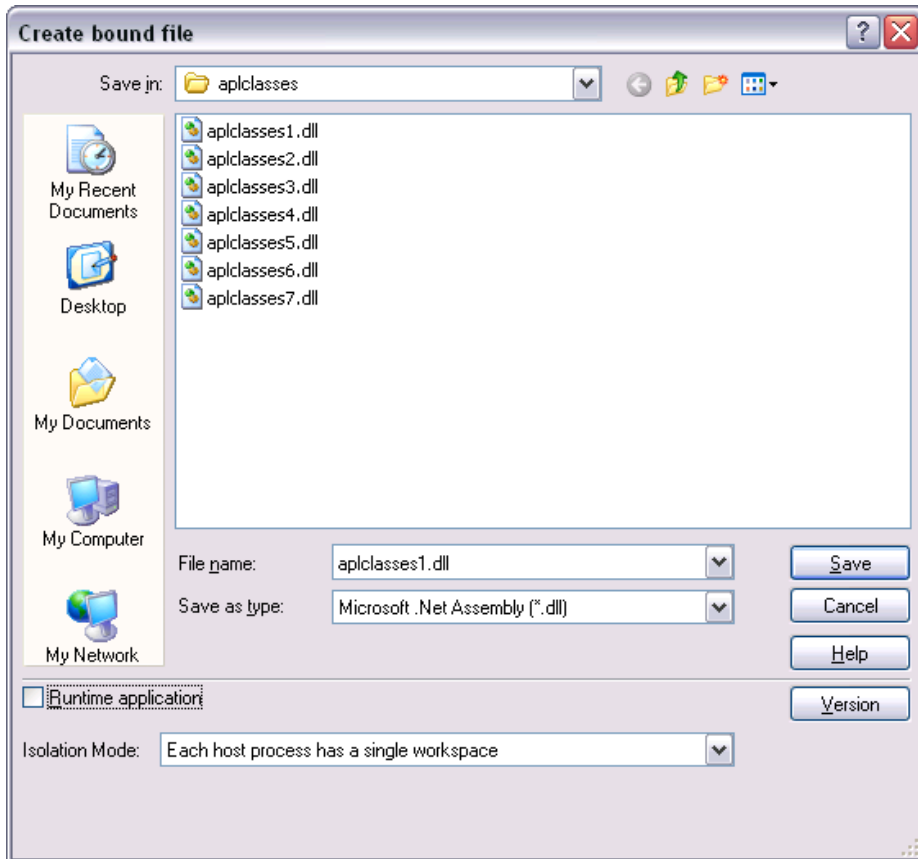
The next step is not strictly necessary, but it does make good sense to `)SAVE` the workspace at this stage. The name you choose for the workspace will be the default name for the assembly

```

)CS
#
)WSID samples\APLClasses\aplclasses1
was CLEAR WS
)SAVE
samples\aplclasses\aplclasses1 saved ...

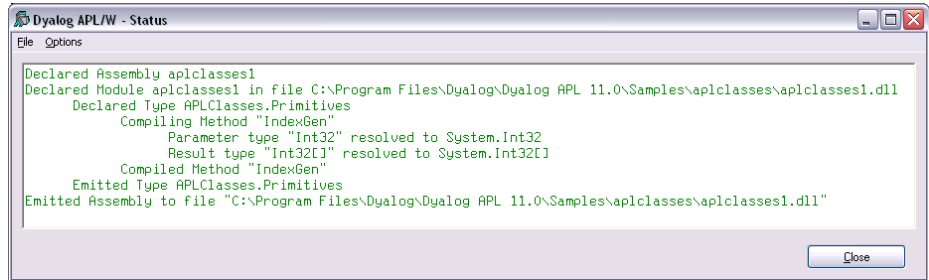
```

Now you are ready to create the assembly. This is done by selecting *Export...* from the Session *File* menu. This displays the following dialog box.



This gives you the opportunity to change the name or path of the assembly. The *Runtime application* checkbox allows you to choose to which if the two versions of the Dyalog APL dynamic link library the assembly will be bound. The Isolation Mode Combo box allows you to choose which Isolation Mode you require. See the *User Guide* for further details.

Finally, click *Save*. APL now makes the assembly and, as it does so, displays information in the Status window as shown below. If any errors occur during this process, the Status window will inform you.



Note that when APL makes a .NET Assembly, it does not save the workspace at the same time. If you made any changes to the options in the dialog on the previous page, or have any unsaved code changes, you should )SAVE the workspace again after exporting it.

## aplfn1.cs

The following C# source, called `samples\APLClasses\aplfn1.cs`, can be used to call your APL .NET Class.

The using statements specify the names of .NET namespaces to be searched for unqualified class names.

The program creates an object named `apl` of type `Primitives` by calling the new operator on that class. Then it calls the `IndexGen` method with a parameter of 10.

```

using System;
using APLClasses;
public class MainClass
{
    public static void Main()
    {
        Primitives apl = new Primitives();
        int[] rslt = apl.IndexGen(10);
        for (int i=0;i<rslt.Length;i++)
            Console.WriteLine(rslt[i]);
    }
}

```

Then, to compile and run the program from a DOS command shell, change directory to the `samples\aplclasses` sub-directory, and then type the following commands shown in **bold**. The first command is required to set up environment variables and your PATH. Note that all this assumes that you have Visual Studio.NET installed. If the following fails you may still be able to call `csc` by resetting the PATH manually by adding its location.

```
APLClasses>setpath.bat
C:\dyalog\samples\aplclasses>"C:\Program Files\
    Microsoft Visual Studio .NET 2003\
    Common7\Tools\"\vsvars32.bat
Setting environment for using Microsoft Visual Studio .NET 2003
tools. (If you have another version of Visual Studio or Visual
C++ installed and wish to use its tools from the command line,
run vcvars32.bat for that version.)
APLClasses>csc /r:APLClasses1.dll aplfns1.cs
Microsoft (R) Visual C# .NET Compiler version 7.10.3052.4 for
Microsoft (R) .NET Framework version 2.0.50727 Copyright (C)
Microsoft Corporation 2001-2002. All rights reserved.

APLClasses>aplfns1
1
2
3
4
5
6
7
8
9
10
```

## Calling IndexGen from Dyalog APL

Assuming `\Dyalog` is where Dyalog APL is installed:

```
⎕USING←'APLClasses,\Dyalog\samples\APLClasses\aplclasses1.dll'
PR←⎕NEW Primitives
PR.IndexGen 10
1 2 3 4 5 6 7 8 9 10
```

## Example 2

In Example 1, we said nothing about a constructor used to create an instance of the `Primitives` class. In Example 2, we will show how this is done.

In fact, in Example 1, APL supplied a default constructor, which is inherited from the base class (`System.Object`) and is called without arguments.

Example 2 will extend Example 1 by adding a constructor that specifies the value of `IO`.

First, we will `)LOAD` the `aplclasses1` workspace we saved in Example 1, and change to the `APLClasses.Primitives.namespace`.

```
)LOAD samples\APLClasses\aplclasses1
samples\APLClasses\aplclasses1 saved ...
)ed o APLClasses.Primitives
```

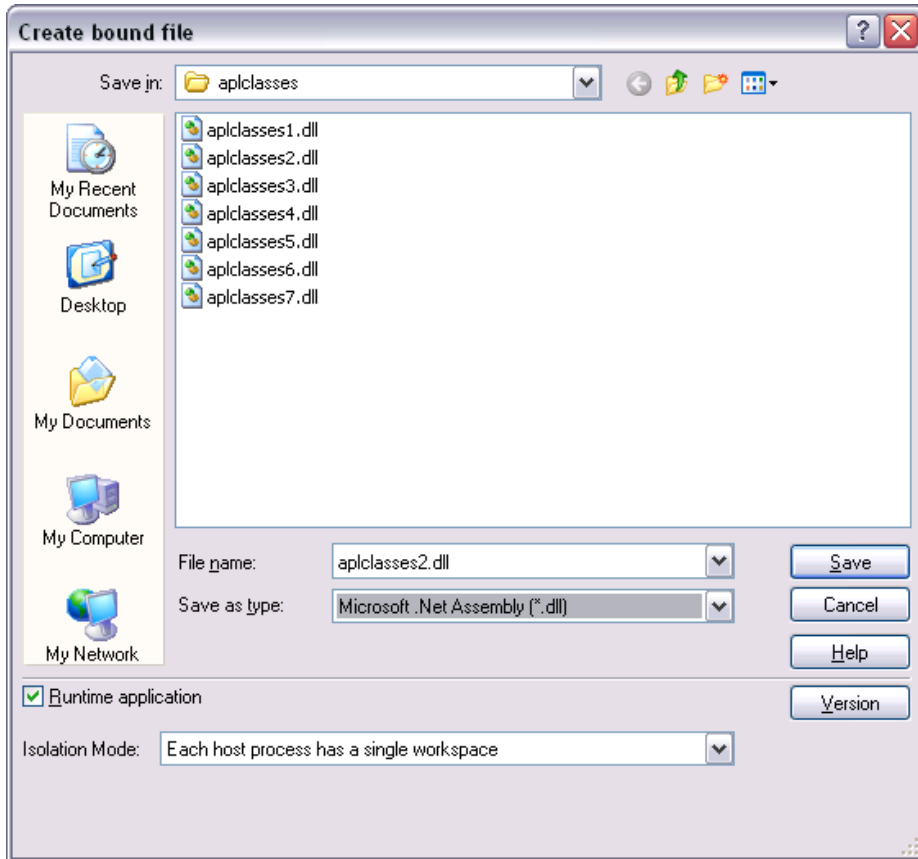
Next, we will define a function called `CTOR` that simply sets `IO` to the value of its argument. The name of this function is purely arbitrary. This function is a *constructor*.

```
▽ CTOR IO
[1]:Access public
[2]:Signature CTOR Int32 IO
[3]:Implements constructor
[4]   IO←IO
▽
```

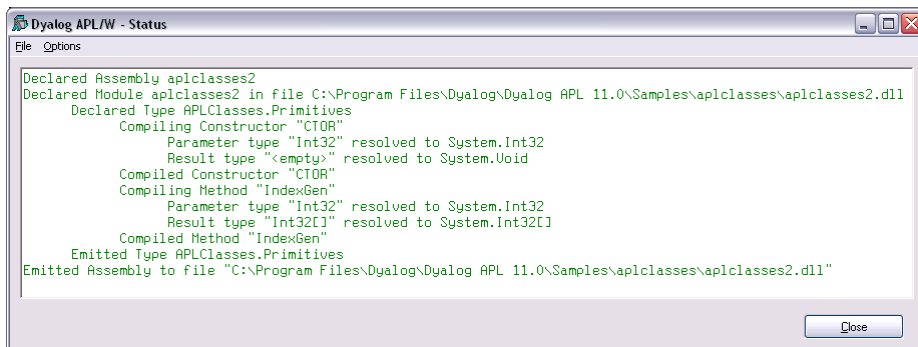
Then we rename and save the workspace:

```
)WSID samples\APLClasses\aplclasses2
was samples\APLClasses\aplclasses1
)SAVE
samples\aplclasses\aplclasses2 saved ...
```

Finally, we can build a new .NET Assembly using *File/Export...* as before.



Please note that, in this case, it is **essential** (for Example 2a) that the *Build runtime assembly* checkbox is not checked. We will need the development version for debugging purposes.



## aplfn2.cs

The following C# source, called `samples\APLClasses\aplfn2.cs`, can be used to call your APL .NET Class.

```
using System;
using APLClasses;
public class MainClass
{
    public static void Main()
    {
        Primitives apl = new Primitives(0);
        int[] rslt = apl.IndexGen(10);

        for (int i=0;i<rslt.Length;i++)
            Console.WriteLine(rslt[i]);
    }
}
```

The program is the same as in the previous example, except that the code that creates an instance of the `Primitives` class is simply changed to specify an argument; in this case 0.

```
Primitives apl = new Primitives(0);
```

When the code is compiled, this call is matched with the various constructors available in the `Primitives` class, in this case the only CTOR constructor which takes a single integer argument. The program compiles successfully with this line calling CTOR with a parameter of 0. When the program runs, the output is 0-9 as expected.

```
APLClasses>setpath.bat
```

```
...
```

```
APLClasses>csc /r:APLClasses2.dll aplfn2.cs
```

```
Microsoft (R) Visual C# .NET Compiler version 7.10.3052.4 for
Microsoft (R) .NET Framework version 2.0.50727
Copyright (C) Microsoft Corporation 2001-2002. All rights
reserved.
```

```
APLClasses>aplfn2
```

```
0
1
2
3
4
5
6
7
8
9
```

## Example 2a

In Example 2, the argument to CTOR, the constructor for the `Primitives` class, was defined to be `Int32`. This means that the .NET Framework will allow a client to specify *any* integer when it creates an instance of the `Primitives` class. What happens if the client uses a parameter of 2? Clearly this is going to cause an APL DOMAIN ERROR when used to set `IO`.

### aplfns2a.cs

The following C# source, called `samples\APLClasses\aplfns2a.cs`, can be used to demonstrate what happens.

```
using System;
using APLClasses;
public class MainClass
{
    public static void Main()
    {
        Primitives apl = new Primitives(2);
        int[] rslt = apl.IndexGen(10);

        for (int i=0;i<rslt.Length;i++)
            Console.WriteLine(rslt[i]);
    }
}
```

The code is the same as in the previous example, except that the line that creates an instance of the `Primitives` class specifies an inappropriate argument; in this case 2.

```
Primitives apl = new Primitives(2);
```

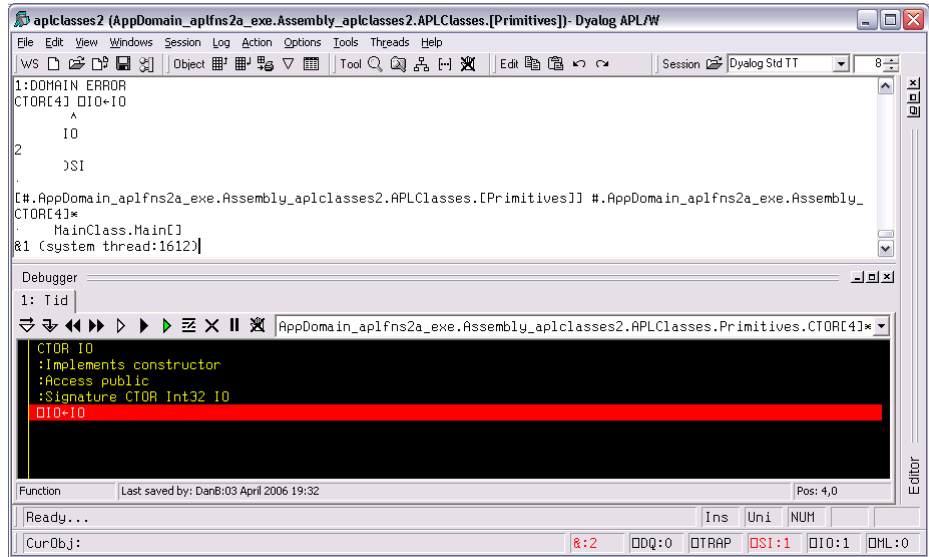
Then, when the program is compiled and run ...

```
APLClasses>setpath.bat
...
APLClasses>csc /r:APLClasses2.dll aplfns2a.cs
Microsoft (R) Visual C# .NET Compiler version 7.10.3052.4 for
Microsoft (R) .NET Framework version 2.0.50727 Copyright (C)
Microsoft Corporation 2001-2002. All rights reserved.
```

```
APLClasses>aplfns2a
```

... the APL Session appears, and the Tracer can be used to debug the problem. You can see that the constructor CTOR has stopped with a DOMAIN ERROR. Meanwhile, the C# program is still waiting for the call (to create an instance of `Primitives`) to finish.





In this case, debugging is simple, and you can simply type:

```

IO←1
→LC

```

Now, the CTOR function completes, the `aplfns2a` program continues and the output is displayed.

```

1
2
3
4
5
6
7
8
9
10

```

Notice that in Dyalog APL, the `)SI` System Command provides information about the entire calling stack, including the .NET function calls that are involved. Notice too that the CTOR function, the constructor for this APL .NET class, is running here in APL thread 1, which is associated with the system thread 1612. See Chapter 12 for further information on debugging APL classes.

## Example 3

The correct .NET behaviour when an APL function fails with an error is to *throw an exception*, and this example shows how to do it.

In the .NET Framework, exceptions are implemented as .NET Classes. The base exception is implemented by the `System.Exception` class, but there are a number of super classes, such as `System.ArgumentException` and `System.ArithmeticException` that inherit from it.

`⊞ SIGNAL` has been extended to allow you to *throw an exception*. To do so, its right argument should be 90 and its left argument should be an object of type `System.Exception` or an object that inherits from `System.Exception`. (Other options for the left argument may be implemented later).

When you create the instance of the `Exception` class, you may specify a string (which will turn up in its `Message` property) containing information about the error.

Starting with the `APLCLASSES2.DWS` workspace, the following changes add exception handling to the `CTOR` function.

```

        )LOAD samples\APLClasses\aplclasses2
samples\aplclasses\aplclasses2 saved ...
)ed o APLClasses.Primitives

```

Then modify the `CTOR` function to perform exception handling in the approved manner.

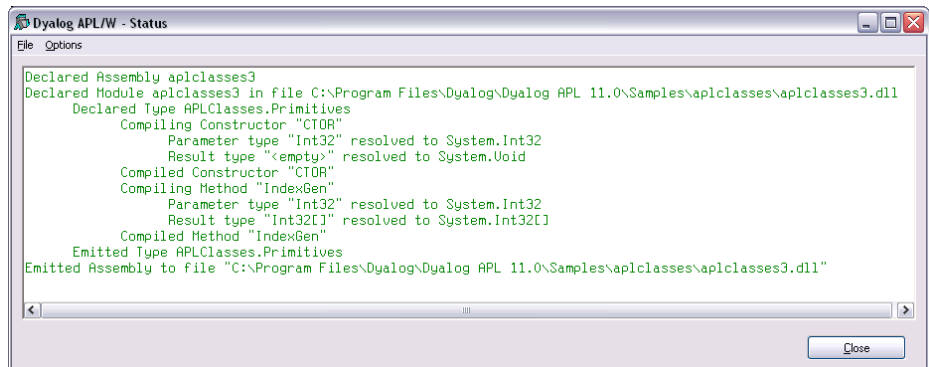
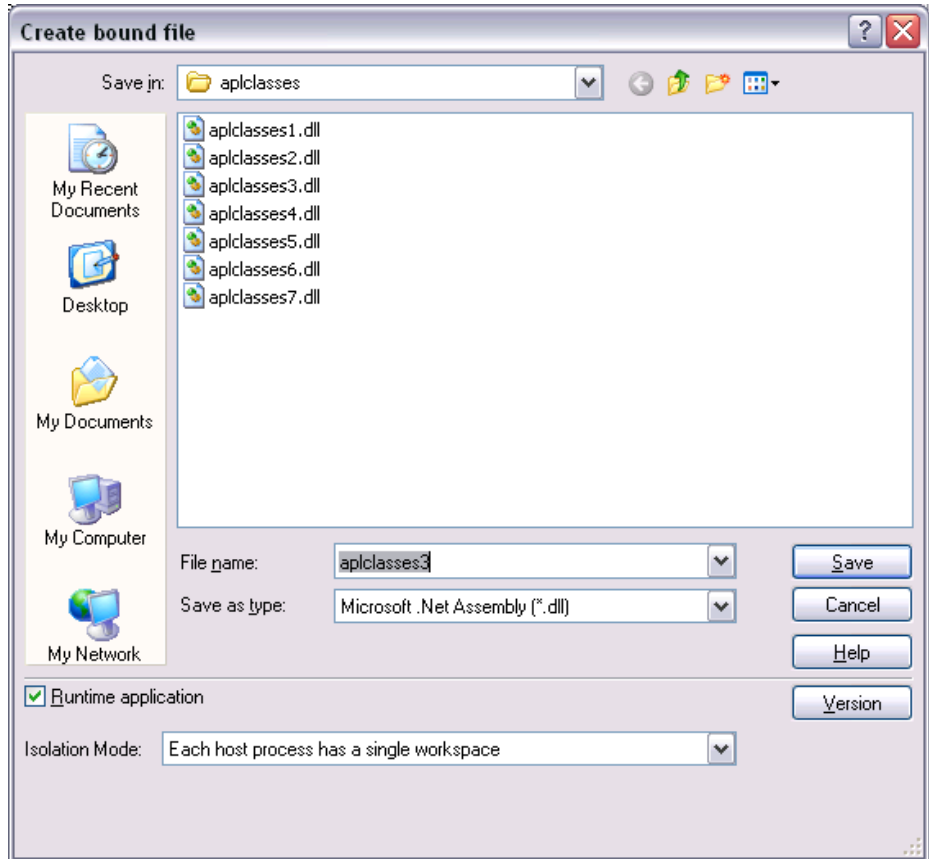
```

        ▽ CTOR IO;EX
[1]      :Access public
[2]      :Signature CTOR Int32 IO
[3]      :Implements constructor
[4]      :If IO∈0 1
[5]          ⊞IO←IO
[6]      :Else
[7]          EX←⊞NEW ArgumentException,⊞⊞'IndexOrigin must be
                                0 or 1'
[8]          EX ⊞SIGNAL 90
[9]      :EndIf
        ▽

        )WSID samples\APLClasses\aplclasses3
was samples\APLClasses\aplclasses2
)SAVE
samples\aplclasses\aplclasses3 saved ...

```

and make a new .NET Assembly called `apclclasses3.dll`.



## aplfn3.cs

The following C# source, called `samples\APLClasses\aplfn3.cs`, can be used to invoke the new CTOR function. `aplfn3.cs` contains code to catch the exception and to display the exception message.

```
using System;
using APLClasses;
public class MainClass
{
    public static void Main()
    try
    {
        Primitives apl = new Primitives(2);
        int[] rslt = apl.IndexGen(10);
        for (int i=0;i<rslt.Length;i++)
            Console.WriteLine(rslt[i]);
    }
    catch (Exception e)
    {
        Console.WriteLine(e.Message);
    }
}
```

Then, when the program is compiled and run ...

```
APLClasses>setpath.bat
APLClasses>csc /r:APLClasses3.dll aplfn3.cs
Microsoft (R) Visual C# .NET Compiler version 7.10.3052.4 for
Microsoft (R) .NET Framework version 2.0.50727 Copyright (C)
Microsoft Corporation 2001-2002. All rights reserved.
APLClasses>aplfn3
IndexOrigin must be 0 or 1
```

## Example 4

This example builds on Example 3 and illustrates how you can implement *constructor overloading*, by establishing several different constructor functions.

By way of an example, when a client application creates an instance of the `Primitives` class, we want to allow it to specify the value of `IO` or the values of both `IO` and `ML`.

The simplest way to implement this is to have two public constructor functions `CTOR1` and `CTOR2`, which call a private constructor function `CTOR` as listed below.

```

)LOAD samples\APLClasses\aplclasses3
c:\...\samples\APLClasses\aplclasses3 saved...

)ed o APLClasses.Primitives

▽ CTOR1 IO
[1] :Implements constructor
[2] :Access public
[3] :Signature CTOR1 Int32 IO
[4] CTOR IO 0
▽

▽ CTOR2 IO ML
[1] :Implements constructor
[2] :Access public
[3] :Signature CTOR2 Int32 IO,Int32 ML
[4] CTOR IO ML
▽

▽ CTOR IO ML;EX
[1] IO ML←IO ML
[2] :If ~IO∈0 1
[3] EX←NEW ArgumentException,«'IndexOrigin must
                                be 0 or 1'
[4] EX □SIGNAL 90
[5] :EndIf
[6] :If ~ML∈0 1 2 3
[7] EX←NEW ArgumentException,«'MigrationLevel
                                must be 0, 1, 2 or 3'
[8] EX □SIGNAL 90
[9] :EndIf
[10] IO ML←IO ML
▽

```

The `:Signature` statements for these three functions show that `CTOR1` is defined as a constructor that takes a single `Int32` parameter, `CTOR2` is defined as a constructor that takes two `Int32` parameters, and `CTOR` has no .NET Properties defined at all.

Note that in .NET terms, `CTOR` is not a *Private Constructor*; it is simply an internal function that is invisible to the outside world.

Next, a function called `GetIOML` is defined and exported as a Public Method. It simply returns the current values of `IO` and `ML`.

```

    ▽ R←GetIOML
[1]   :Access public
[2]   :Signature Int32[]←GetIOML
[3]   R←IO ML
    ▽

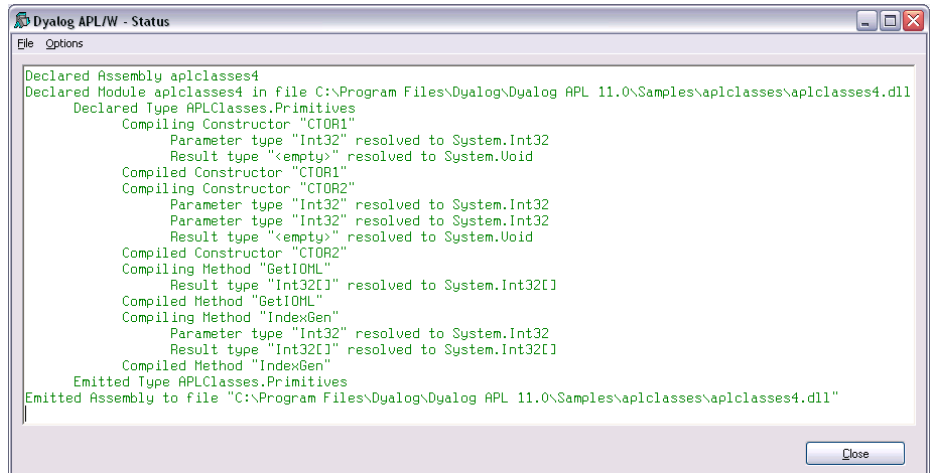
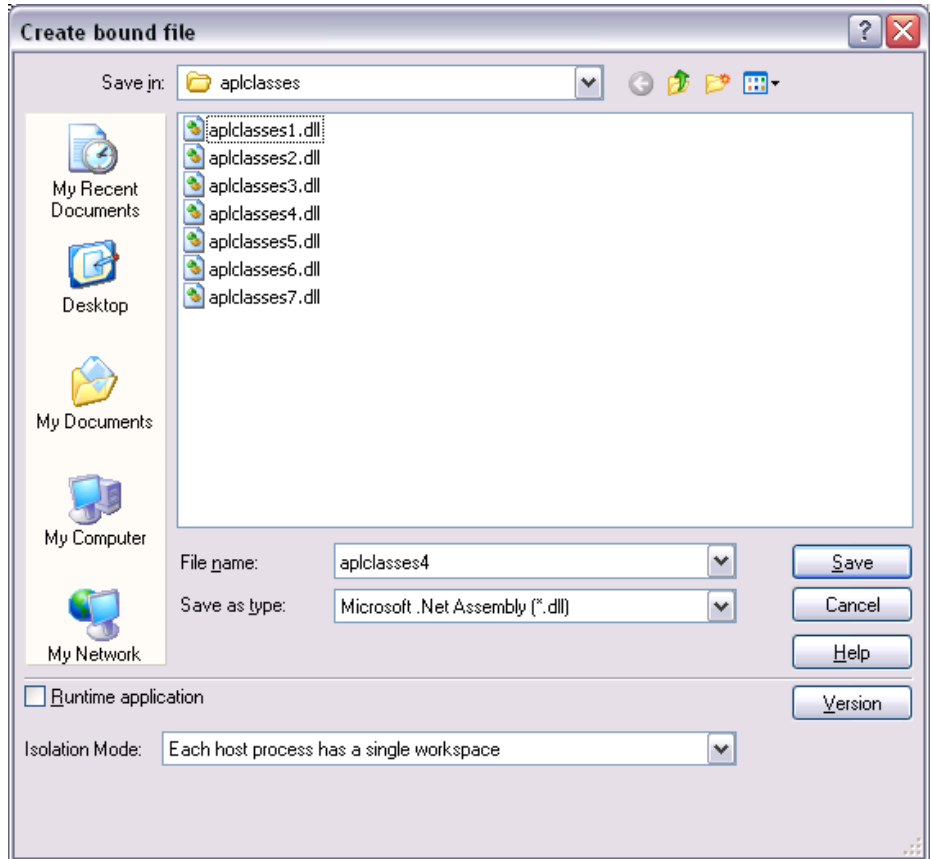
```

Having done this, the workspace is renamed `aplclasses4.dws`, and saved, and a new Assembly `aplclasses4.dll` is built.

```

        )WSID samples\APLClasses\aplclasses4
was samples\APLClasses\aplclasses4
        )SAVE
samples\aplclasses\aplclasses4 ...

```



## aplfn4.cs

The following C# source, called `samples\APLClasses\aplfn4.cs`, may be used to invoke the two different constructor functions **CTOR1** and **CTOR2** in the new `aplclasses4.dll` Assembly .

```
using System;
using APLClasses;
public class MainClass
{
    public static void Main()
    {
        Primitives apl10 = new Primitives(1);
        int[] rslt10 = apl10.GetIOML();
        for (int i=0;i<rslt10.Length;i++)
            Console.WriteLine(rslt10[i]);
        Primitives apl03 = new Primitives(0,3);
        int[] rslt03 = apl03.GetIOML();
        for (int i=0;i<rslt03.Length;i++)
            Console.WriteLine(rslt03[i]);
    }
}
```

In this example, the code creates two instances of the `Primitives` class named `apl10` and `apl03`. The first is created with a constructor parameter of (1); the second with a constructor parameter of (0, 3). The C# compiler matches the first call with **CTOR1**, because **CTOR1** is defined to accept a single `Int32` parameter. The second call is matched to **CTOR2** because **CTOR2** is defined to accept two `Int32` parameters

Then, when the program is compiled and run ...

```
APLClasses>setpath.bat
...
APLClasses>csc /r:APLClasses4.dll aplfn4.cs
Microsoft (R) Visual C# .NET Compiler version 7.10.3052.4 for
Microsoft (R) .NET Framework version 2.0.50727. Copyright (C)
Microsoft Corporation 2001-2002. All rights reserved.
```

```
APLClasses>aplfn4
1
0
0
3
```



## Example 5

This example takes things a stage further and illustrates how you can implement *method overloading*.

In this example, the requirement is to export three different versions of the `IndexGen` method; one that takes a single number as an argument, one that takes two numbers, and a third that takes any number of numbers. These are represented by three functions named `IndexGen1`, `IndexGen2` and `IndexGen3` respectively. Because monadic `ι` performs all of these operations, the three APL functions are in fact identical. However, their public interfaces, as defined in their `:Signature` statement, are all different.

The overloading is achieved by entering the same name for the exported method (`IndexGen`) in the box provided, for each of the three APL functions.

```

)LOAD samples\APLClasses\aplclasses5
samples\aplclasses\aplclasses5 saved ...
)ed o APLClasses.Primitives

(those fns should be present:)

CTOR  CTOR1  CTOR2  IndexGen1  IndexGen2  IndexGen3

```

```

▽ R←IndexGen1 N
[1] :Access public
[2] :Signature Int32[]←IndexGen Int32 N
[3] R←ιN
▽

```

This is the version we have seen before. The method is defined to take a single argument of type `Int32`, and to return a 1-dimensional array (vector) of type `Int32`.

```

▽ R←IndexGen2 N
[1] :Access public
[2] :Signature Int32[,]←IndexGen Int32 N1, Int32 N2
[3] R←ιN
▽

```

This version is defined to take two arguments of type `Int32`, and to return a 2-dimensional array, each of whose elements is a 1-dimensional array (vector) of type `Int32`.

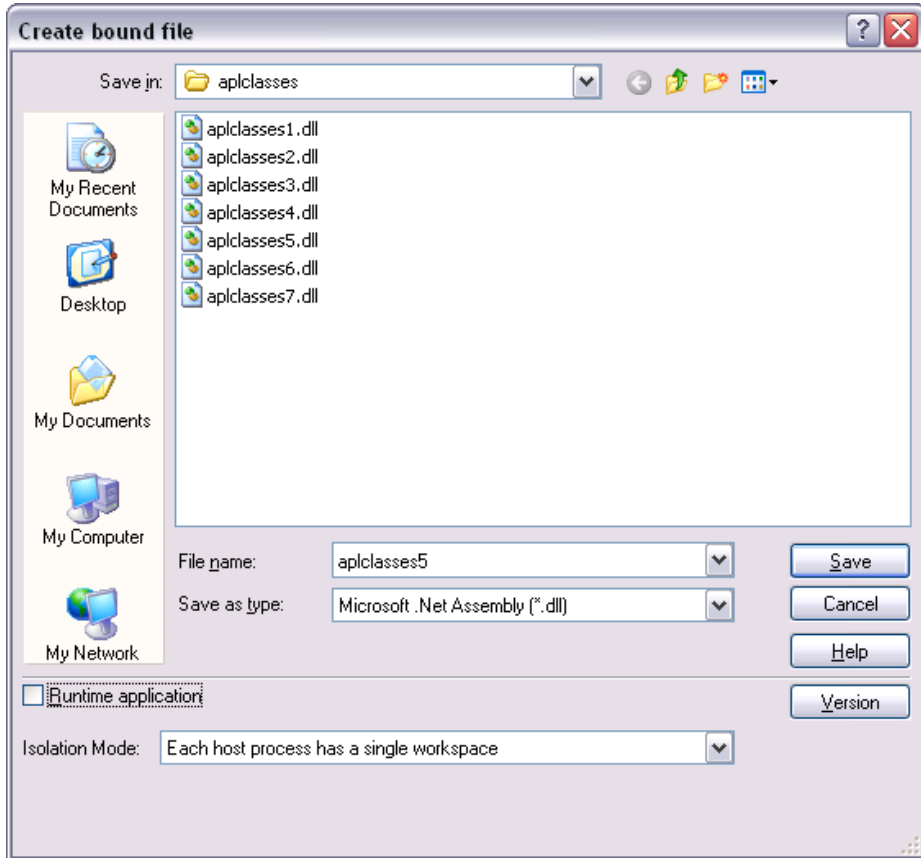
```

▽ R←IndexGen3 N
[1] :Access public
[2] :Signature Array←IndexGen Int32[] N
[3] R←ιN
▽

```

In principle, we could define 7 more different versions of the method, taking 3, 4, 5 etc numeric parameters. Instead, this method is defined more generally, to take a single parameter that is a 1-dimensional array (vector) of numbers, and to return a result of type `Array`. In practice we might use this version alone, but for a C# programmer, this is harder to use than the two other specific cases.

Notice also that all function use the same descriptive name, `<IndexGen>`.



```
Declared Assembly aplclasses5
Declared Module aplclasses5 in file C:\Program Files\Dyalog\Dyalog APL 11.0\Samples\aplclasses\aplclasses5.dll
Declared Type APLClasses.Primitives
  Compiling Constructor "CTOR1"
    Parameter type "Int32" resolved to System.Int32
    Result type "<empty>" resolved to System.Void
  Compiled Constructor "CTOR1"
  Compiling Constructor "CTOR2"
    Parameter type "Int32" resolved to System.Int32
    Parameter type "Int32" resolved to System.Int32
    Result type "<empty>" resolved to System.Void
  Compiled Constructor "CTOR2"
  Compiling Method "GetIOHL"
    Result type "Int32[]" resolved to System.Int32[]
  Compiled Method "GetIOHL"
  Compiling Method "IndexGen1"
    Parameter type "Int32" resolved to System.Int32
    Result type "Int32[]" resolved to System.Int32[]
  Compiled Method "IndexGen1"
  Compiling Method "IndexGen2"
    Parameter type "Int32" resolved to System.Int32
    Parameter type "Int32" resolved to System.Int32
    Result type "Int32[,] " resolved to System.Int32[, ]
  Compiled Method "IndexGen2"
  Compiling Method "IndexGen3"
    Parameter type "Int32[]" resolved to System.Int32[]
    Result type "Array" resolved to System.Array
  Compiled Method "IndexGen3"
Emitted Type APLClasses.Primitives
Emitted Assembly to file "C:\Program Files\Dyalog\Dyalog APL 11.0\Samples\aplclasses\aplclasses5.dll"
```

## aplfns5.cs

The following C# source, called `samples\APLClasses\aplfns5.cs`, can be used to invoke the three different variants of `IndexGen`, in the new `aplclasses5.dll` Assembly.

```
using System;
using APLClasses;
public class MainClass
{
    static void PrintArray(int[] arr)
    {
        for (int i=0;i<arr.Length;i++)
        {
            Console.Write(arr[i]);
            if (i!=arr.Length-1)
                Console.Write(",");
        }
    }

    public static void Main()
    {
        Primitives apl = new Primitives(0);
        int[] rslt = apl.IndexGen(10);
        PrintArray(rslt);
        Console.WriteLine("");

        int[,] rslt2 = apl.IndexGen(2,3);
        for (int i=0;i<2;i++)
        {
            for (int j=0;j<3;j++)
            {
                int[] row = rslt2[i,j];
                Console.Write("(");
                PrintArray(row);
                Console.Write(")");
            }
            Console.WriteLine("");
        }

        int[] args = new int[3];
        args[0]=2;
        args[1]=3;
        args[2]=4;
        Array rslt3 = apl.IndexGen(args);
        Console.WriteLine(rslt3);
    }
}
```

Then, when the program is compiled and run ...

```
APLClasses>setpath.bat
...
APLClasses>csc /r:APLClasses5.dll aplfns5.cs
Microsoft (R) Visual C# .NET Compiler version 7.10.3052.4 for
Microsoft (R) .NET Framework version 2.0.50727. Copyright (C)
Microsoft Corporation 2001-2002. All rights reserved.

APLClasses>aplfns5
0,1,2,3,4,5,6,7,8,9
(0,0) (0,1) (0,2)
(1,0) (1,1) (1,2)
System.Object[, ,]
```

It is possible for a function to have several `:Signature` statements. Given that our three functions perform exactly the same operation, it might have made more sense to use a single function:

```
▽ R←IndexGen1 N
[1] :Access public
[2] :Signature Int32[]←IndexGen Int32 N
[3] :Signature Int32[,]←IndexGen Int32 N1, Int32 N2
[4] :Signature Array←IndexGen Int32[] N
[5] R←ιN
▽
```

## Interfaces

*Interfaces* define additional sets of functionality that classes can implement; however, interfaces contain no implementation, except for static methods and static fields. An interface specifies a contract that a class implementing the interface must follow. Interfaces can contain shared (known as "static" in many compiled languages) or instance methods, shared fields, properties, and events. All interface members must be public. Interfaces cannot define constructors. The .NET runtime allows an interface to require that any class that implements it must also implement one or more other interfaces.

When you define a class, you list the interfaces which it supports following a colon after the class name. The value of `⎕USING` (possibly set by `:Using`) is used to locate Interface names.

If you specify that your class implements a certain *Interface*, you must provide all of the members (methods, properties, and so forth) defined for that *Interface*. However, some Interfaces are only marker Interfaces and do not actually specify any members.

An example is the `TemperatureControlCtl2` custom control described in Chapter 10, which derives from `System.Web.UI.Control`. The first line of this class definition reads:

```
:Class TemperatureConverterCtl2: System.Web.UI.Control,  
    System.Web.UI.IPostBackDataHandler,  
    System.Web.UI.IPostBackEventHandler
```

Following the colon, the first name is the base class. Following the (optional) base class name is the list of interfaces which are implemented. The `TemperatureControlCtl2` custom control implements two interfaces named `IPostBackDataHandler` and `IPostBackEventHandler`. These interfaces are required for a custom control that intends to render the HTML for its own form elements in a Web page. These interfaces define certain methods that get called at the appropriate time by the page framework when a Web page is constructed for the browser. It is therefore essential that the class implements all the methods specified by the interface, even if they do nothing.

The base class, `System.Web.UI.Control`, defines an optional Interface called `INamingContainer`. A class based on `Control` that implements `INamingContainer` specifies that its child controls are to be assigned unique ID attributes within an entire application. This is a marker interface with no methods or properties defined for it.

See these examples in Chapter 10 for further details.

# Chapter 5:

## Dyalog APL and IIS

### Introduction

Microsoft Internet Information Services (IIS) is a comprehensive Web Server software package that allows you to publish information on your Intranet, or on the World Wide Web. IIS is included with Professional and Server versions of all recent Windows operating systems; all you need add is a network connection to run your own Web site.

IIS includes Active Server Page (ASP) technology. The basic idea of ASP is to permit web pages to be created dynamically by the web server. An ASP file is a character file that contains a mixture of HTML and scripts. When IIS receives a request for an ASP file, it executes the server-side scripts contained in the file to build the Web page that is to be sent to the browser. In addition to server-side scripts, ASP files can contain HTML (including related client-side scripts) as well as calls to components that can perform a variety of tasks such as database lookup, calculations, and business logic.

Basically, each script inside an ASP page generates a stream of HTML. The server runs the scripts and assembles the resulting HTML into a single stream (Web page) that is sent to the browser.

ASP.NET is a new version of ASP and is based upon the Microsoft .NET Framework technology. It offers significantly better performance and a host of new features including support for *Web Services*.

## IIS Applications and Virtual Directories

IIS supports the concept of an *Application*. An application is a logically separate service or web site. IIS can run any number of Applications concurrently. The files associated with an application are stored in a physical directory on disk, which is linked to an IIS *Virtual Directory*. The name of the Virtual Directory is the name of the Application or Web Site.

The Dyalog APL distribution contains a directory named `Dyalog\Samples\asp.net` and a set of sub-directories each of which contains a sample application.

During the installation of Dyalog APL, these are automatically registered as IIS Virtual Directories, under a common root called `dyalog.net`<sup>1</sup>. Versions of Dyalog APL prior to Version 11.0 created Virtual Directories under `apl.net`.

When you want to run the Web Services and Web Page examples, you do so by specifying the URL `http://localhost/dyalog.net/`

These samples can be easily found by selecting the *Documentation Centre* menu item from the Help menu on the Dyalog session, and scrolling down to the Tutorials section.

---

<sup>1</sup>Actually `dyalog.net.classic` or `dyalog.net.unicode`, according to your installed version of Dyalog.



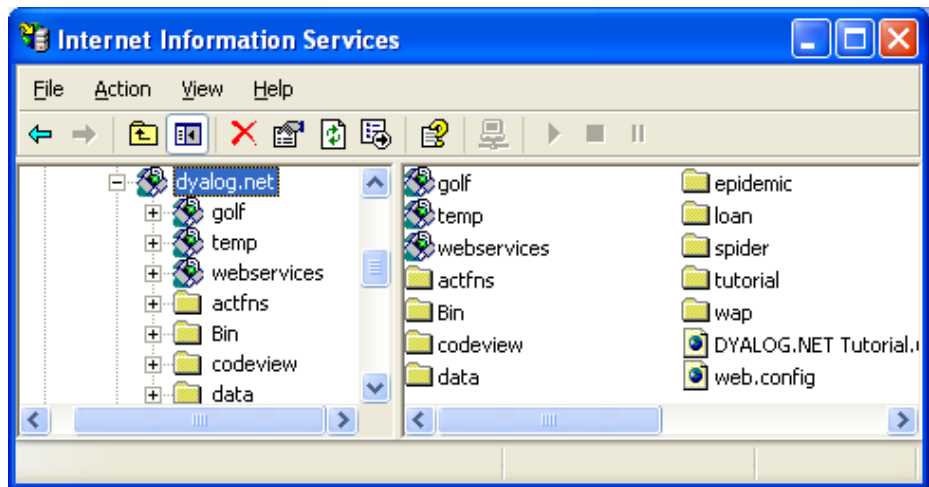
# Internet Services Manager

As its name suggests, Internet Services Manager is a tool for managing IIS. If you are developing Web Pages and/or Web Services, you will be using this tool a lot, and it makes sense to add it as a shortcut on your desktop.

To do this, open *Control Panel*, then open *Administrative Tools*, right-click *Internet Services Manager*, and select *Send To Desktop (create shortcut)*.

## The *dyalog.net* Virtual Directory

Following a successful installation of Dyalog APL, the *dyalog.net* Virtual Directory should appear in Internet Services Manager as shown below.

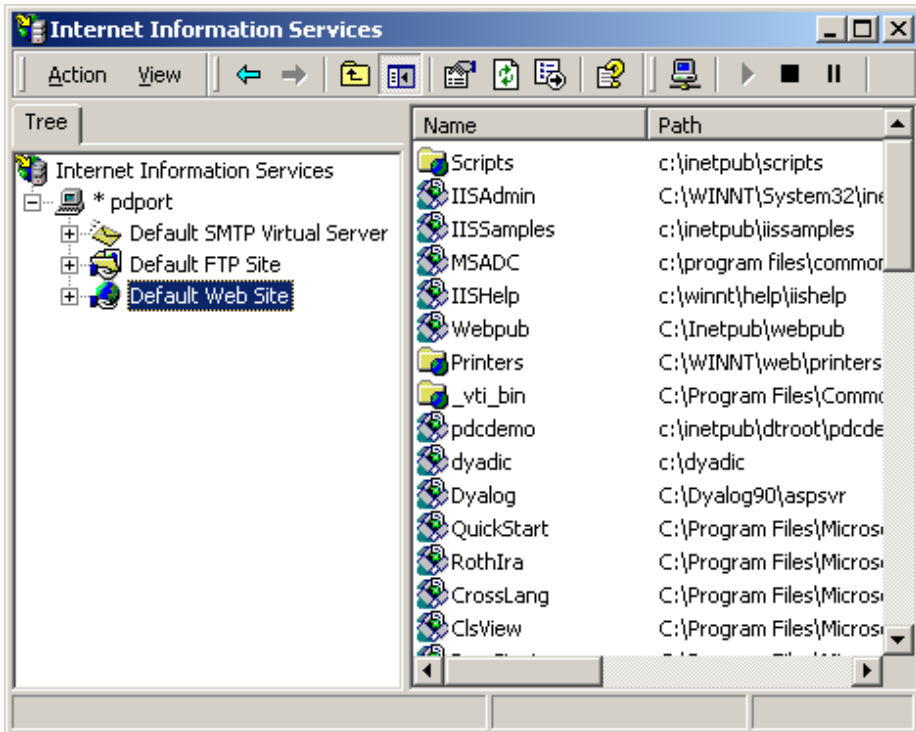


In case you need to set up your own IIS Virtual Directories yourself, the procedure is described below.

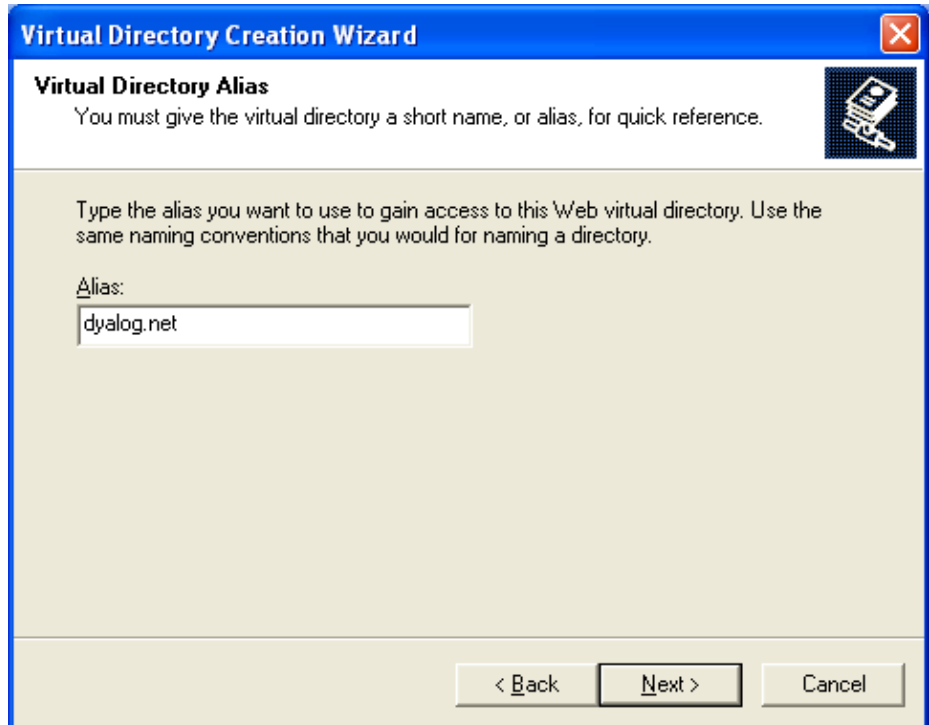
## Creating the *dyalog.net* Virtual Directory

If that Dyalog installation package did not install the Virtual Directories, or should you wish to install them again "by hand", perform the following actions.

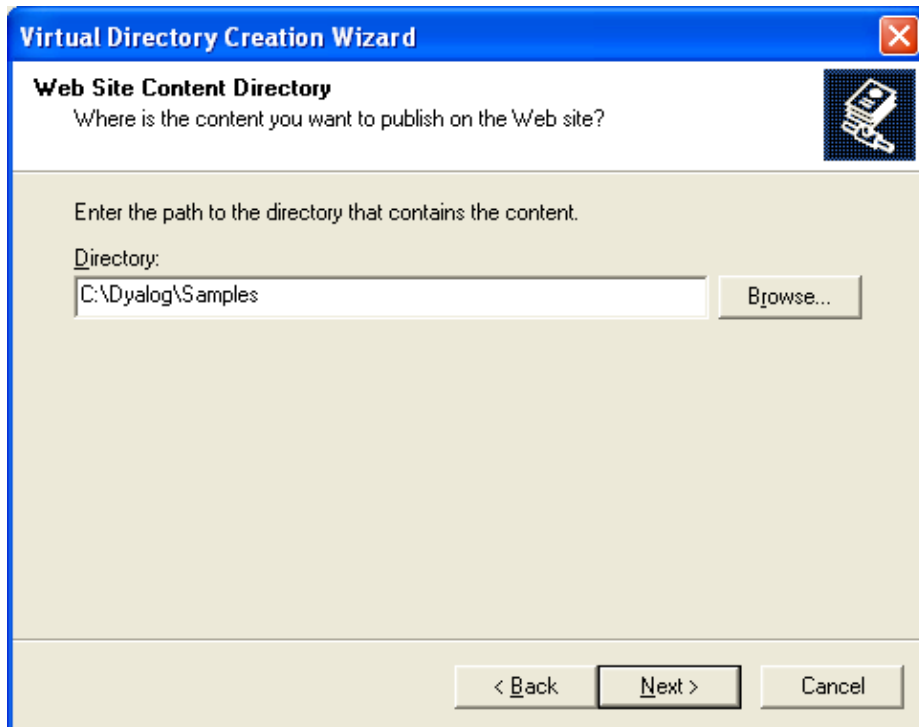
Start *Internet Services Manager*, open the icon associated with your computer (in this case, *pdport*) and select *Default Web Site* (or the appropriate name).



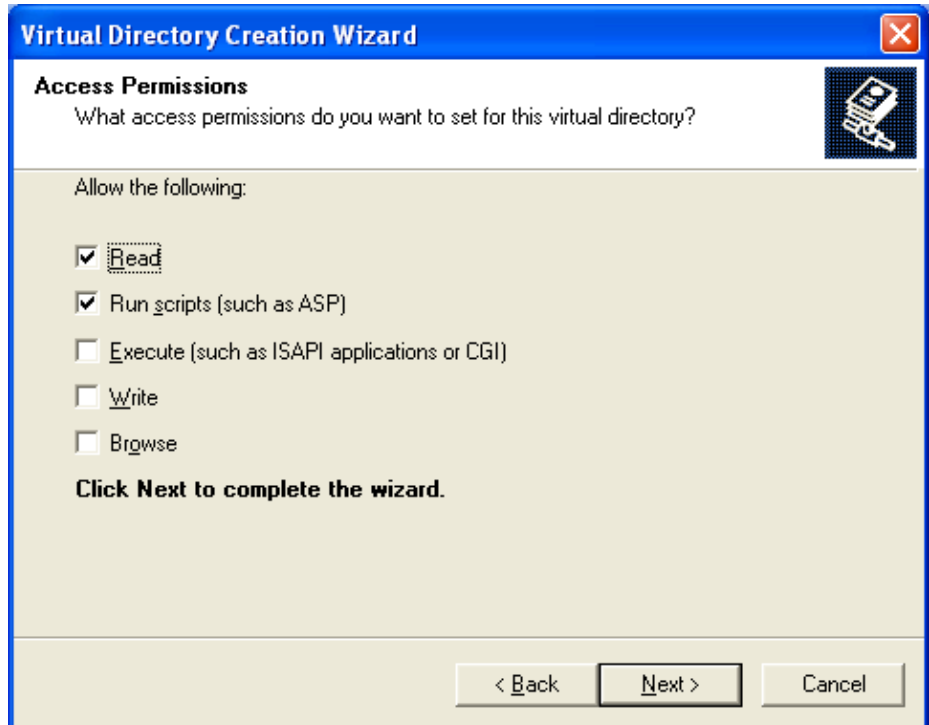
Select *New Virtual Directory* from the *Action* menu or from the item's context menu. This brings up the *Virtual Directory Creation Wizard*. Click *Next* to bring up the first page and enter *dyalog.net* into the *Alias* field.



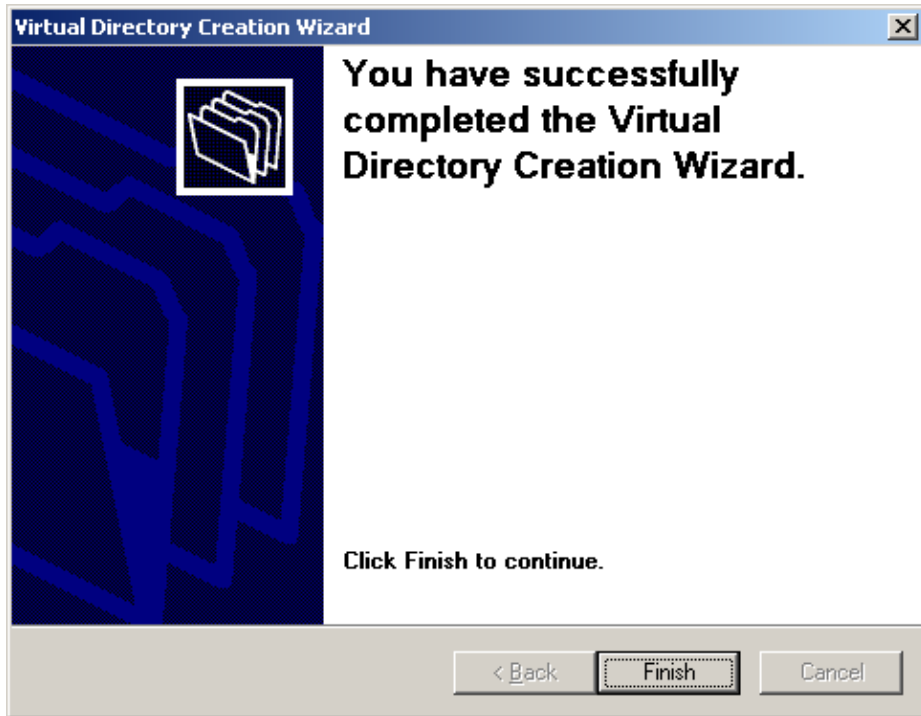
Click Next, then enter the full pathname to the `Dyalog\samples\asp.net` directory as shown below.



Accept the default Access Permissions, as shown below, and click *Next*.



Then finally, click *Finish*.

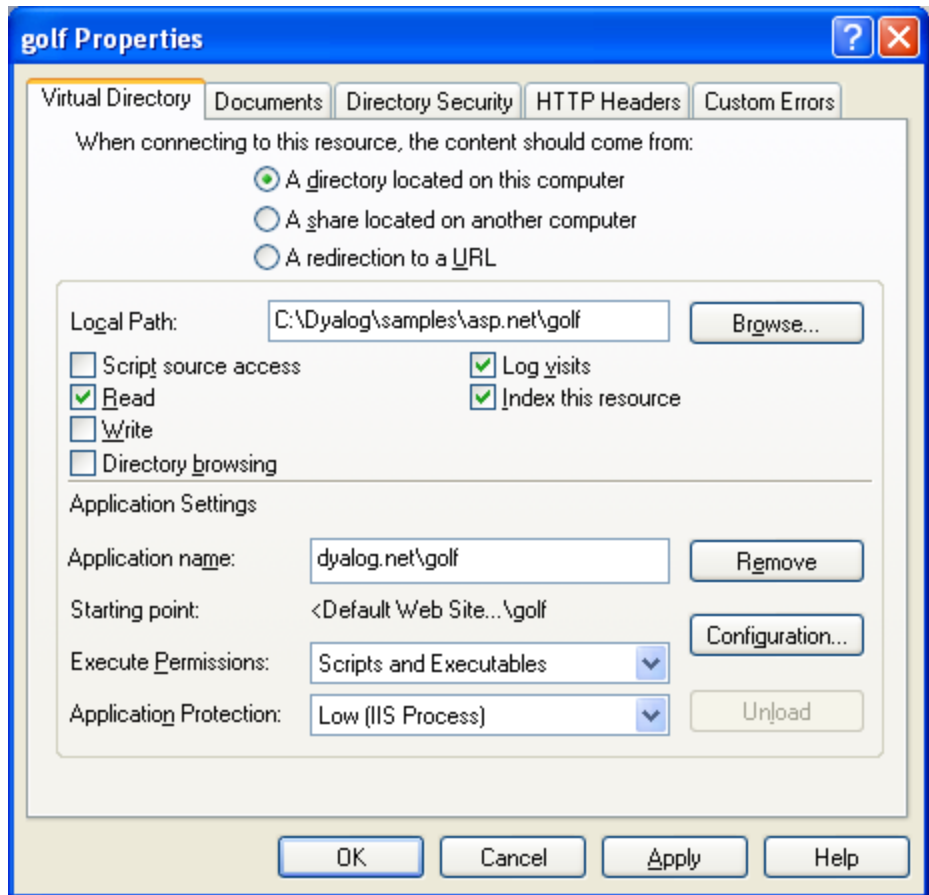


## Creating the *dyalog.net* Virtual Sub-Directories

The `golf`, `temp` and `webservices` sub-directories in `dyalog.net` represent separate IIS Applications, so these need to be registered as IIS Virtual Directories too.

Open the newly created *dyalog.net* item shown in the left pane of *Internet Services Manager*, bring up the context menu of the *Golf* sub-directory, and select *Properties*.

Click the *Create* button; this turns the sub-directory into an IIS Virtual Directory (a separate IIS application) named *Golf*.



Note that the *Application Protection* entry dictates whether your application is loaded into the IIS process (Low), a shared DLLHost task (Medium) or its own DLLHost task (High). The last choice isolates your application from all other IIS applications, and is the safest option.

Follow the same procedure to define `Temp` and `webservices` as Virtual Directories (as sub-directories of `dyalog.net`).

It is not necessary to do this now, but you will need to do this during development and it won't hurt now.

**Restart IIS.** You can do this from the context menu of the item associated with your computer at the top of the tree. Restarting IIS causes it to unload all the assemblies associated with your Applications.





# Chapter 6:

## Writing Web Services

### Introduction

A Web Service can be thought of as a Remote Procedure Call. However, it is a remote procedure call that can be made over the Internet using character-based messages.

Web Services are implemented using Simple Object Access Protocol (SOAP), Extensible Mark-up Language (XML) and Hypertext Transfer Protocol (HTTP). Web Services do not require proprietary network protocols or software. Web Service calls and responses can successfully be transmitted over the Internet without the need to specially configure firewalls.

A Web Service is a class that may be called by any program running on the computer, any program running on a computer on the same LAN, or any program running on any computer on the internet.

Web Services are hosted (i.e. executed) by ASP.NET running under Microsoft IIS. Any one Web Service sits on a single server computer and runs there under ASP.NET/IIS. The messages that invoke the Web Service, pass its arguments, and return its results, utilise standard HTTP/SOAP/XML protocols.

A Web Service consists of a single text script file, with the extension `.asmx`, in an IIS Virtual Directory on the server computer.

A Web Service may expose a number of Methods and Properties. Methods may be called *synchronously* (the calling process waits for the result) or *asynchronously* (the calling process invokes the method, continues for a bit, and then subsequently checks for the result of the previous call).

## Web Service (.asmx) Scripts

Web Services may be written in a variety of languages, including APLScript, the scripting version of Dyalog APL (see Chapter 10).

The first statement in the script file declares the language and the name of the service. For example, the following statement declares a Dyalog APL Web Service named `GolfService`.

```
<%@ WebService Language="Dyalog" Class="GolfService" %>
```

Note that `Language="Dyalog"` is specifically connected to the Dyalog APL script compiler through the application's `web.config` file or through the global ASP.NET system file `Machine.config`. Note that versions of Dyalog prior to 11.0 used `Language="APL"`.

The syntax of this first line is common to all Web Services, regardless of the language in which they are written.

A Dyalog APL Web Service script starts with a `:Class` statement and ends with an `:EndClass` statement. These statements are directives used by the Dyalog APL script compiler and are specific to Dyalog APL.

The `:Class` statement declares the name of the Class (which must be the same as the name declared in the `WebService` statement) and the *Base Class* from which it inherits, which is normally `System.Web.Services.WebService`.

```
    :Class GolfService: System.Web.Services.WebService
```

Following the `:Class` statement, there may appear any number of APL expressions and function bodies. Following these there must be a `:EndClass` statement. Internal sub-classes (nested classes) may also be defined within the main `:Class . . . :EndClass` block.

Because the functions usually take arguments and return results whose types must be known, the statement

```
    :Using System
```

must almost always appear **immediately** after the `:Class` statement to locate them.

## Compilation

When the Web Service, specified by the `.asmx` file, is called **for the first time**, ASP.NET invokes the appropriate language compiler (in this case, the Dyalog APL Script compiler) whose job is to produce an Assembly that defines and describes a class. When the Web Service is used subsequently, the request is satisfied by creating and using an instance of the class. However, ASP.NET detects if the `.asmx` script has been modified, and recompiles it in this case.

The Dyalog APL Script compiler creates a DLL containing a workspace, which itself contains the Web Service class. The class contains all the functions, which are defined within the script, together with any variables that were established by expressions in the script. A single function comprises all the statements enclosed within a pair of `del` ( $\nabla$ ) symbols.

For example, the following script would define a class, instances of which would run using `ML←2`, containing a single function `FOO` and a variable `X`.

```
:Class MyClass
  ML←2
  X←10
  ▽ Z←FOO Y
    Z←Y+X
  ▽
:EndClass
```

Note that all expressions in the class script are executed by the script compiler when it creates the assembly. They are not executed when the Web Service is invoked.

If your script contains a `ⓈCY` statement, it will be executed by the compiler when establishing the class. This may be used to import functions from other workspaces and obviate the need to include them in the `.asmx` file.

## Exporting Methods

Your Web Service will be of no use unless it exports at least one method. To export a function as a method, you must include declaration statements. Such declarations may be supplied anywhere within the function body, but it is recommended that they appear together as the first block of statements in your code. All declaration statements begin with the colon (:) character and the following declaration statements are supported:

```
:Access WebMethod
```

This statement causes the function to be exported as a method and **must** be present.

```
:Signature type ← fname type name1, type name2, ...
```

This statement declares the data type of the result and the arguments of the method where **type** may specify any valid .NET type that is supported by Web Services. Note that the assignment arrow (←) is necessary if the function returns a result.

The declaration of each parameter of the method is separated from the next by a comma. Each **name** may be any ASCII character string. Note that names are optional.

### Add1

```
▽ R←Add1 args
  :Access WebMethod
  :Signature Int32←Add Int32 arg1,Int32 arg2
  R←+/args
▽
```

The **Add1** function defined above is exported as a method named **Add**, that takes exactly (and only) two parameters of type `Int32` and returns a result of type `Int32`. Armed with this definition, which is recorded in the metadata associated with the class, the .NET Framework guarantees that the method will only be called in this way.

### Add2

```
▽ R←Add2 arg
  :Access WebMethod
  :Signature Double←Add Double[] arg1
  R←+/arg
▽
```

The **Add2** function defined above is exported as a method that takes an array of `Double` and returns a result of type `Double`. Depending on the type of the arguments provided when the method is invoked, .NET and Dyalog APL will call **Add1** or **Add2** - or generate an exception if the argument does not match any of the signatures.

## Web Service Data Types

In principle, Web Services are designed to support most, if not all, of the data types supported by the .NET Framework, and to support any new .NET classes that you choose to define.

In practice, the current set of data types supported by Web Services is somewhat restricted; in particular:

- Multi-dimensional arrays are not supported; only vectors.
- Arbitrary nested arrays are not supported.

However, despite these restrictions, it is possible to build effective Web Services, as you will see in the following examples.

## Execution

When your Web Service (or Page) is invoked, ASP.NET requests an instance of the corresponding Class from the Assembly (DLL) that was created when it was compiled. The first time this happens for any Dyalog APL Web Service or Web Page, the Dyalog APL dynamic link library (see Chapter 12) is loaded into the ASP.NET host process and the namespace corresponding to your Web Service class is )**COPYed** from the Assembly. The Dyalog APL dynamic link library then delivers an instance of this namespace to the client (calling) process.

In general, every call on a method in a Web Service causes a new instance of the Web Server class to be created. If you need to maintain/update variables between calls, you need to write them to permanent storage.

If a client invokes a different Dyalog APL Web Service or Web Page, its class is )**COPYed** from its Assembly into the workspace managed by the Dyalog APL dynamic link library. When you export a class, you can select one of three Isolation Modes:

1. Each host process has a single workspace
2. Each AppDomain has its own workspace
3. Each Assembly has its own workspace

In this context, "workspace" is synonymous with "Dyalog APL process": Each workspace is managed by a separate process running dyalog.dll. Under option 1, all Dyalog APL Web Services (and Web Pages) hosted by the IIS host process share the same workspace when they are invoked.

The isolation mode selected has implications for the way that you access and manage global resources such as component files. Finer isolation modes may be implemented in future versions of Dyalog APL.

## Global.asax and Application and Session Objects

When a Web Service runs, it has access to the Application and Session objects. These are objects provided by ASP.NET through which you can manage the execution of the Web Service. ASP.NET creates an Application object when it first starts the Application, i.e. when any client requests any Web Service or Web Page stored in the same IIS Virtual Directory. It also creates a Session object for each client process.

When the first request comes in for an ASP.NET application, ASP.NET checks for an optional file named `global.asax`, and if it is there it compiles it. The application's `global.asax` instance is then used to apply application events.

`global.asax` typically defines callback functions to be executed on the various Application and Session events, such as `Application_Start`, `Application_End`, `Session_Start`, `Session_End` and so forth.

Dyalog APL allows you to use APL functions in the `global.asax` script. This allows you to initialise your APL application when it is first invoked, and to close it down cleanly when it is terminated.

For example, you can use `global.asax` to tie a component file on start-up, and untie it on termination.

## Sample Web Service: EG1

The first APLExample sample is supplied in `samples\asp.net\webservices\eg1.asmx` which is mapped via an IIS Virtual Directory to the URL

`http://localhost/dyalog.net/webservices/eg1.asmx`

```
<%@ WebService Language="Dyalog" Class="APLExample" %>

:Class APLEXample: System.Web.Services.WebService
:Using System

  ▽ R←Add args
    :Access WebMethod
    :Signature Int32←Add Int32 arg1,Int32 arg2
    R←+/args
  ▽

:EndClass
```

The `Add` function defined above is exported as a method that takes exactly (and only) two parameters of type `Int32` and returns a result of type `Int32`.

Line [3] could in fact be coded as:

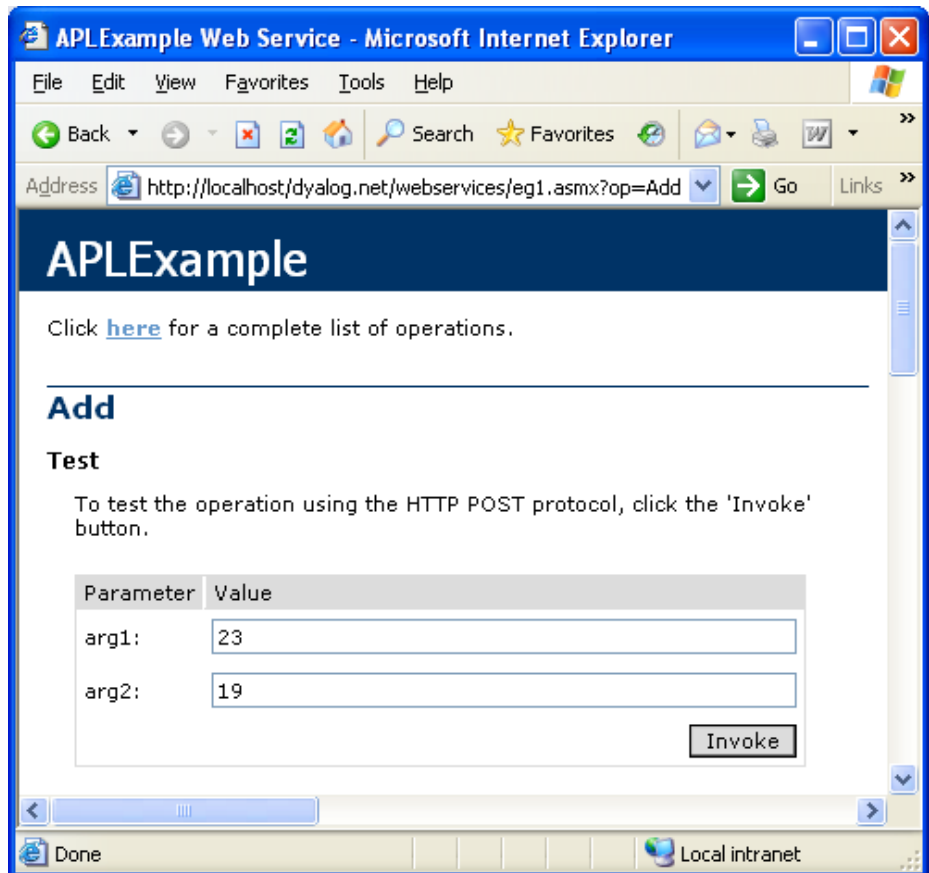
```
R←args[1]+args[2]
```

because .NET guarantees that a client can only call the method by providing two 32-bit integers as parameters.

## Testing APLEExample from IE

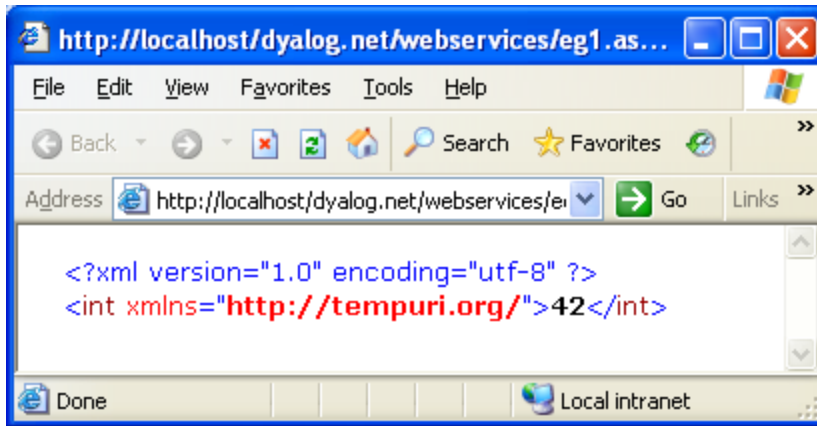
If you connect, using Internet Explorer, to a URL that represents a Web Service, it displays a page that displays information about the service and the methods that it contains. In certain cases, but by no means all, the page also contains form fields that let you invoke a method from the browser.

The screen shot below shows the page displayed by IE when it is pointed at `eg1.asmx`. It shows that the Web Service is called `APLEExample`, and that it exports a single method called `Add`. Furthermore, the `Add` method takes two parameters of type `int`, named `arg1` and `arg2`.



The following screen shot shows the result of entering the values 23 and 19 into the form fields and then pressing the Invoke button.

In this case, the method returns an `int` value 42.



It is important to understand what is happening here.

Accessed in this way from a browser, a Web Service appears to be behaving like a Web Server; this is not the case.

It is simply that the browser detects that the target URL is a Web Service, and invokes an ASP+ page named `DefaultSdlHelpGenerator.aspx` that inspects the compiled class and returns an HTML view of the Web service.



## Sample Web Service: LoanService

The LoanService sample is supplied in  
 Dyalog\Samples\asp.net\Loan\Loan.asmx, which is mapped via an IIS  
 Virtual Directory to the URL  
 http://localhost/dyalog.net/Loan/Loan.asmx

This APLScript sample defines a class named LoanService that is based upon  
**System.Web.Services.WebService**. The LoanService class defines a  
 sub-class called LoanResult and a method called CalcPayments.

```
<%@ WebService Language="Dyalog" Class="LoanService" %>
:Class LoanService: System.Web.Services.WebService
:Using System
  :Class LoanResult
  :Access public
    :Field Public Int32[] Periods
    :Field Public Double[] InterestRates
    :Field Public Double[] Payments
  :EndClass

  ▽ R←CalcPayments X;LoanAmt;LenMax;LenMin;IntrMax;
    IntrMin;PERIODS;INTEREST;NI;NM
[1]  :Access WebMethod
[2]  :Signature LoanResult←CalcPayments Int32 LoanAmt,
    Int32 LenMax,Int32 LenMin,
    Int32 IntrMax,Int32 IntrMin
[3]
[4]  A Calculates loan repayments
[5]  A Argument X specifies:
[6]  A   LoanAmt   Loan amount
[7]  A   LenMax    Maximum loan period
[8]  A   LenMin    Minimum loan period
[9]  A   IntrMax   Maximum interest rate
[10] A   IntrMin   Minimum interest rate
[11]
[12] LoanAmt LenMax LenMin IntrMax IntrMin←X
[13] R←NEW LoanResult
[14] R.Periods←1+LenMin+11+LenMax-LenMin
[15] R.InterestRates←0.5×1+(2×IntrMin)+11+2×
    IntrMax-IntrMin
[16] NI←pINTEREST←R.InterestRates÷100×12
[17] NM←pPERIODS←R.Periods×12
[18] R.Payments←,(LoanAmt)×((NI,NM)pNM/INTEREST)÷
    1-1÷(1+INTEREST)°. *PERIODS

  ▽
:EndClass
```

`CalcPayments` takes five integer parameters (see comments for their descriptions) and returns an object of type `LoanResult`.

Note that the block of `APLScript` that defines the sub-class `LoanResult` must reside between the `:Class` and `:EndClass` statements of the main class, `LoanService`. You may define any number of internal classes in this way.

The `LoanResult` class is made up only of `Fields` and it does not export any methods or properties. Furthermore, there are no constructor methods defined and it relies solely on its default constructor that is inherited from its base class, `System.Object`. The default constructor is called without any parameters and in fact does nothing except to create an instance of the class. In particular, the fields it contains initialised to zero. In this case, that is sufficient, as all the fields will be filled in explicitly later.

```

:Class LoanResult
:Access public
:Field Public Int32[] Periods
:Field Public Double[] InterestRates
:Field Public Double[] Payments
:EndClass

```

The `:Class` statement starts the definition of a new class and specifies its name. The `:EndClass` statement terminates it definition.

The three `:Field` declaration statements specify the names and data types of three public fields. The `Public` attributes are necessary to make the fields visible to methods within the `LoanService` class as a whole, as well as to external clients.

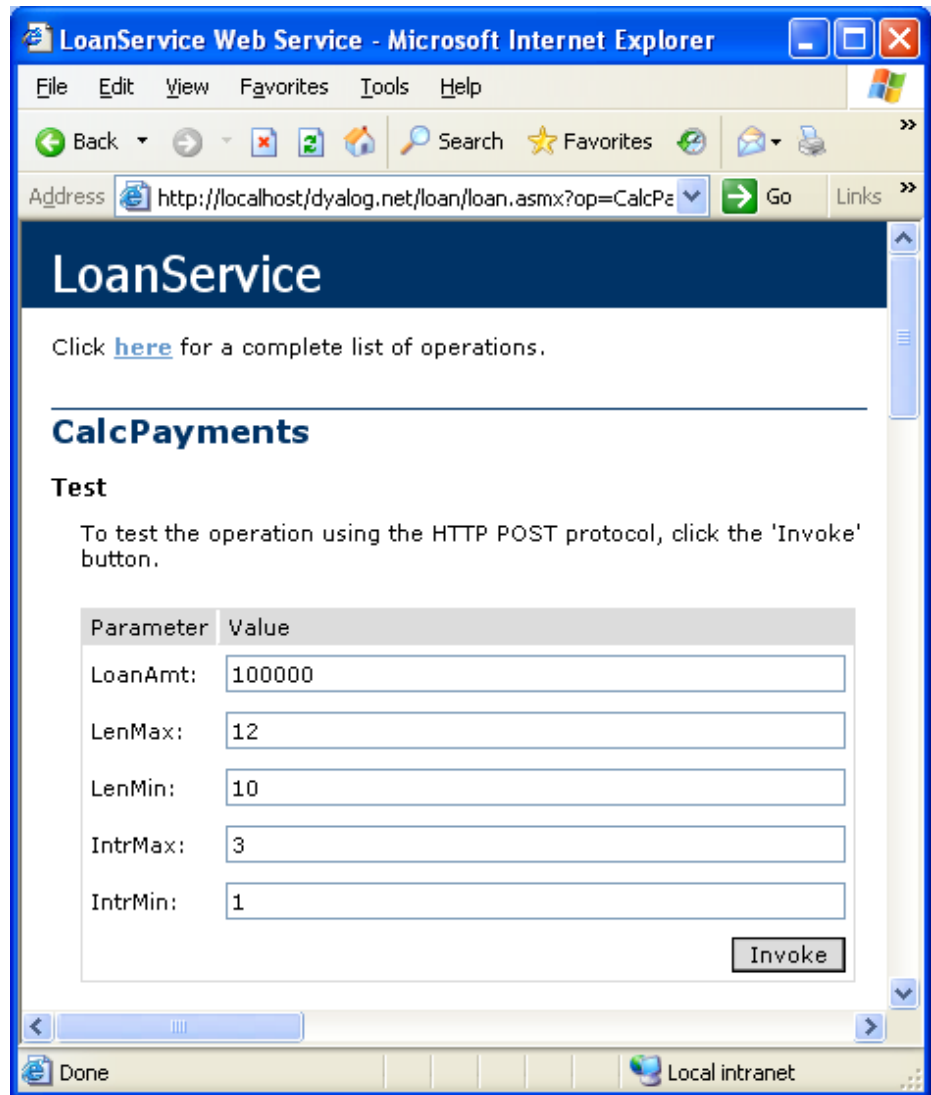
The `Periods` field is defined to be an array of integers; the `InterestRates` field an array of `Double`. Both these arrays are 1-dimensional, i.e. vectors. These will contain the numbers of years, and the different interest rates, to which the repayments matrix applies.

Notice however that `Payments` is also defined to be 1-dimensional when in fact it is, more naturally, a 2-dimensional matrix. The reason for this is that, currently, Web Services do not support multi-dimensional arrays. This is a .NET restriction and not a Dyalog restriction.

`CalcPayments [13]` gets a new instance of the `LoanResult` class by doing `⎕New LoanResult`. It then assigns values to each of the three fields in lines `[14]`, `[15]` and `[18]`.

## Testing LoanService from IE

Like the methods exported by the APLEExample Web Services described above, the CalcPayments method exported by LoanService is callable from a browser and the page that is displayed when you point IE at it is shown below.



To test the CalcPayments method, you can enter numbers into the form fields in this page, as shown in the screen shot above, and then press the *Invoke* button. The result of the method is then displayed in a separate window as illustrated below.

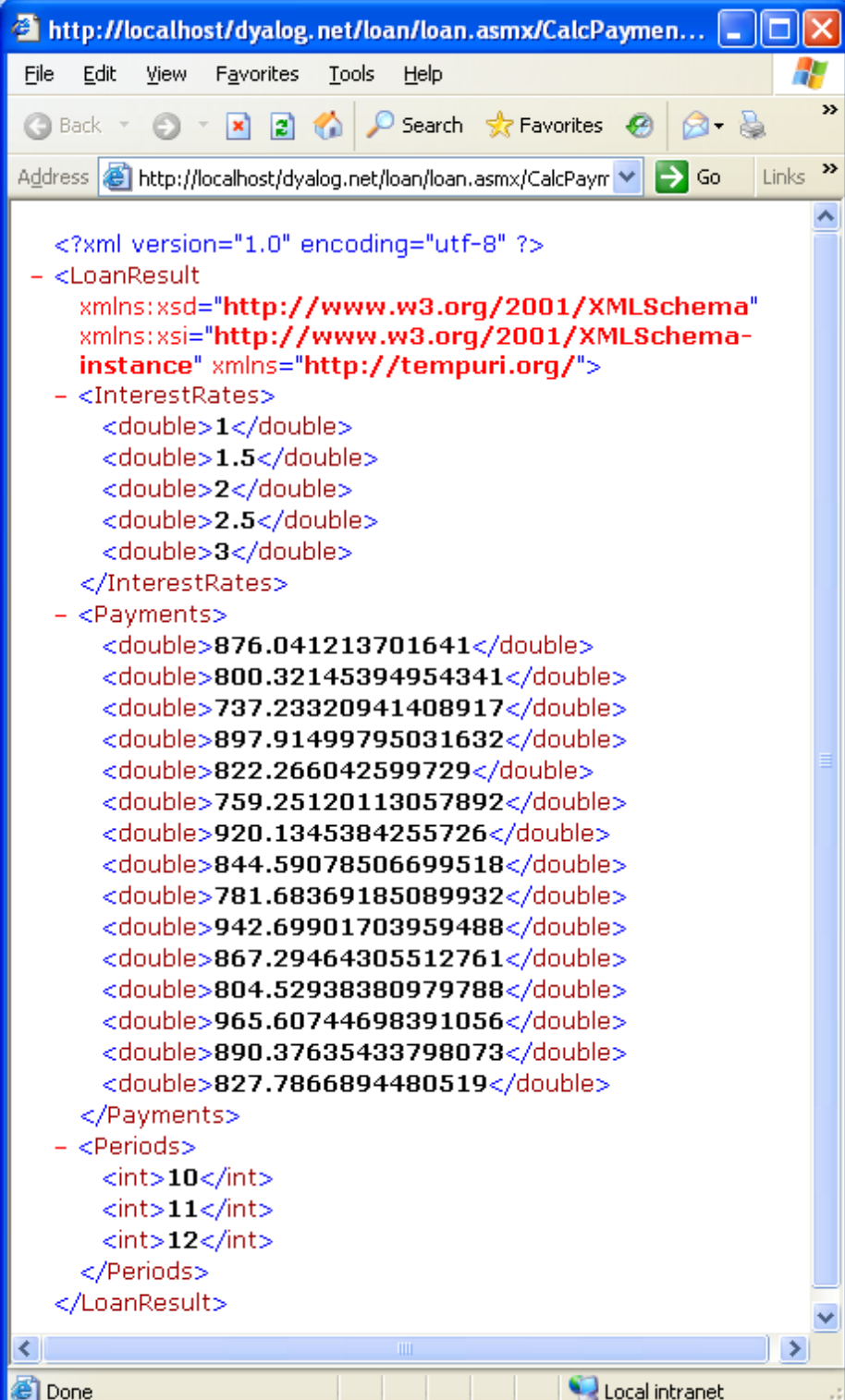
Notice that the result is described using XML, which is in fact the very language used to invoke a Web Service and return its result.

You can see that the result is of type `LoanResult`, and it contains 3 fields named `Payments`, `InterestRates` and `Periods`. This information was derived by our definition of the `LoanResult` class in the `APLScript` file.

As you can see, the `InterestRates` field shows that it contains a vector of floating-point values (`double`) from the minimum rate to the maximum rate that we specified on the input form. This time, the increment is 0.5.

Similarly, the `Payments` field contains the calculated repayment values.

Finally the `Periods` field, contains a vector of integers from the minimum period to the maximum period that we specified on the input form, in increments of 1.



The screenshot shows a web browser window with the address bar containing `http://localhost/dyalog.net/loan/loan.asmx/CalcPaymen...`. The browser's content area displays an XML response. The XML is color-coded: blue for the root and closing tags, red for namespace declarations, and black for the data values. The response is a SOAP envelope containing a `<LoanResult>` element. Inside `<LoanResult>`, there are three sub-elements: `<InterestRates>`, `<Payments>`, and `<Periods>`. `<InterestRates>` contains five `<double>` values: 1, 1.5, 2, 2.5, and 3. `<Payments>` contains ten `<double>` values: 876.041213701641, 800.32145394954341, 737.23320941408917, 897.91499795031632, 822.266042599729, 759.25120113057892, 920.1345384255726, 844.59078506699518, 781.68369185089932, and 942.69901703959488. `<Periods>` contains three `<int>` values: 10, 11, and 12.

```
<?xml version="1.0" encoding="utf-8" ?>
- <LoanResult
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://tempuri.org/">
- <InterestRates>
  <double>1</double>
  <double>1.5</double>
  <double>2</double>
  <double>2.5</double>
  <double>3</double>
</InterestRates>
- <Payments>
  <double>876.041213701641</double>
  <double>800.32145394954341</double>
  <double>737.23320941408917</double>
  <double>897.91499795031632</double>
  <double>822.266042599729</double>
  <double>759.25120113057892</double>
  <double>920.1345384255726</double>
  <double>844.59078506699518</double>
  <double>781.68369185089932</double>
  <double>942.69901703959488</double>
  <double>867.29464305512761</double>
  <double>804.52938380979788</double>
  <double>965.60744698391056</double>
  <double>890.37635433798073</double>
  <double>827.7866894480519</double>
</Payments>
- <Periods>
  <int>10</int>
  <int>11</int>
  <int>12</int>
</Periods>
</LoanResult>
```

## Sample Web Service: GolfService

`GolfService` is an example Web Service that resides in the directory `samples\asp.net\Golf` and is associated with the IIS Virtual Directory `dyalog.net/Golf`. This example makes extensive use of internal classes to define data structures that are appropriate for a client application, such as C# or VB.

The directory contains a `global.asax` script, which is used to initialise the application.

The Golf Web Service example manages the reservation of tee-times at golf courses. All the data is held in a component file called `GolfData.dcf`. This file may be initialised using the function `Golf.INITFILE` in the workspace `samples\asp.net\webervices\webervices.dws`. You may need to alter the file path first.

Each golf course managed by the application has a unique code (integer) and a name (string). This is handled by defining a class (structure) called `GolfCourse` with two fields, `Code` and `Name`.

`GolfService` provides 3 methods:

`GetCourses()`

Returns a list of Golf Courses (`CourseCode` and `CourseName`). The result of this method is an array of `GolfCourse` objects.

`GetStartingSheet(CourseCode, Date)`

Returns the starting sheet for a specified golf course on a given day. A starting sheet is a list of starting times with a list of the golfers booked to start their round at that time. The result of this method is a `StartingSheet` object.

`MakeBooking(CourseCode, TeeTime, GimmeNearest, Name1, Name2, Name3, Name4)`

Requests a tee reservation at the course specified by `CourseCode`. `TeeTime` is a `DateTime` object that specifies the requested date and time. `GimmeNearest` is `Boolean`. If 1, requests the nearest tee-time to that specified; if 0, requests only the specified tee-time. `Name1-4` are strings specifying up to 4 players. Note that all parameters are required. The result of this method is a `Booking` object.

## GolfService: Global.asax

```
<script language="Dyalog" runat=server>
  ▽ Application_Start;GOLFID
    :Access Public
    GOLFID←'c:\Dyalog\samples\asp.net\golf\GolfData' □FTIE 01
    Application['GOLFID']←GOLFID
  ▽
  ▽ Application_End;GOLFID
    :Access Public
    :Trap 6
    GOLFID←Application['GOLFID']
    □FUNTIE GOLFID
    :EndTrap
  ▽
</script>
```

The `Application_Start` function is called when the `GolfService` Web Service is invoked for the first time. It ties the `GolfData` component file then stores the tie number in a new Item called `GOLFID` in the `Application` object. This item is then subsequently available to methods in the `GolfService` for the duration of the application.

The `Application_End` function is invoked when the `GolfService` Web Service terminates. It unties the `GolfData` component file.

This example may be considered slightly weak in that the location of the data file is hard-coded in the application's `Global.asax` file. An alternative is to store this information in the `<appsettings>` section of the appropriate `web.config` file or in the global `machine.config` file. This is preferable if the resource (in this case a file name) is to be accessed from more than one script. For further information on ASP.NET *config* files, see the documentation for the .NET Framework SDK.

Note that the `GolfData` file may be initialised using the function `Golf.INITFILE` in the `samples\asp.net\webservices\webservices.dws` workspace. The function will prompt you for the path of the file, initialize it and update the `Global.asax` file accordingly.

---

<sup>1</sup>This file needs to be located where it can be modified.

## GolfService: GolfCourse class

The `GolfCourse` class is effectively a structure with two fields named `Code` and `Name`. `Code` is an integer code that provides a shorthand way to refer to a specific golf course; `Name` is a `String` containing its full name.

```

:Class GolfCourse
  :Access Public
  :Field Public Int32 Code
  :Field Public String Name

  ▽ ctor args
    :Implements Constructor
    :Access public
    :Signature fn Int32, String
      Code Name←args
  ▽
  ▽ ctor_def
    :Implements Constructor
    :Access public
    ctor ~1 ''
  ▽
:EndClass

```

The `GolfCourse` class provides two constructors. The first, named `ctor_def`, takes no arguments and therefore overrides the default constructor that is inherited from `System.Object`. `ctor_def` calls `ctor` to initialise the instance with a `Code` of `~1` and an empty `Name`.

The constructor named `ctor` accepts two parameters named `CourseCode` (an integer) and `CourseName` (a string), and simply assigns these values into the corresponding fields.

Therefore, valid ways to create an instance of a `GolfCourse` are:

```

GC←NEW GolfCourse
GC.(Code Name)←1 'St Andrews'

```

Or, more simply

```

GC←NEW GolfCourse (1 'St Andrews')

```

Note that the names of the constructor functions are not visible outside the class. Constructors are identified by their signatures (basically, the `:Implements Constructor` statement) and not by their names.



## GolfService: Slot class

The `Slot` class is effectively a structure with two fields named `Time` and `Players`. `Time` is a `DateTime` object that represents a time that can be reserved on the first tee. `Players` is an array of (up to 4) strings that contains the names of the golfers who have reserved to start their round of golf at that time.

```
:Class Slot
  :Access Public
  :Field Public DateTime Time
  :Field Public String[] Players

  ▽ ctor1 arg
  :Implements Constructor
  :Access public
  :Signature fn DateTime
    Time←arg
    Players← 0p<'
  ▽
  ▽ ctor2 args
  :Implements Constructor
  :Access public
  :Signature fn DateTime, String[]
    Time Players←args
  ▽
  ▽ ctor_def
  :Implements Constructor
  :Access public
  ▽
:EndClass
```

This class provides two constructor functions named `ctor1` and `ctor2`. However, for internal reasons, if a class defines any constructor functions, it is currently necessary to provide a dummy default constructor (the form of the constructor that takes no parameters); hence `ctor_def`.

The constructor `ctor1` accepts a single `DateTime` parameter, which it assigns to the `Time`, field, and initialises the `Players` field to an empty array.

The constructor `ctor2` accepts two arguments, a specified tee time, and an array of strings that contains golfers' names. It assigns these parameters to `Time` and `Players` respectively.

## GolfService: Booking class

The `Booking` class represents the result of the `MakeBooking` method. It contains 4 fields named `OK`, `Course`, `TeeTime` and `Message`.

`OK` is `Boolean` and indicates whether or not the attempt to make a reservation was successful. If `OK` is false (0), the `Message` field (a string) indicates the reason for failure.

If `OK` is true (1) the `Course` field contains an instance of a `GolfCourse` object, and the `TeeTime` field contains an instance of a `Slot` object. Together, these objects identify the reserved golf course and starting slot. The latter specifies both the starting time, and the names of all the golfers who have been allocated that starting time and who will therefore play together.

```

:Class Booking
  :Access Public
  :Field Public Boolean OK
  :Field Public GolfCourse Course
  :Field Public Slot TeeTime
  :Field Public String Message

  ▽ ctor args
    :Implements Constructor
    :Access public
    :Signature fn Boolean, GolfCourse, Slot, String
      OK Course TeeTime Message←args
  ▽
  ▽ ctor_def
    :Access public
    :Implements Constructor
  ▽
:EndClass

```

This class provides a single constructor method, which must be called with values for all four fields.

## GolfService: StartingSheet class

The `StartingSheet` class represents the result of the `GetStartingSheet` method. It contains 5 fields named `OK`, `Course`, `Date`, `Slots` and `Message`. `OK` is `Boolean` and indicates whether or not a starting sheet is available for the specified course and date.

If `OK` is false (0), the `Message` field (a string) indicates the reason for failure.

If `OK` is true (1) the `Course` field contains an instance of a `GolfCourse` object, the `Date` field contains the date in question, and the `Slots` field contains an array of `Slot` objects. Each `Slot` object specifies a starting time and the names of golfers who are booked to play at that time.

```
:Class StartingSheet
  :Access Public
  :Field Public Boolean OK
  :Field Public GolfCourse Course
  :Field Public DateTime Date
  :Field Public Slot[] Slots
  :Field Public String Message

  ▽ ctor args
    :Implements Constructor
    :Access public
    :Signature fn Boolean, GolfCourse, DateTime
      OK Course Date←args
  ▽

  ▽ ctor_def
    :Implements Constructor
    :Access public
  ▽
:EndClass
```

Like the `Booking` class, the `StartingSheet` class provides a single constructor method. In this case, the constructor is called with values for just 3 of the fields; the values of the other fields are expected to be assigned later.

## GolfService: GetCourses function

```

    ▽ R←GetCourses; COURSECODES; COURSES; INDEX; GOLFFID
[1]  R
[2]  :Access WebMethod
[3]  :Signature GolfCourse[]←fn
[4]
[5]  GOLFFID←Application[←'GOLFFID']
[6]  COURSECODES COURSES INDEX←[]FREAD GOLFFID 1
[7]  R←[]NEW"GolfCourse,""←"↓↑COURSECODES COURSES
    ▽

```

The `GetCourses` function retrieves the tie number of the `GolfData` component file from the `Application` object and reads its first component.

The function then creates a `GolfCourse` object for each of the courses recorded on the file, and returns the array of `GolfCourse` objects as its result.

## GolfService: GetStartingSheet function

The `GetStartingSheet` function retrieves the tie number of the `GolfData` component file from the `Application` object and reads its first component. Line [10] creates an instance of a `StartingSheet` object and uses it to initialise the result `R`. The value of the `OK` field is set to zero to indicate failure.

It then validates the requested `CourseCode`. If invalid, it simply sets the `Message` field in the result and returns it. Similarly, it checks to see if there is a starting sheet on file for the requested date. If not, it sets the `Message` field to indicate this, and returns.

Note that line [15] extracts the `Year`, `Month` and `Day` properties from the requested tee time, a `DateTime` object, and converts them to an IDN. This is used to index the component containing the starting sheet for that day.

```

▽ R←GetStartingSheet ARGS;CODE;COURSE;DATE;GOLFID;
  COURSECODES;COURSES;INDEX;COURSEI;IDN;DATES;COMPS;
  IDATE;TEETIMES;GOLFERS;I;T
[1]  R
[2]  :Access WebMethod
[3]  :Signature StartingSheet←fn Int32 CCode,
                                     DateTime Date
[4]
[5]  CODE DATE←ARGS
[6]  GOLFID←Application[<'GOLFID']
[7]  COURSECODES COURSES INDEX←FREAD GOLFID 1
[8]  COURSEI←COURSECODES⊘CODE
[9]  COURSE←NEW GolfCourse (CODE(COURSEI>COURSES,<'))
[10] R←NEW StartingSheet (0 COURSE DATE)
[11] :If COURSEI>ρCOURSECODES
[12]     R.Message←'Invalid course code'
[13]     :Return
[14] :EndIf
[15] IDN←2 ⊘NQ'. 'DateToIDN',DATE.(Year Month Day)
[16] DATES COMPS←FREAD GOLFID,COURSEI>INDEX
[17] IDATE←DATES⊘IDN
[18] :If IDATE>ρDATES
[19]     R.Message←'No Starting Sheet available'
[20]     :Return
[21] :EndIf
[22] TEETIMES GOLFERS←FREAD GOLFID,IDATE>COMPS
[23] R.OK←1
[24] T←NEW'DateTime','<'<DATE.(Year Month Day)),''
      3↑↓[1]24 60↑TEETIMES
[25] R.Slots←NEW'Slot','<'T,∘<'↓GOLFERS
▽

```

Line[23] sets the OK field of the result to 1 (success).

Line[24] converts the stored tee times (in minutes) to DateTime objects.

Line[25] combines the tee times and golfers into a vector of 2-element arrays, and creates a Slot object for each of them. The result is assigned to the Slots field of the result R.

## GolfService: MakeBooking function

The `MakeBooking` function checks that the requested tee-time is available, for the specified number of players and updates the starting sheet accordingly. The result of the function is a `Booking` object.

`MakeBooking` first retrieves the tie number of the `GolfData` component file from the Application object and reads its first component.

Lines[13 14] create instances of `GolfCourse` and `Slot` objects, which at this stage are not validated. Line[15] then initialises the result `R`, a `Booking` object, which includes these instances. At this stage, `R.OK` is 0 indicating failure.

Line[16] validates the requested `CourseCode`, and, if invalid, simply sets `R.Message` and returns.

Similarly, lines [20 23] check that the requested tee time is within the next 30 days from now. If not, the function assigns the appropriate error message to `R.Message` and returns. Note that these two statements employ the APL primitive function `>` (rather than the `op_GreaterThan` method) to compare the requested tee time (a `DateTime` object) with a new `DateTime` object that represents *now* and *now+30 days* respectively.

Notice that line[24] uses the `AddDays` method to create a new `DateTime` object that represents *now + 30 days*. An alternative expression, to get *now+30 days* is:

```
TEETIME.Now+[]NEW TimeSpan (30 0 0 0)
```

Lines[28-47] are concerned with retrieving the appropriate component from the file, initialising it or re-using an old one, if it is not present. Each component represents the starting sheet for a particular course on a particular day.

Lines[48-63] check whether or not the requested slot is available (for the specified number of golfers). If not it returns an error message as before or, if `GimmeNearest` is 1 (true), it attempts to allocate the slot closest to the requested time.

If an appropriate slot is found, Lines[72 73] update the `Slot` object with the assigned time and names of the golfers. Line[74] then inserts the modified `Slot` object into the result, and sets the `OK` field to 1 (true) to indicate success.

```

    ▽ R←MakeBooking ARG$;CODE;COURSE;SLOT;TEETIME;GOLFID;
        COURSECODES;COURSES;INDEX;COURSEI;IDN;
        DATES;COMPS;IDATE;TEETIMES;GOLFERS;
        OLD;COMP;HOURS;MINUTES;NEAREST;TIME;
        NAMES;FREE;FREETIMES;I;J;DIFF

[1]  A
[2]  :Access WebMethod
[3]  :Signature Booking←Int32 CourseCode,
        DateTime TeeTime,
        Boolean GimmeNearest,
        String Name1,
        String Name2,
        String Name3,
        String Name4

[4]
[5]
[6]  A If GimmeNearest=0, books (or fails) for specified time
[7]  A If GimmeNearest=1, books (or fails) for nearest to
        specified time

[8]
[9]  CODE TEETIME NEAREST+3↑ARG$
[10] GOLFID←Application[←'GOLFID']
[11] COURSECODES COURSES INDEX←FREAD GOLFID 1
[12] COURSEI←COURSECODES:CODE
[13] COURSE←NEW GolfCourse,←CODE(COURSEI=COURSES,←')
[14] SLOT←NEW Slot TEETIME
[15] R←NEW Booking (0 COURSE SLOT ')
[16] :If COURSEI>ρCOURSECODES
[17]     R.Message←'Invalid course code'
[18]     :Return
[19] :EndIf
[20] :If TEETIME.Now>TEETIME
[21]     R.Message←'Requested tee-time is in the past'
[22]     :Return
[23] :EndIf
[24] :If TEETIME>TEETIME.Now.AddDays 30
[25]     R.Message←'Requested tee-time is more than
        30 days from now'

[26]     :Return
[27] :EndIf
[28] IDN←2 [NQ]'.' 'DateToIDN',TEETIME.(Year Month Day)
[29] DATES COMPS←FREAD GOLFID,COURSEI>INDEX
[30] IDATE←DATES:IDN
[31] :If IDATE>ρDATES
[32]     TEETIMES←(60×7)+10×-1+1+8×6
        A 10 minute intervals, 07:00 to 15:00
[33]     GOLFERS←((ρTEETIMES),4)ρ←'
        A up to 4 golfers allowed per tee time
[34]     :If 0=OLD↔(DATES<
        2 [NQ]'.' 'DateToIDN',3↑[TS])/ρDATES
[35]     COMP←(TEETIMES GOLFERS)FAPPEND GOLFID
[36]     DATES,←IDN
[37]     COMPS,←COMP
[38]     (DATES COMPS)FREPLACE GOLFID,COURSEI>INDEX
[39]

```

```

      :Else
[40]      DATES[OLD]←IDN
[41]      (TEETIMES GOLFERS)⊞FREPLACE
          GOLFID,COMP←OLD=COMPS
[42]      DATES COMPS ⊞FREPLACE GOLFID,COURSEI>INDEX
[43]      :EndIf
[44]      :Else
[45]      COMP+IDATE=COMPS
[46]      TEETIMES GOLFERS←⊞FREAD GOLFID COMP
[47]      :EndIf
[48]      HOURS MINUTES←TEETIME.(Hour Minute)
[49]      NAMES←(3↓ARGS)~θ''
[50]      TIME←60⊥HOURS MINUTES
[51]      TIME←10×⌊0.5+TIME÷10 ♂ Round to nearest
          10-minute interval
[52]      :If ~NEAREST
[53]      I←TEETIMES⊥TIME
[54]      :If I>ρTEETIMES
[55]      :OrIf (ρNAMES)>ρ,/+/0=ρ''GOLFERS[I;]
[56]      R.Message←'Not available'
[57]      :Return
[58]      :EndIf
[59]      :Else
[60]      :If ~v/FREE←(ρNAMES)≤ρ,/+/0=ρ''GOLFERS
[61]      R.Message←'Not available'
[62]      :Return
[63]      :EndIf
[64]      FREETIMES←(FREE×TEETIMES)+32767×~FREE
[65]      DIFF←|FREETIMES-TIME
[66]      I←DIFF⊥|/DIFF
[67]      :EndIf
[68]      J←(ρ, /0=ρ''GOLFERS[I;])/⊥4
[69]      GOLFERS[I;(ρNAMES)↑J]←NAMES
[70]      (TEETIMES GOLFERS)⊞FREPLACE GOLFID COMP
[71]      TEETIME←⊞NEW DateTime,←TEETIME.(Year Month Day),
          3↑24 60⊥I>TEETIMES
[72]      SLOT.Time←TEETIME
[73]      SLOT.Players←(ρ, /0<ρ''GOLFERS[I;])/GOLFERS[I;]
[74]      R.(OK TeeTime)←1 SLOT
▽

```

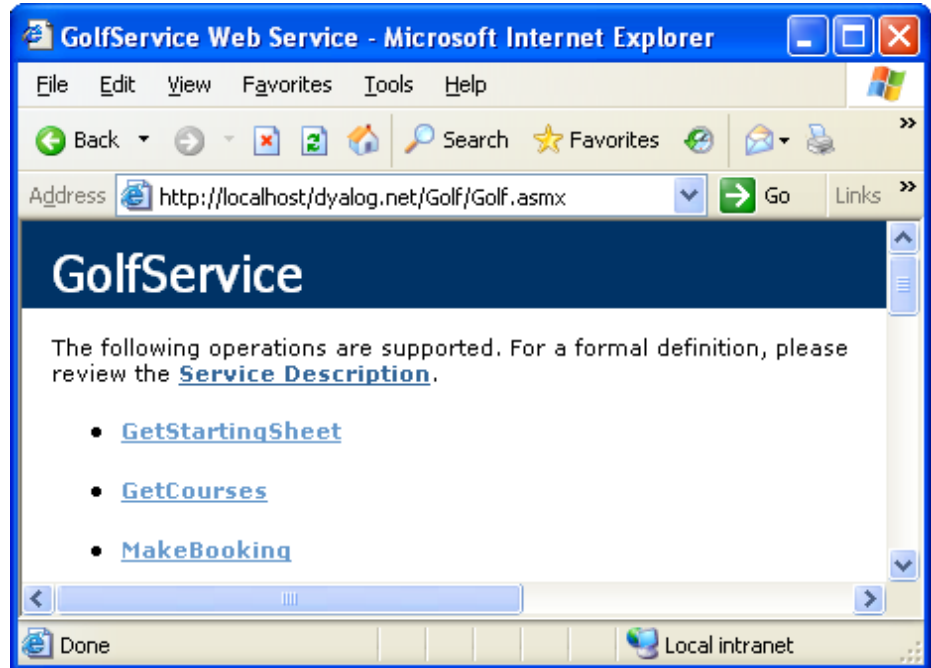


## Testing GolfService from IE

If you point your browser at the URL

`http://localhost/dyalog.net/Golf/Golf.asmx`, GolfService will be compiled and ASP.NET will fabricate a page about it for the browser to display as shown below.

The three methods exposed by GolfService are listed.

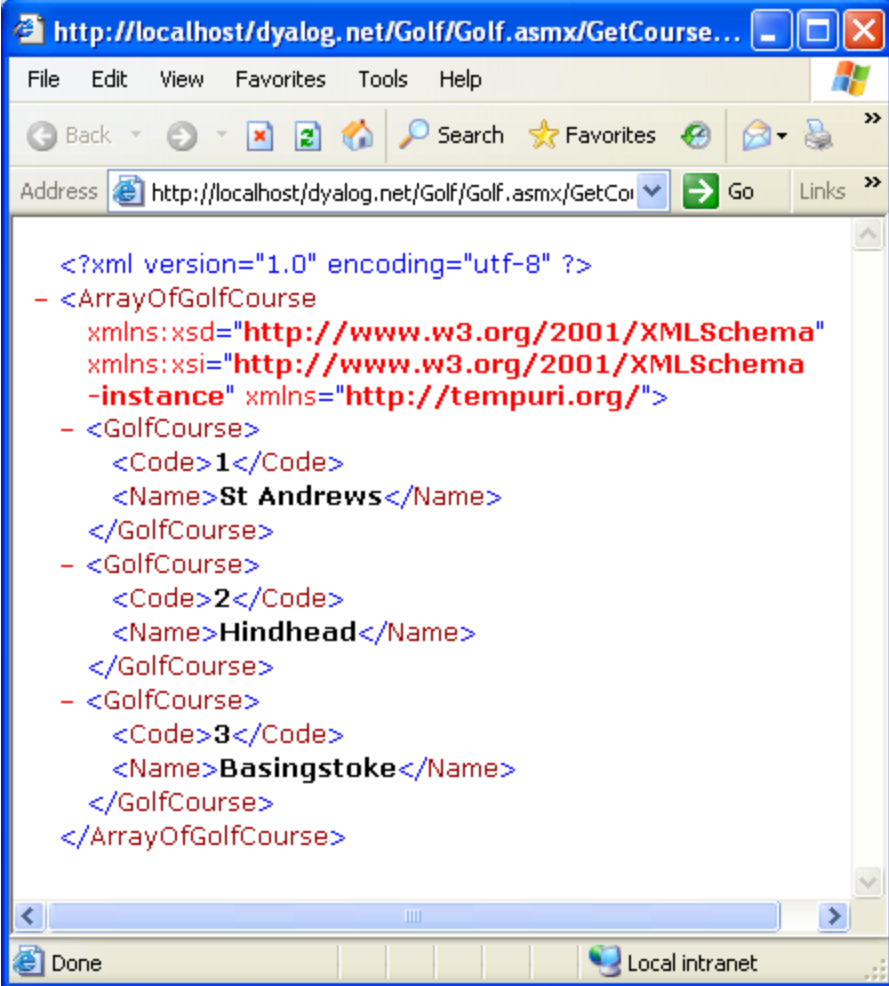


Invoking the `GetCourses` method generates the following output.

Notice that the data type of the result is `ArrayOfGolfCourse`, and the data type of each element of the result is `GolfCourse`. Furthermore, the public fields defined for the `GolfCourse` object are clearly named.

All this information is derived from the declarations in the `Golf.asmx` script.

As supplied, the GolfData component file contains only 3 golf courses as shown below.



```

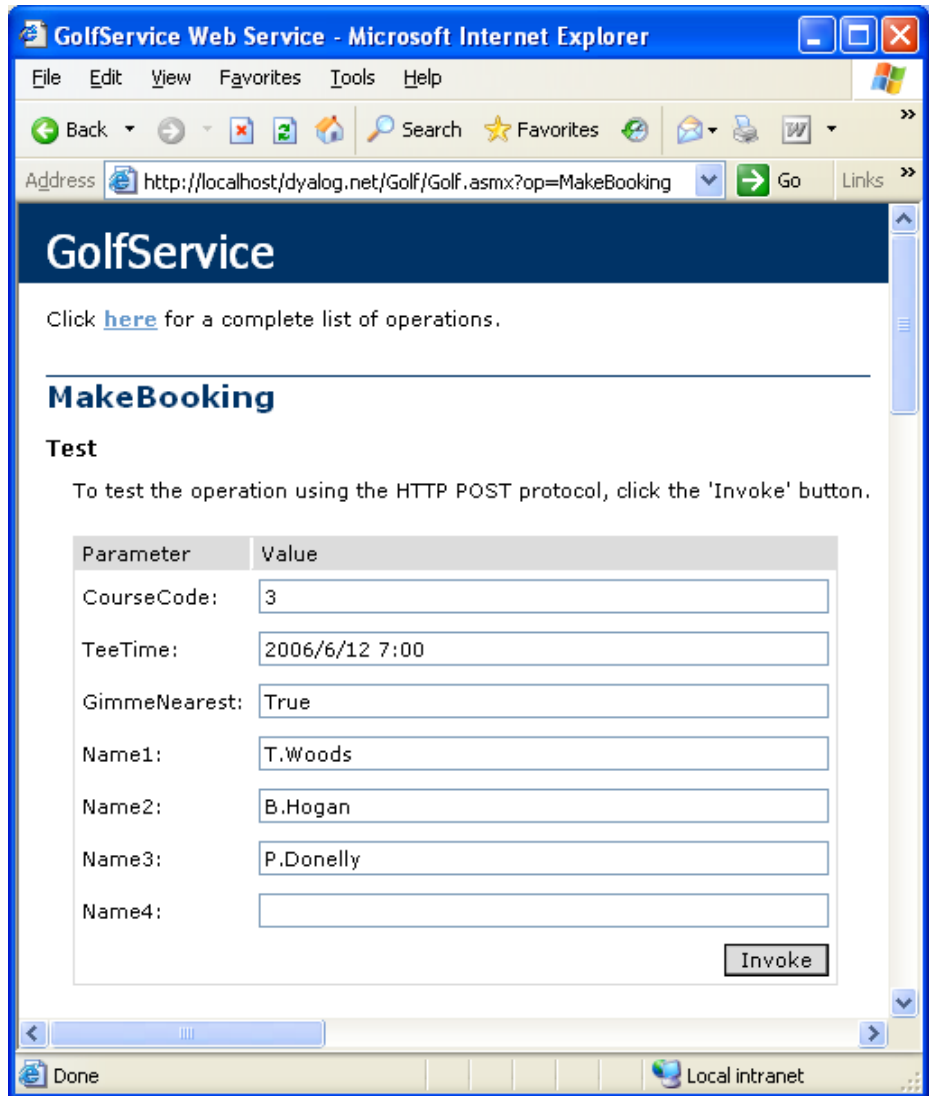
<?xml version="1.0" encoding="utf-8" ?>
- <ArrayOfGolfCourse
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema
-instance" xmlns="http://tempuri.org/">
- <GolfCourse>
  <Code>1</Code>
  <Name>St Andrews</Name>
</GolfCourse>
- <GolfCourse>
  <Code>2</Code>
  <Name>Hindhead</Name>
</GolfCourse>
- <GolfCourse>
  <Code>3</Code>
  <Name>Basingstoke</Name>
</GolfCourse>
</ArrayOfGolfCourse>

```

ASP.NET generates a Form containing fields that allow the user to invoke the MakeBookings method as shown below.

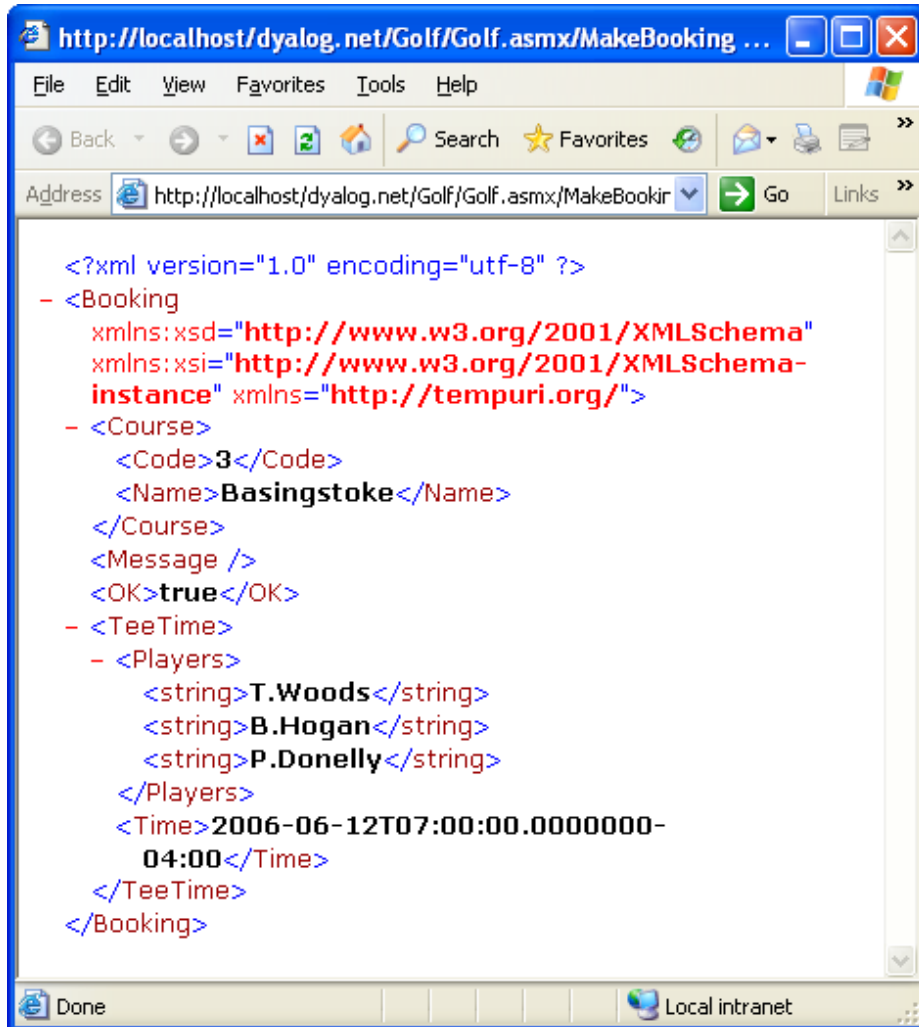
Notice the way a DateTime value is specified. Note too that the GimmeNearest parameter is Boolean, so you must enter "True" or "False". If you enter 0 or 1, it will cause an error and the application will refuse to try to call MakeBookings because you have specified the wrong type for a parameter.

When you try this yourself, remember to enter a date that is within the next 30 days, and a time between 07:00 and 15:00. Alternatively, you may wish to experiment with invalid data to check the error handling.



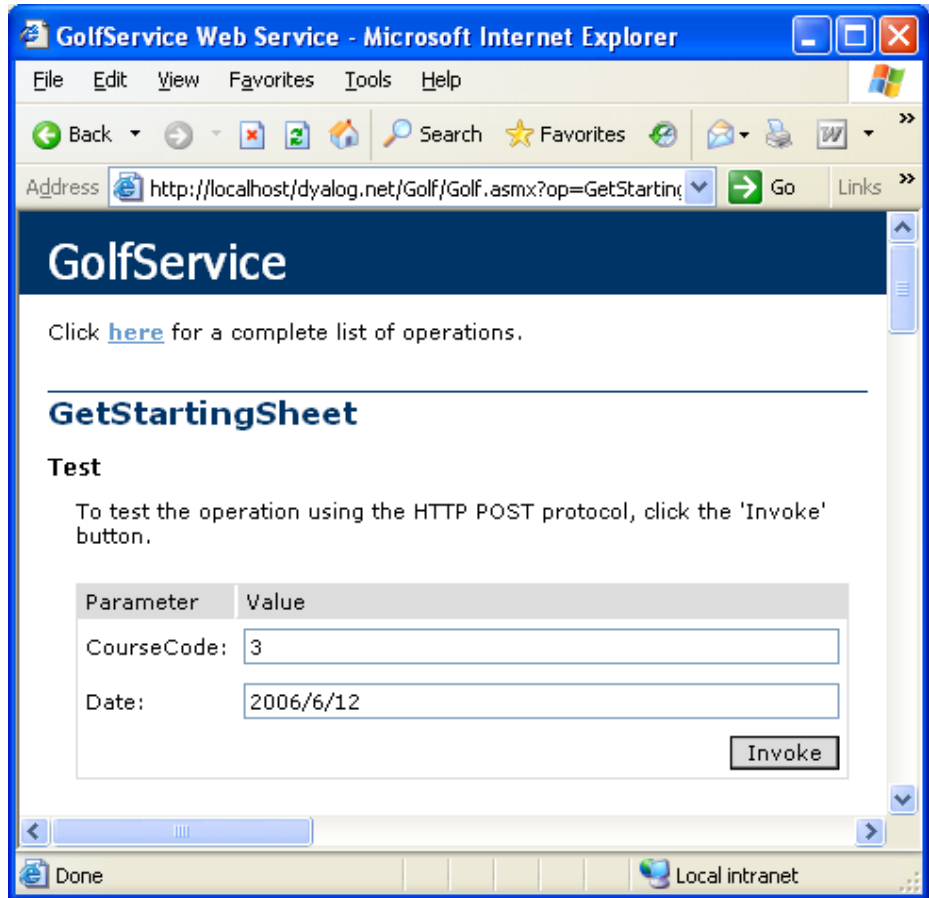
The result of invoking MakeBooking with this data is shown below.

Notice how all the information about the Booking object structure, including the structure of the sub-objects, is provided.



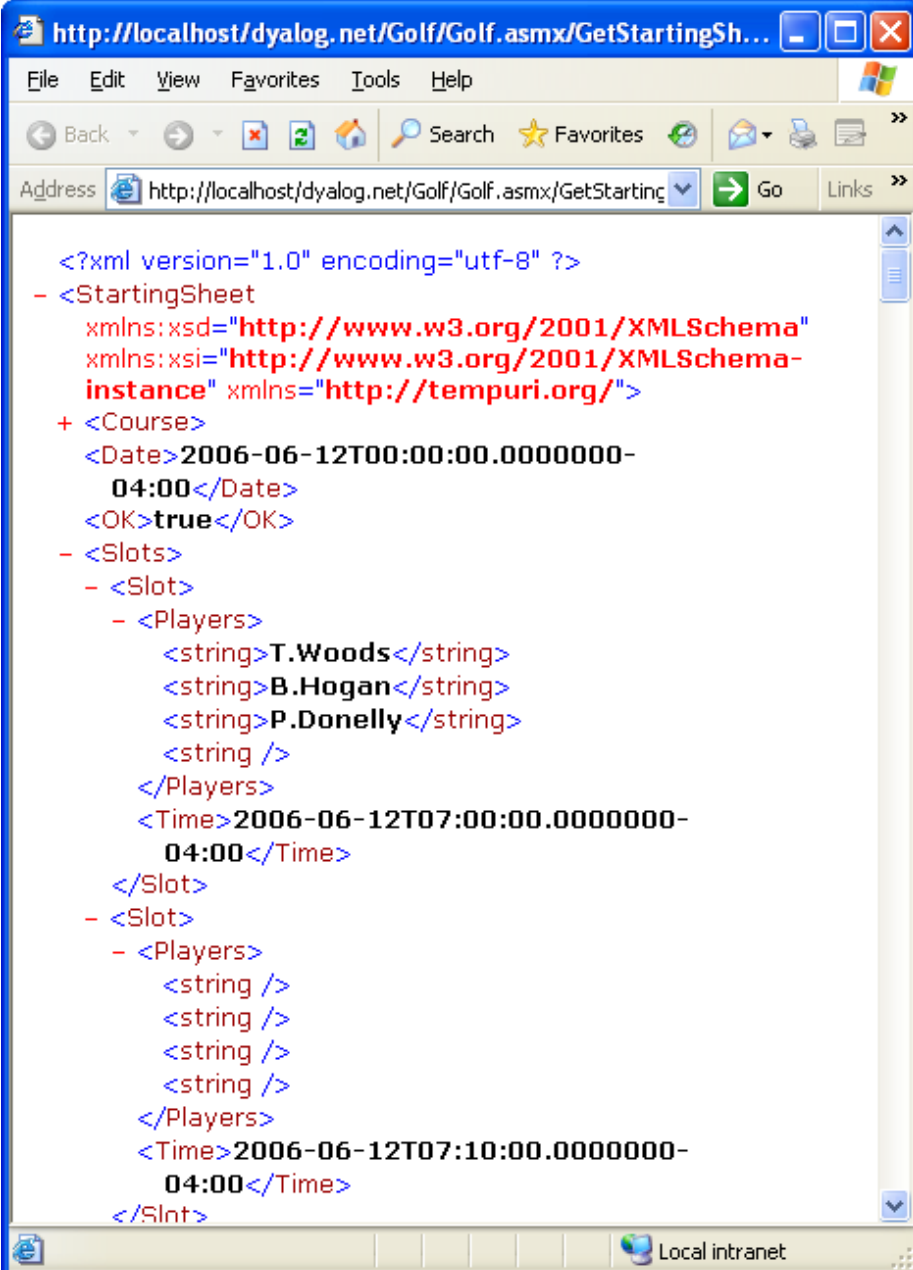
The following picture shows data suitable for invoking the `GetStartingSheet` method.

If you try this for yourself, choose a course and date on which you have made at least one successful booking.



Finally, the result of the `GetStartingSheet` function is illustrated below.

The output clearly shows that the result, a `StartingSheet` object, contains an array of `Slot` objects, each of which contains a `Time` field and a `Players` field.



The screenshot shows a web browser window with the address bar containing the URL `http://localhost/dyalog.net/Golf/Golf.aspx/GetStartingSh...`. The browser's menu bar includes File, Edit, View, Favorites, Tools, and Help. The address bar also shows a 'Go' button and a 'Links' button. The main content area displays XML data in a tree view format, with the root element being `<?xml version="1.0" encoding="utf-8" ?>`. The XML structure is as follows:

```
<?xml version="1.0" encoding="utf-8" ?>
- <StartingSheet
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://tempuri.org/"
+ <Course>
  <Date>2006-06-12T00:00:00.0000000-04:00</Date>
  <OK>true</OK>
- <Slots>
- <Slot>
  - <Players>
    <string>T.Woods</string>
    <string>B.Hogan</string>
    <string>P.Donelly</string>
    <string />
  </Players>
  <Time>2006-06-12T07:00:00.0000000-04:00</Time>
</Slot>
- <Slot>
  - <Players>
    <string />
    <string />
    <string />
    <string />
  </Players>
  <Time>2006-06-12T07:10:00.0000000-04:00</Time>
</Slot>
```

The browser's status bar at the bottom indicates 'Local intranet'.

## Using GolfService from C#

The `csharp` sub-directory in `samples\asp.net\golf` contains sample files for accessing the `GolfService` Web Service from C#. The C# source code in `Golf.cs` is shown below.

```
using System;

class MainClass {

    static void Main(String[] args)
    {
        GolfService golf = new GolfService();
        int nArgs = args.Length;
        Booking booking;

        booking=golf.MakeBooking(
/* Course Code          */ 1,
/* Desired Tee Time */ DateTime.Parse(args[0]),
/* nearest is OK      */ true,
/* player 1           */ (nArgs > 1) ? args[1] : "",
/* player 2           */ (nArgs > 2) ? args[2] : "",
/* player 3           */ (nArgs > 3) ? args[3] : "",
/* player 4           */ (nArgs > 4) ? args[4] : ""
        );

        Console.WriteLine(booking.OK);
        Console.WriteLine(booking.TeeTime.Time.ToString());
        foreach (String player in booking.TeeTime.Players)
            Console.WriteLine(player);
    }
}
```

The following example shows how you may run the C# program `golf.exe` from a DOS prompt. Please remember to specify a reasonable date and time rather than the one used in this example.

```
csharp>golf 2006-08-07T08:00:00 T.Woods A.Palmer P.Donnelly
True
25/08/2008 08:00:00
T.Woods
A.Palmer
P.Donnelly

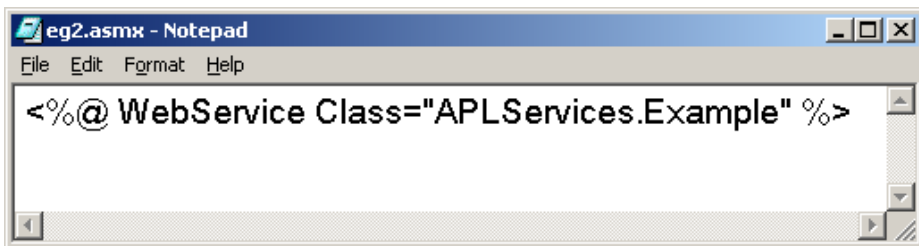
csharp>
```

## Sample Web Service: EG2

In all the previous examples, we have relied upon ASP.NET to compile the `APLScript` into a .NET class prior to running it. This sample illustrates how you can make a .NET class yourself.

For this example, the Web Service script, which is supplied in the file `samples\asp.net\webservices\eg2.aspx` (mapped via an IIS Virtual Directory to the URL `http://localhost/dyalog.net/webservices/eg2.aspx`) is reduced to a single statement that merely invokes the pre-defined class called `APLServices.Example`.

The entire file, viewed in Notepad, is shown below.



Given this instruction, ASP.NET will locate the `APLServices.Example` Web Service by searching the `Bin` sub-directory for assemblies. Therefore, to make this work, we have only to create a .NET assembly in `samples\asp.net\Bin`. The assembly should contain a .NET Namespace named `APLServices`, which in turn defines a class named `Example`.

The procedure for creating .NET classes and assemblies in Dyalog APL was discussed in Chapter 3. Making a WebService class is done in exactly the same way.

Starting with a `CLEAR WS`, we first create a namespace called `APLServices`. This will act as the container corresponding to a .NET Namespace in the assembly.

```
        )NS APLServices
#.APLServices
```

Within `APLServices`, we next create a class called `Example` that inherits from `System.Web.Services.WebService`. This is the Web Service class.



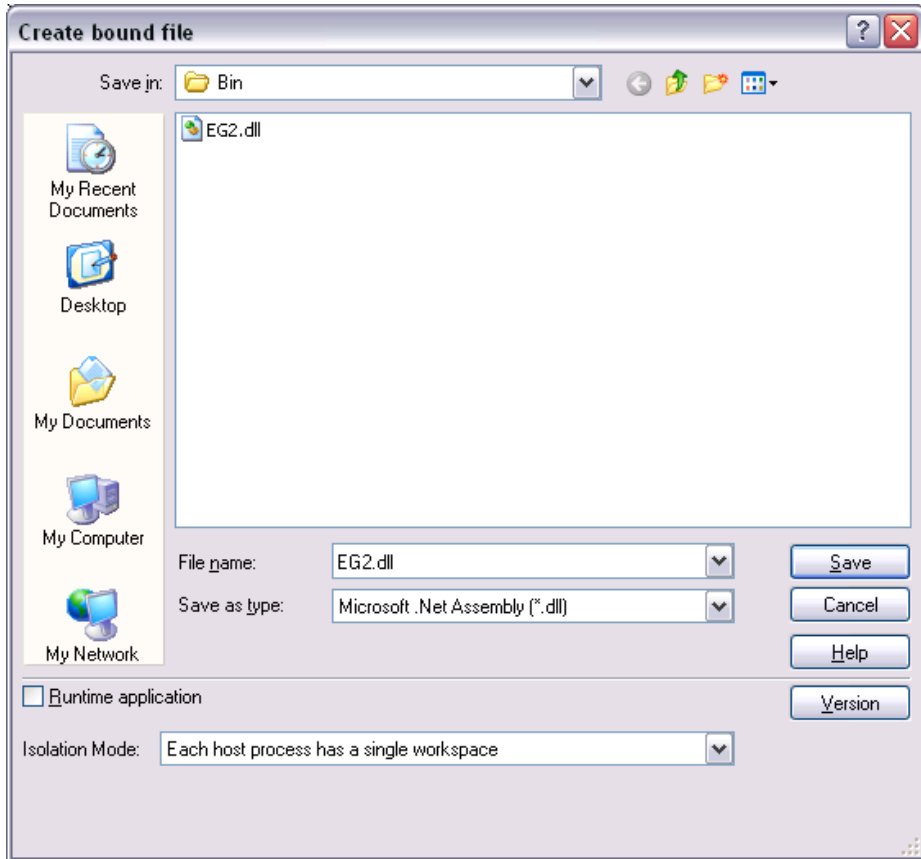
```
        )CS APLServices
#.APLServices
        )ED oExample
:Class Example: WebService
:Using System
:Using System.Web.Services, System.Web.Services.dll
    ▽ R←Add arg
        :Access webmethod
        :Signature Int32←Add Int32 arg1, Int32 arg2
        R←+/arg
    ▽
:endclass
```

Within `APLServices.Example`, we have a function called `Add` that will represent the single method to be exported by this Web Service.

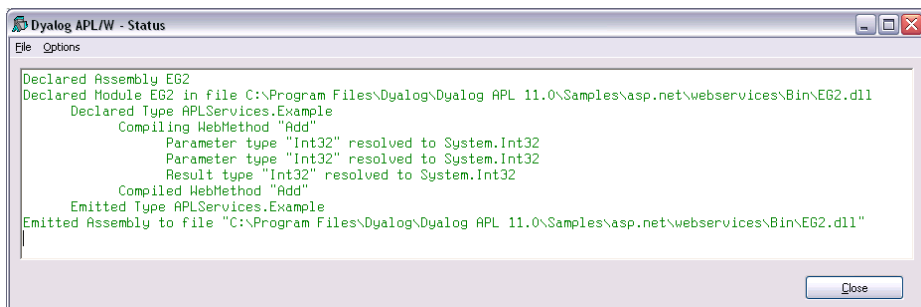
It is a good idea to `)SAVE` the workspace, although this is not absolutely essential.

```
        )CS
#
        )WSID Samples\asp.net\webservicess\Bin\EG2
was CLEAR WS
        )SAVE
Samples\asp.net\webservicess\Bin\EG2 saved ...
```

Then, select the *Export...* item from the *Session File* menu, and save the assembly in `samples\asp.net\webservicess\Bin`. The name of the assembly is unimportant.



When you click *Save*, the Status Window displays the following information to confirm that the assembly has been created correctly.

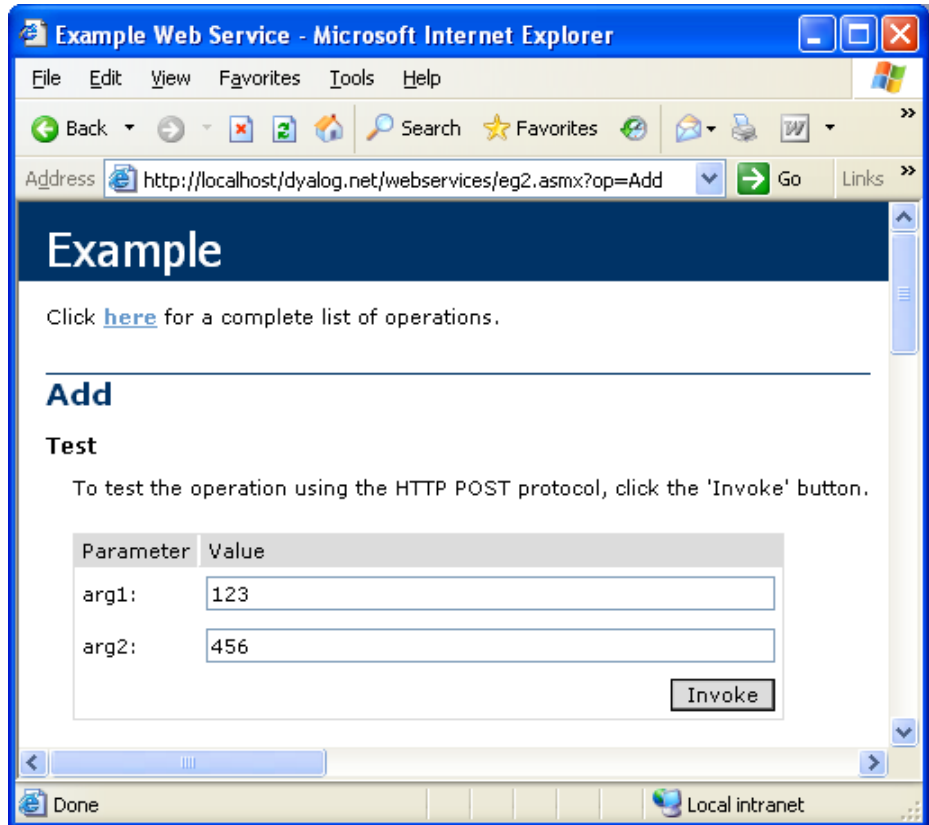


## Testing EG2 from IE

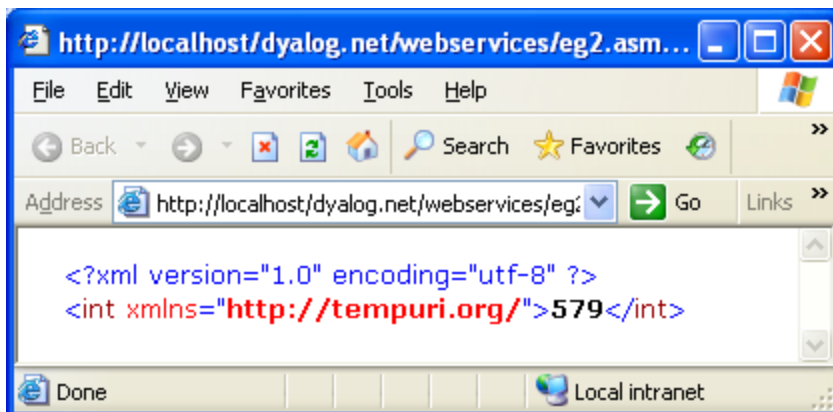
If you point your browser at the URL

`http://localhost/dyalog.net/webservices/eg2.asmx`, ASP.NET will fabricate a page about it for the browser to display as shown below.

The Add method exposed by `APLServices.Example` is shown, together with a Form from which you can invoke it.



If you enter the numbers 123 and 456 in the fields provided, then press *Invoke*, the method will be called and the result displayed as shown below.



---

# Chapter 7:

## Calling Web Services

### Introduction

In order to call a Web Service, you need a "proxy class" on the client, which exposes the same methods and properties as the web service. The proxy creates the illusion that the web service is present on the client. Client applications create instances of the proxy class, which in turn communicate with the Web Service via IIS, using TCP/IP and HTTP/XML protocols.

Microsoft provides a utility called `WSDL.EXE` that queries the metadata (Web Service Definition Language) of a Web Service and generate C# source code for a matching proxy class.

### The MakeProxy function

The `MakeProxy` function is provided in the supplied workspace `samples\asp.net\webservices\webservices.dws`.

`MakeProxy` is monadic and its argument specifies the URL of the Web Service to which you want to connect. For example, the following expressions uses `MakeProxy` to connect to the `LoanService` sample Web Service provided with `Dyalog .Net`:

```
MakeProxy 'http://localhost/dyalog.net/Loan/Loan.asmx '
```

`MakeProxy` runs the Microsoft utility `WSDL.EXE` passing the name of your URL to it as an argument. The utility then creates a C# source code file in your current directory that contains the code necessary to create a proxy class. The name of the C# file is the name of the Web Service (as declared in its header line) followed by the extension `.cs`.

`MakeProxy` then calls the C# compiler to compile this file, creating an assembly with the same name, but with a `.dll` extension, in your current directory. This assembly contains a `.NET` class of the same name.

`MakeProxy` attempts to determine the correct path for `WSDL.EXE` and `CSC.EXE`, but future versions of Microsoft.NET or Visual Studio require changes, in which case you will have to modify this function to locate these tools.

## Using LoanService from Dyalog APL

For example, the above call to `MakeProxy` will create a C# source code file called `LoanService.cs`, and an assembly called `LoanService.dll` in your current directory. The name of the proxy class in `LoanService.dll` is `LoanService`.

You use this proxy class in exactly the same way that you use any .NET class. For example:

```

      □USING ←,c',.\LoanService.dll'
      LN←□NEW LoanService
      LN.CalcPayments 100000 20 10 15 2
LoanResult

```

Notice that, as expected, the result of `CalcPayments` is an object of type `LoanResult`. For convenience, we will assign this to `LR` and then reference its fields:

```

      LR←LN.CalcPayments 100000 20 10 15 2
      LR.Periods
10 11 12 13 14 15 16 17 18 19 20
      LR.InterestRates
2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5
...
      LR.(((ρInterestRates),ρPeriods)ρPayments)
920.1345384 844.5907851 781.6836919 728.4970675 682.947
...

```

The `Payments` field is, of course, a vector because it was defined that way. However, as can be seen above, it is easy to give it the "right" shape.

When you execute the `CalcPayments` method in the proxy class, the class transforms and packages up your arguments into an appropriate SOAP/XML stream and sends them, using TCP/IP, to the URL that represents the Web Service wherever that URL is on the internet or your Intranet. It then decodes the SOAP/XML that comes back, and returns the response as the result of the method.

Note that, depending upon the speed of your connection, and the logical distance away of the Web Service itself, calling a Web Service method can take a significant amount of time; regardless of how much time it actually takes to execute on its server.

## Using GolfService from Dyalog APL

The workspace `samples\asp.net\webservices\webservices` contains functions that present a GUI interface to the `GolfService` web service.

The `GOLF` function accesses `GolfService` through a proxy class. `GOLF` is called with an argument of 0 or 1. Use 1 to force `GOLF` to create or rebuild the proxy class, which it does by calling `MakeProxy`. You must use an argument of 1 the first time you call `GOLF`, or if you ever change the `GolfService` APL code.

Note that you cannot make the proxy for `GolfService` unless the Web Server class has been compiled on the server. At present, the only way to trigger the compilation of `golf.asmx` into a Web Service is to visit the page once using Internet Explorer as described in the previous chapter.

The first few lines of the function are listed below. If the argument is 1, line[2] makes the proxy class `GolfService.DLL` in the current directory; if not it is assumed to be there already. Line[6] defines `⎕USING` to use it, and Line[7] creates a new instance which is assigned to `GS`. Line[8] calls the `GetCourses` method, which returns a vector of `GolfCourse` objects. Notice how namespace reference array expansion is used to extract the course codes and names from the `Code` and `Name` fields respectively.

```

▽ GOLF FORCE;F;DLL;COURSES;COURSECODES;N;GS;⎕USING
[1]   :If FORCE≠0
[2]       DLL←MakeProxy
           'http://localhost/dyalog.net/golf/golf.asmx'
[3]   :Else
[4]       DLL←'.\GolfService.dll'
[5]   :EndIf
[6]   ⎕USING←'System'(' ',',',DLL)
[7]   GS←⎕NEW GolfService
[8]   COURSECODES COURSES←↑⊆↑GS.GetCourses.(Code Name)

```

The following screen shot illustrates the user interface provided by `GOLF`. In this example, the user has typed the names of two golfers (one rather more famous than the other - at least in APL circles) and then presses the *Book it!* button.

This action fires the BOOK callback function which is shown below.

```

    ▽ BOOK;CCODE;YMD;HOUR;MINUTES;FLAG;NAMES;BOOKING;M
[1]   CCODE↔F.COURSE.SelItems/COURSECODES
[2]   YMD←3↑F.DATE.(IDNToDate⇒DateTime)
[3]   HOUR MINUTES←2↑1↓F.TIME.DateTime
[4]   FLAG←1=F.Nearest.State
[5]   NAMES←F.(Name1 Name2 Name3 Name4).Text
[6]   BOOKING←GS.MakeBooking CCODE
      (⎕NEW DateTime (YMD,HOUR MINUTES 0)),FLAG,NAMES
[7]   'M'⎕WC'MsgBox'
[8]   :If BOOKING.OK
[9]       M.Text←'Tee reserved for
      ',~2↓,/,BOOKING.TeeTime.Players,`c`, '
[10]      M.Text,←' at ',BOOKING.Course.Name
[11]      M.Text,←' on ',BOOKING.TeeTime.Time.
      (ToLongDateString,' at ',ToShortTimeString)
[12]   :Else
[13]      M.Text←BOOKING.(Course.Name,' ',
      TeeTime.Time.(ToLongDateString,
      ' at ',ToShortTimeString),' ',Message)
[14]   :EndIf
[15]   ⎕DQ'M'
    ▽

```

Line[6] calls the `MakeBooking` method of the `GS` object, passing it the data entered by the user. The result, a `Booking` object, is assigned to `BOOKING`. Line[8] checks its `OK` field to tell whether or not the reservation was successful. If so, lines[9-11] display the message box illustrated below.



Notice how the various fields are extracted and notice how the `ToLongDateString` and `ToShortTime` String methods are employed.



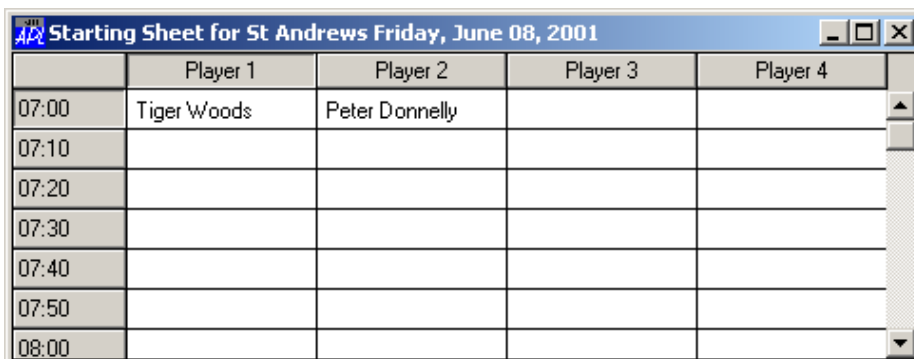
Pressing the *Starting Sheet* button runs the SS callback listed below.

```

▽ SS;CCODE;YMD;M;SHEET;OK;COURSE;TEETIME;S;DATA;N
;TIMES
[1] CCODE←F.COURSE.SelItems/COURSECODES
[2] YMD←3↑F.DATE.(IDNToDate⇒DateTime)
[3] SHEET←GS.GetStartingSheet CCODE(□NEW DateTime YMD)
[4] :If SHEET.OK
[5]     DATA←↑(SHEET.Slots).Players
[6]     TIMES←(SHEET.Slots).Time
[7]     'S'□WC'Form'('Starting Sheet for ',
        SHEET.Course.Name,' ',
        SHEET.Date.ToLongDateString)
        ('Coord' 'Pixel')('Size' 400 480)
[8]     'S.G'□WC'Grid'DATA(0 0)(S.Size)
[9]     S.G.RowTitles←TIMES.ToShortTimeString
[10]    S.G.ColTitles←'Player 1' 'Player 2'
        'Player 3' 'Player 4'
[11]    S.G.TitleWidth←60
[12]    □DQ'S'
[13] :Else
[14]    'M'□WC'MsgBox'('Starting Sheet for ',
        SHEET.Course.Name,' ',
        SHEET.Date.ToLongDateString)
        ('Style' 'Error')
[15]    M.Text←SHEET.Message
[16]    □DQ'M'
[17] :EndIf
▽

```

Line[3] calls the `GetStartingSheet` method of the `GS` object. The result, a `StartingSheet` object, is assigned to `SHEET`. Line[4] checks its `OK` field to see if the call succeeded. If so, lines[5-12] display the result in a Grid, which is illustrated below.



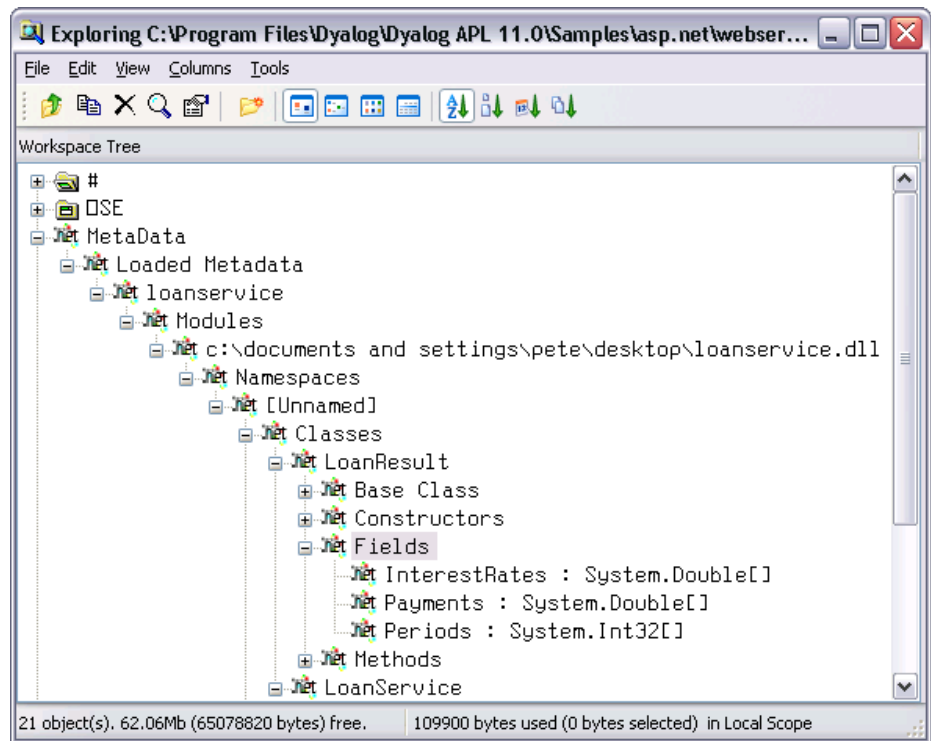
	Player 1	Player 2	Player 3	Player 4
07:00	Tiger Woods	Peter Donnelly		
07:10				
07:20				
07:30				
07:40				
07:50				
08:00				

## Exploring Web Services

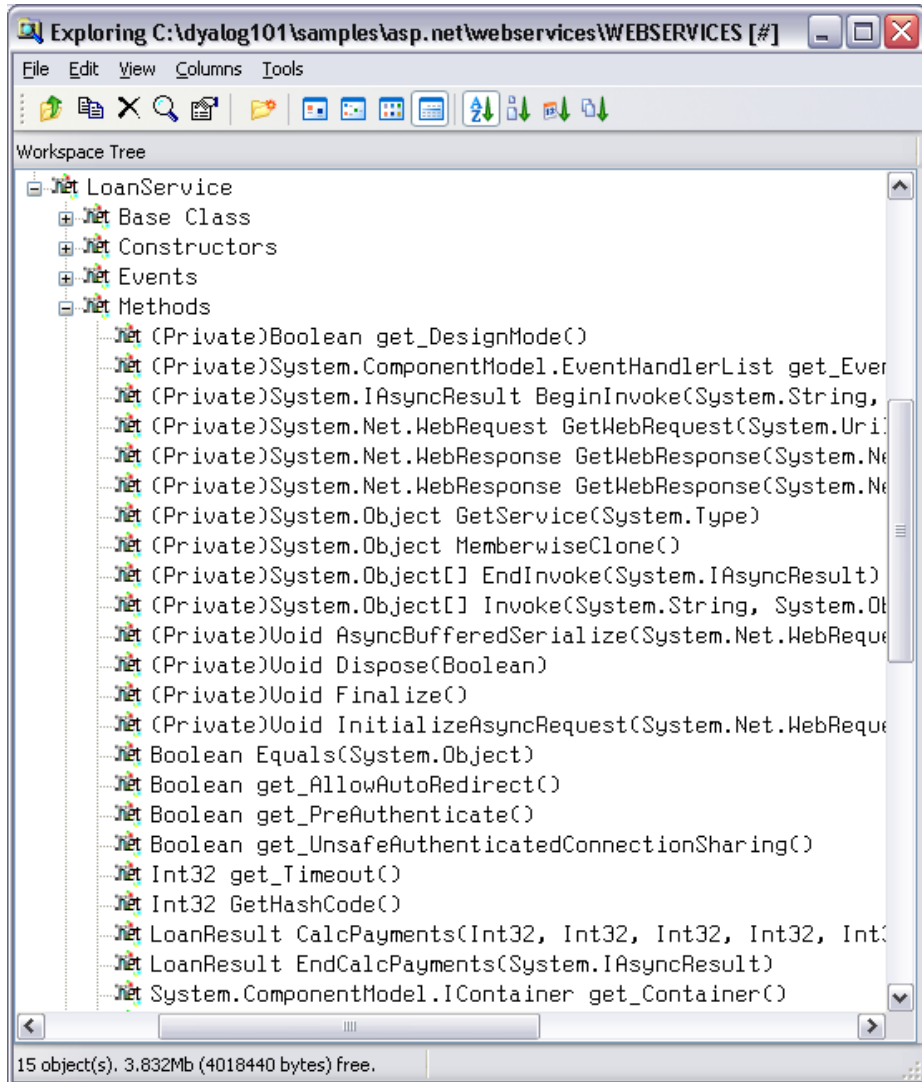
You can use the Workspace Explorer to browse the proxy class associated with a Web Service, in exactly the same way that you can browse any other .NET Assembly. The following screen shots show the *Metadata* for *LoanService*, loaded from the *LoanService.dll* proxy.

Remember, *LoanService* was written in APLScript, but it appears and behaves just like any other .NET class.

The first picture displays the structure of the *LoanResult* class.



The second picture shows the methods exposed by *LoanService*. In addition to *CalcPayments*, which was written in APLScript, there are a large number of other methods, which have been inherited from the base class.



## Asynchronous Use

Web Services provide both synchronous (client calls the function and waits for a result) and asynchronous operation.

Each method is exposed as a function with the same name (the synchronous version) together with a pair of functions with that name prefixed with **Begin** and **End** respectively.

The **Beginxxx** functions take two additional parameters; a delegate class that represents a callback function and a state parameter.

To initiate the call, you execute the **Beginxxx** method using the standard parameters followed by two objects. The first is an object of type `System.AsyncCallback` that represents an asynchronous callback, i.e. a callback to be invoked when the asynchronous call is complete. The second is an object which is used to supply extra information. We will see how callbacks are used later in this section. If you are not using a callback, these items should be null object references. You can specify a reference to a null object using the expression (`NS''`). For example, using the `LoanService` sample as above:

```
A←LN.BeginCalcPayments 10000 16 10 12
                        9(NS'')(NS'')
```

The result is an object of type `WebClientAsyncResult`.

```
A
System.IAsyncResult CLASS
System.Web.Services.Protocols.WebClientAsyncResult
```

Then, some time later, you call the **Endxxx** method with this object as a parameter. For example:

```
LN.EndCalcPayments A
LoanResult
```

You can execute several asynchronous calls in parallel:

```
A1←LN.BeginCalcPayments 20000 20 10 15
                        7(NS'')(NS'')
A2←LN.BeginCalcPayments 30000 10 8 12
                        3(NS'')(NS'')
```

```
LN.EndCalcPayments A1
LoanResult
LN.EndCalcPayments A2
LoanResult
```

## Using a callback

The simple approach described above is not always practical. If it can take a significant amount of time for the web service to respond, you may prefer to have the system notify you, via a callback function, when the result from the method is available.

The example function `TestAsyncLoan` in the workspace `samples\asp.net\webervices\webervices.dws` illustrates how you can do this. It is somewhat artificial, but hopefully explains the mechanism that is involved.

`TestAsyncLoan` itself is just a convenience function that calls `AsyncLoan` with suitable arguments. `TestAsyncLoan` takes an argument of 1 or 0 that determines whether or not a Proxy class for `LoanService` is to be built.

```

▽ TestAsyncLoan MAKEPROXY
[1] (≡MAKEPROXY), ' AsyncLoan 10000 10 8 5 3'
[2] MAKEPROXY AsyncLoan 10000 10 8 5 3
▽

```

The `AsyncLoan` function and its callback function `GetLoanResult` are more interesting.

```

▽ {MAKEPROXY}AsyncLoan ARG;DLL;SINK;LN;AS;AR
[1] :If 2≠≡NC'MAKEPROXY' ♦ MAKEPROXY←0 ♦ :EndIf
[2] :If MAKEPROXY
[3]   DLL←MakeProxy'http://localhost/dyalog.net/loan/
      loan.asmx'
[4] :Else
[5]   DLL←'.\LoanService.dll'
[6] :EndIf
[7]   ≡USING←'System'(', ',DLL)
[8]   LN←≡NEW LoanService
[9]   AS←≡NEW System.AsyncCallback,≡OR'GetLoanResult'
[10]  AR←LN.BeginCalcPayments ARG,AS,LN
[11]  'AsyncLoan waits for async call to complete'
[12]  :While 0=AR.IsCompleted
[13]    ≡←'.'
[14]  :EndWhile
▽
▽ GetLoanResult arg;OBJ;LR;RSLT
[1]  'GetLoanResult callback fires ...'
[2]  OBJ←arg.AsyncState
[3]  LR←OBJ.EndCalcPayments arg
[4]  RSLT←LR.((ρPeriods),(ρInterestRates))ρPayments
[5]  RSLT←((<''),LR.Periods),(LR.InterestRates),[1]RSLT
[6]  'Result is'
[7]  ≡←RSLT
▽

```

The effect of running `TestAsyncLoan` is as follows:

```

TestAsyncLoan 0
0 AsyncLoan 10000 10 8 4 3

...AsyncLoan waits for async call to complete...
...GetLoanResult callback fires ...

...Result is
      3          3.5          4
8 117.2957193 105.7694035 96.5607447
9 119.5805173 108.0741442 98.88586746
121.892753 110.409689 101.2451382

```

`AsyncLoan[8]` creates a new instance of the `LoanService` class called `LN`. The next line creates an object of type `System.AsyncCallback` named `AS`. This object, which is termed a *delegate*, identifies the callback function that is to be invoked when the asynchronous call to `CalcPayments` is complete. In this case, the name of the callback function is `GetLoanResult`. Note that `OR` is necessary because the `AsyncCallback` constructor must be called with a parameter of type `System.Object`. The line `AsyncLoan[10]` calls `BeginCalcPayments` with the parameters for `CalcPayments`, followed by references to `AS` (which identifies the callback) and `LN`, which identifies the object in question. The latter will turn up in the argument supplied to the `GetLoanResult` callback. Lines[12-14] loop, displaying dots, until the asynchronous call is complete. `GetLoanResult` will be invoked during or immediately after this loop, and will be executed in a different APL thread.

When the `GetLoanResult` callback is invoked, its argument `arg` is an object of type `System.Web.Services.Protocols.WebClientAsyncResult`. It is in fact a reference to the same object `AR` that was the result returned by `BeginCalcPayments`.

This object has an `AsyncState` property that references the `LoanService` object `LN` that we passed as the final parameter to `BeginCalcPayments`. `GetLoanResult[2]` retrieves this object and assigns it to `OBJ`. `GetLoanResult[3]` calls the `EndCalcPayments` method, passing it `arg` as the `AsyncResult` parameter as before. The resulting `LoanResult` object is then formatted and displayed.





# Chapter 8:

## Writing ASP.NET Web Pages

### Introduction

Under Microsoft IIS, a *static* web page is defined by a simple text file with the extension .htm or .html that contains simple HTML. When a browser requests such a page, IIS simply reads it and sends its content back to the client. The contents of a static web page are constant and, until somebody changes it, the page appears the same to all users at all times.

A *dynamic* web page is represented by a simple text file with the extension .aspx. Such a file may contain a mixture of (static) HTML, ASP.NET objects and a *server-side script*. ASP.NET objects are built-in .NET classes that generate HTML when the page is processed. Scripts contain functions and subroutines that are invoked by events (such as the Page\_Load event) or by user interaction.

Typically, a script will generate HTML dynamically, when the page is loaded. For example, a script could perform a database operation and return an HTML table containing a list of products and prices. A script may also contain code to process user interaction, for example to process the contents of a Form that is filled in and then submitted by the user. These scripts are referred to as server-side scripts because they are executed on the server. The browser sees only the results produced by the scripts and not the scripts themselves. Code in a server-side script always involves the generation of a new page by the server for display in the browser.

The first time ASP.NET processes a .NET web page, it compiles the entire page into a .NET Assembly. Subsequently, it calls the code in the assembly directly. The language used to compile the page is defined in the <script> section, which is typically defined at the top of the page. If the <script> section is omitted, or if it fails to explicitly specify the language attribute, the page is compiled using the default scripting language. This is configurable, but is typically VB or C#.

This Chapter is made up almost entirely of examples, the source code of which is supplied in the samples\asp.net directory and the sub-directories it contains. This directory is mapped as an IIS Virtual Directory named `dyalog.net`, so you may execute the examples by specifying the URL `http://localhost/dyalog.net/` followed by the name of the sub-directory and page. You can get an overview of the samples by starting on the page `http://localhost/dyalog.net/index.htm` and follow links from there.

To use `APLScript` effectively in Web Pages, you need to have a thorough understanding of how ASP.NET works.

In the first example, an outline description ASP.NET technology is provided. For further information, see the Microsoft .NET Framework documentation and *Beginning ASP.NET using VB.NET*, Wrox Press Ltd, ISBN 1861005040.

## Your first APL Web Page

The first web page example is `tutorial/intro1.aspx`, which is listed below. This page displays a button whose text is reversed each time you press it.

```
<script language="Dyalog" runat="server">

▽Reverse args
:Access public
:Signature Reverse Object,EventArgs
(>args).Text←ϕ(>args).Text
▽

</script>

<html>
<body>
<Form runat=server>
  <asp:Button id="Pressme"
    Text="Press Me"
    runat="server"
    OnClick="Reverse"
  />
</form>
</body>
</html>
```

In this example, the page language is defined in the `<script>` section to be "Dyalog". This in turn is mapped to the `APLScript` compiler via information in the application's `web.config` file or the global IIS configuration file, `machine.config`.

The page layout is described in the section between the `<html>` and `</html>` tags. This page contains a Form in which there is a Button labelled (initially) "Press Me"

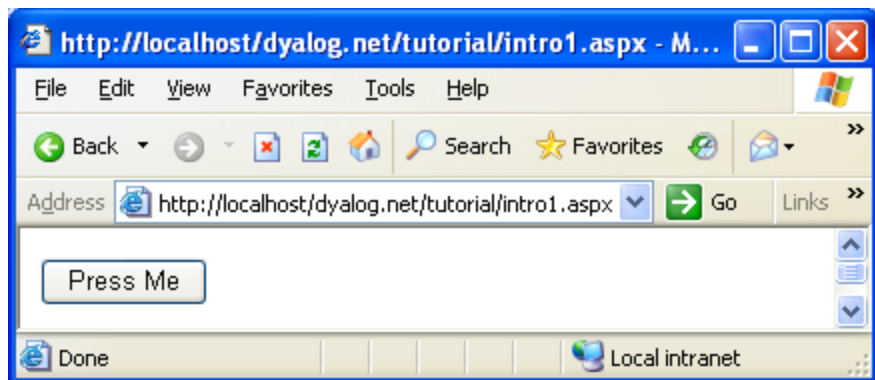
The Form and Button page elements may appear to be simple HTML, but in fact there is more to them than meets the eye and they are actually both types of ASP.NET *intrinsic controls*.

Firstly, the `runat="server"` attribute indicates that an HTML element should be parsed and treated as an HTML server control. Instead of being handled as pure text that is to be transmitted to the browser "as is", an HTML server control is effectively compiled into statements that then generate HTML when executed. Furthermore, an HTML server control can be accessed programmatically by code in the Script, whereas a pure HTML element cannot. On its own, `runat="server"` identifies the HTML element as a so-called *basic* intrinsic control.

When you add `runat="server"` to a Form, ASP.NET automatically adds other attributes that cause the values of its controls to be POSTed back to the same page. In addition, ASP.NET adds a HIDDEN control to the form and stores state information in it. This means that when the page is reloaded into the browser the state and contents of some or all of its controls can be maintained, without the need for you to write additional code.

The `asp:` prefix for the Button, identifies the control as a *special* ASP.NET intrinsic control. These are fully-fledged .NET Classes in the .NET Namespace `System.Web.UI.WebControls` that expose properties corresponding to the standard attributes that are available for the equivalent HTML element. You manipulate the control as an object, while it, at runtime, emits HTML that is inserted into the page.

At this point, it is instructive to study what happens when the page is first loaded and the appearance of the page is illustrated below.



The HTML that is transmitted to the browser is:

```
<html>
<body>
  <form name="ctrl1" method="post" action="intro1.aspx"
id="ctrl1">
  <input type="hidden" name="__VIEWSTATE"
value="YTB6NTQ3ODg0MjcyX19feA==5725bd57" />

          <input type="submit" name="Pressme" value="Press Me"
id="Pressme" />
    </form>
</body>
</html>
```

Firstly, notice that, as expected, the contents of the `<script>` section are not present. Secondly, because the Form and Button are intrinsic controls, ASP.NET has added certain attributes to the HTML that were not specified in the source code.

The Button now has the added attribute `input type="submit"`, which means that pressing the Button causes the contents of the Form to be transmitted back to the sever.

The Form now has `method="post"` and `action="intro1.aspx"` attributes, which means that, when the Form is submitted, the data is POSTed back to `intro1.aspx`, the page that generated the HTML in the first place.

So when the user presses the button, the browser sends back a POST statement, with the contents of the Form, including the value of the HIDDEN field, requesting the browser to load `intro1.aspx`.

In the server, ASP.NET reloads the page and processes it again. In fact, because of the stateless nature of HTTP, the server does not know that it is reprocessing the same page, except that it is being executed by a POST command with the hidden data embedded in the Form that it put there the first time around. This is the mechanism by which ASP.NET *remembers* the state of a page from one invocation to another.

This time, because a POST back is loading the page, and because the `Pressme` button caused the POST, ASP.NET executes the function associated with its `onClick` attribute, namely the `APLScript` function **Reverse**.

When it is called, the argument supplied to `Reverse` contains two items. The first of these is an object that represents the control that generated the `onClick` event; the second is an object that represents the event itself. In fact, **Reverse** and its argument are very similar to a standard Dyalog APL callback function.

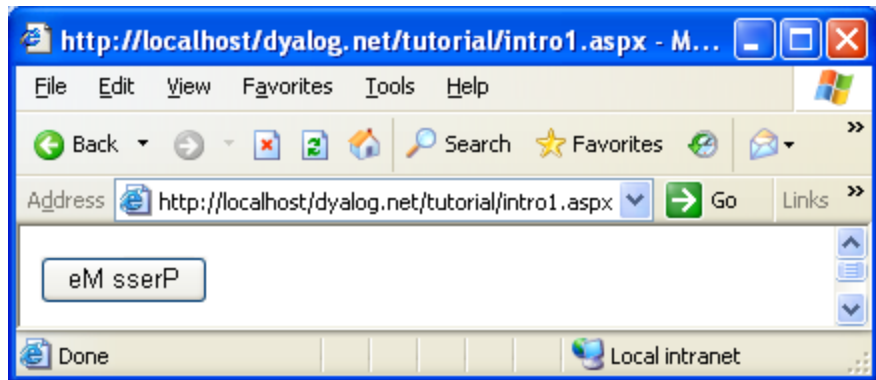
```

▽Reverse args
:Access public
:Signature Reverse Object,EventArgs
(=args).Text←φ(=args).Text
▽

```

The code in the `Reverse` function is simple. The expression `(=args)` is a namespace reference (ref) to the Button, and `(=args).Text` refers to its `Text` property whose value is reversed. Note that `Reverse` could just as easily refer to the Button by name, and use `Pressme.Text` instead.

After pressing the button, the page is redisplayed as shown below:



This time, the HTML generated by `intro1.aspx` is:

```

<html>
<body>
    <form name="ctrl1" method="post" action="intro1.aspx"
id="ctrl1">
    <input type="hidden" name="__VIEWSTATE"
value="YTB6NTQ3ODg0MjcyX2Ewe19oejV6MXhfYTB6X2h6NXoxeF9hMHph
MHpoelRlXHh0X2VNIHNzZXJQeF9feF9feHhfeHhfeF9feA==45acf576"
/>

        <input type="submit" name="Pressme" value="eM sserP"
id="Pressme" />
    </form>
</body>
</html>

```

Returning to the `Reverse` function, note that the declaration statements at the top of the function are essential to make it callable in this context.

```

▽Reverse args
:Access public
:Signature Reverse Object,EventArgs
(=args).Text←φ(=args).Text
▽

```

Firstly the **Reverse** function must be declared as a public member of the script. This is achieved with the statement.

```
:Access Public
```

Secondly, the .NET runtime will only call the function if it possesses the correct signature, which is derived from its parameters and their types.

The required signature for a method connected to an event, such as the `OnClick` event of a `Button`, is that it takes two parameters; the first of which is of type `System.Object` and the second is of type `System.EventArgs`. The **Reverse** function declares its parameters with the statements:

```
:Signature Reverse Object,EventArgs
```

Note that the parameter declarations do not include the `System` prefix. This is because when the script is compiled the names are resolved using the current value of `⎕USING`. When the `APLScript` is *compiled*, the default value for `⎕USING` is automatically defined to contain `System` along with most of the other namespaces that will be used when writing web pages

(Strictly speaking, the first argument is expected to be of type `System.Web.UI.WebControls.Button`, but as this type inherits ultimately from `System.Object` the function signature is satisfied.)

Note that if the **Reverse** function is defined with a signature that does not match that expected signature for the `OnClick` callback, the function will not be run.

Furthermore, if the function associated with the `OnClick` statement is not defined as a public method in the `APLScript` the page will appear to compile but the **Reverse** function will not get executed.

Note that unlike Web Services, there is no requirement for a **:Class** or **:EndClass** statement in the script. This is because a file with an `.aspx` extension implicitly generates a class that inherits from `System.Web.UI.Page`.

## The Page\_Load Event

Intro3.aspx illustrates how you can dynamically initialise the contents of a Web Page using the Page\_Load event. This example also introduces another type of Web Control, the DropDownList object.

```
<script language="Dyalog" runat="server">

∇Page_Load
:Access Public
:if 0=IsPostBack
    list.Items.Add c'Apples'
    list.Items.Add c'Oranges'
    list.Items.Add c'Bananas'
:endif
∇
∇Select args
:Access public
:Signature Reverse Object,EventArgs
out.Text←'You selected ',list.SelectedItem.Text
∇

</script>

<body>
<form runat=server>
<asp:DropDownList id="list" runat="server"/>
<p>
<asp:Label id=out runat="server" />
<p>
<asp:Button id="btn"
Text="Submit"
runat="server"
OnClick="Select"
/>
</form>
</body>
```

When an ASP.NET web page is loaded, it generates a Page\_Load event. You can use this event to perform initialisation simply by defining a public function called Page\_Load in your APLScript. This function will automatically be called every time the page is loaded. The Page\_Load function should be niladic.

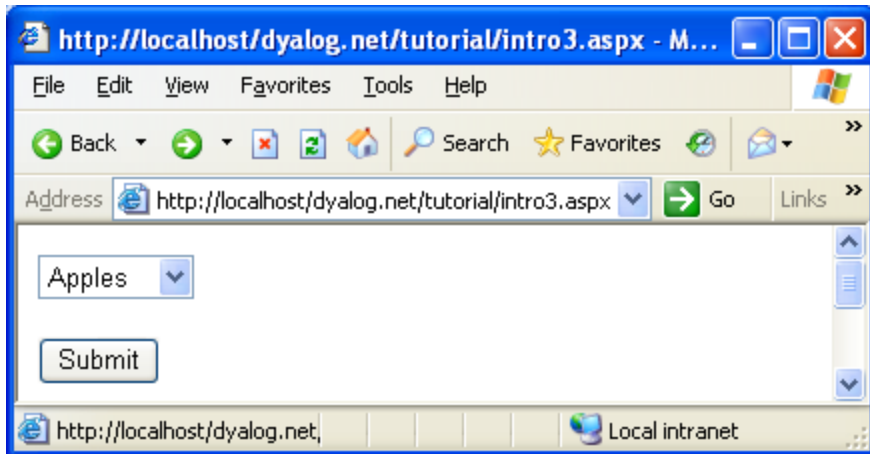
Note that, if the page employs the technique illustrated in `Intro1.aspx`, whereby the page is continually POSTed back to itself by user interaction, your `Page_Load` function will be run every time the page is loaded and you may not wish to repeat the initialisation every time. Fortunately, you can distinguish between the initial load, and a subsequent load caused by the post back, using the `IsPostBack` property. This property is inherited from the `System.Web.UI.Page` class, which is the base class for any `.aspx` page.

The `Page_Load` function in this example checks the value of `IsPostBack`. If 0 (the page is being loaded for the first time) it initialises the contents of the `list` object, adding 3 items "Apples", "Oranges" and "Bananas". The explanation for the statement:

```
list.Items.Add ("...")
```

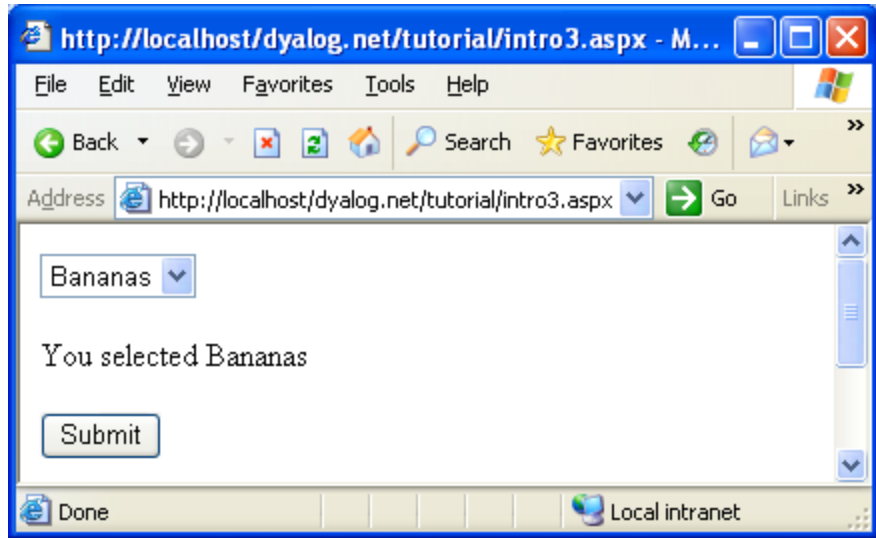
is that the `DropDownList` WebControl has an `Items` property that is a collection of `Listitem` objects. The collection implements an `Add` function that takes a `String` Argument that can be used to add an item to the list.

Notice that the name of the object `list` is defined by the `id="list"` attribute of the `DropDownList` control that is defined in the page layout section of the page.



In this example, the page is processed by a POST back caused by pressing the `Submit` button. As it stands, changing the selection in the `list` object does not cause the text in the `out` object to be changed; you have to press the `Submit` button first.





However, you can make this happen automatically by adding the following attributes to the `list` object (see `intro4.aspx`):

```
AutoPostBack="true"
```

```
OnSelectedIndexChanged="Select"/>
```

`AutoPostBack` causes the object to generate HTML that will provoke a post back whenever the selection is changed. When it does so, the `OnSelectedIndexChanged` event will be generated in the server-side script which in turn will call `Select`, which in turn will cause the text in the out object to change.

Note that this technique, which can be used with most of the ASP.NET controls including `CheckBox`, `RadioButton` and `TextBox` controls, relies on a round trip to the server every time the value of the control changes. It will not perform well except on a fast connection to a lightly loaded server.

## Code Behind

It is often desirable to separate the code content of a page completely from the HTML and other text, layout or graphical information by placing it in a separate file. In ASP.NET parlance, this technique is known as *code behind*.

The `intro5.aspx` example illustrates this technique.

```
%@Page Language="Dyalog" Inherits="FruitSelection"
src="fruit.apl" %>

<html>
<body>
<form runat="server" >
<asp:DropDownList id="list" runat="server"
autopostback="true"
OnSelectedIndexChanged="Select"/>
<p>
<asp:Label id=out runat="server" />
</form>
</body>
</html>
```

The statement

```
%@Page Language="Dyalog" Inherits="FruitSelection"
src="fruit.apl" %>
```

says that this page, when compiled, should inherit from a class called `FruitSelection`. Furthermore, the `FruitSelection` class is written in the "Dyalog" language, and its source code resides in a file called `fruit.apl`. `FruitSelection` is effectively the *base class* for the `.aspx` page.

In this case, `fruit.apl` is simply another text file containing the APLScript code and is shown below.

```
:Class FruitSelection: System.Web.UI.Page
:Using System

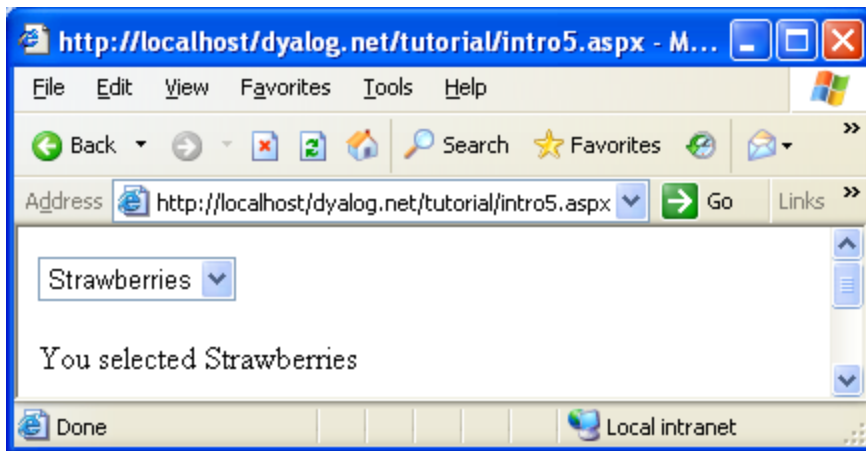
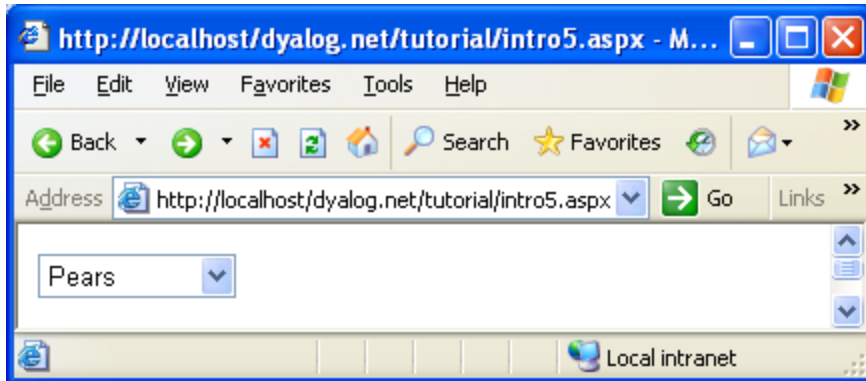
▽Page_Load
:Access Public
:if 0=IsPostBack
    list.Items.Add c'Pears'
    list.Items.Add c'Nectarines'
    list.Items.Add c'Strawberries'
:endif
▽

▽Select args
:Access public
:Signature Select Object,EventArgs
out.Text←'You selected ',list.SelectedItem.Text
▽
:EndClass
```

The first thing to notice is that the file requires `:Class` and `:EndClass` statements. These are required to tell the `APLScript` compiler the name of the class being defined, and the name of its base class. When the source code is in a `.aspx` file, this information is provided automatically by the `APLScript` compiler.

The name of the class, in this case `FruitSelection`, must be the same name as is referenced in the `.aspx` web page file itself (`intro5.aspx`). The base class must be `System.Web.UI.Page`

The body of the script is just the same as the script section from the previous example. Only the names of the fruit have been changed so that it is clear which example is being executed.



## Workspace Behind

The previous section discussed how APL logic can be separated from page layout, by placing it in a separate APLScript file which is referred to from the `.aspx` web page. It is also possible to have the code reside in a separate *workspace*. This allows you to develop web pages using a traditional workspace approach, and it is probably the quickest way to give an HTML front-end to an existing Dyalog APL application.

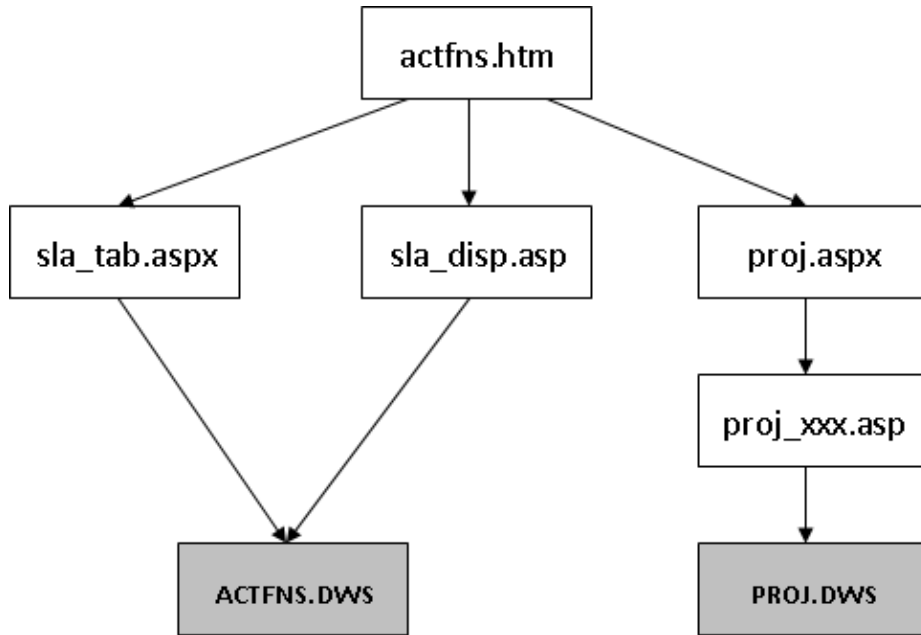
In the previous example, you saw that the `fruit.apl` file defined a new class called `FruitSelection` that inherits from `System.Web.UI.Page`. This class contains a `Page_Load` function that (by virtue of its name) overrides the `Page_Load` method of the underlying base class and will be called every time the web page is loaded or posted back. The `Page_Load` function takes whatever action is required; for example, initialisation. The class also contained a callback function to perform some action when the user pressed a button.

A similar technique is employed when the code behind the web page is implemented in a separate workspace. The workspace should contain a class that inherits from `System.Web.UI.Page`. This class may contain a `Page_Load` function that will be invoked every time the corresponding web page is loaded, and as many callback functions as are required to provide the application logic. The workspace is hooked up to one or more web pages by the `Inherits=<classname>` and `src=<workspace>` declarations in the Page directive statement that appears at the beginning of the web page script.

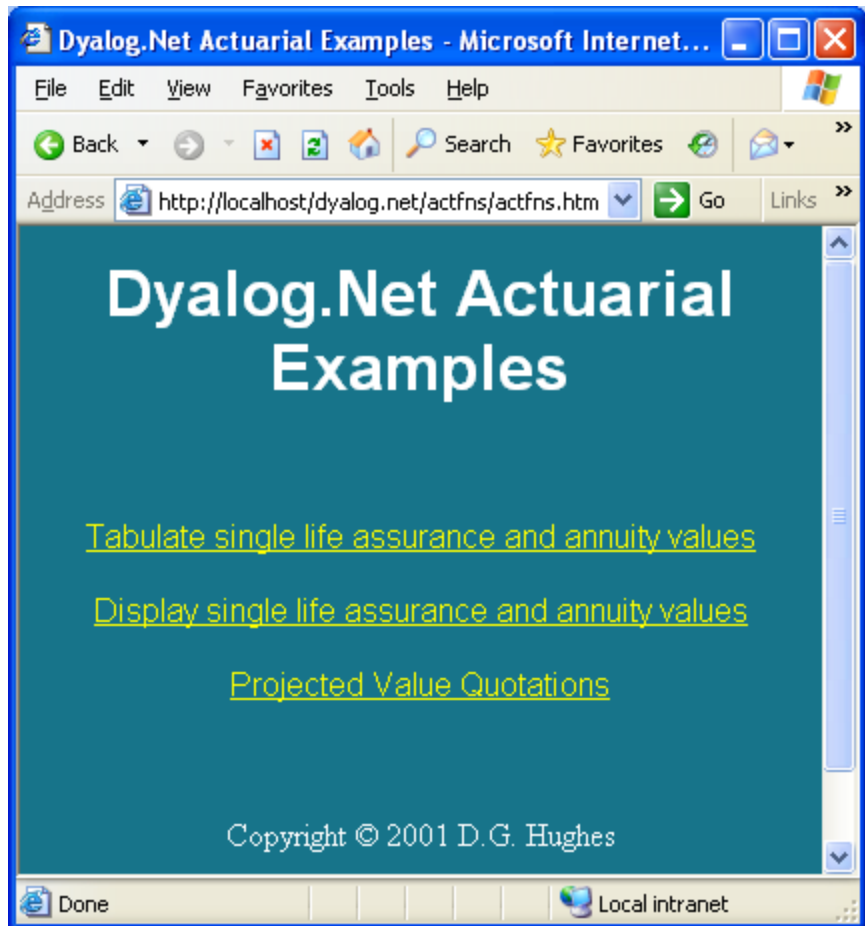
The `ACTFNS` sub-directory in `samples\asp.net` contains some examples of Dyalog APL systems that have been converted to run as Web applications using this technique.

Dyalog is grateful to David Hughes who provided the original workspaces and advised on their conversion.

The two workspaces are named `ACTFNS.DWS` and `PROJ.DWS`. The original code used the Dyalog APL GUI to display an input Form, collect and validate the user's input, and calculate and display the results. The original logic supported field level validation and results were immediately recalculated whenever any field was changed. With some exceptions, this has been changed so that the user must press a button to tell the system to recalculate the results. This approach is more appropriate in an Internet application, especially when connection speed is low. Apart from this change, the applications run more-or-less as originally designed.



The diagram above illustrates the structure of the web application and the various files involved. The starting page, `actfns.htm`, simply provides a menu of choices which link to various `.aspx` web pages. These pages in turn are linked to one of the two workspaces via the `src=""` declaration



The `actfns.htm` start page offers 3 application choices

The screenshot shows a web browser window titled "ACTFNS Example - Microsoft Internet Explorer". The address bar shows "http://localhost/apl.net/actfns/sla\_tab.aspx". The page title is "Single Life Assurance and Annuity Values".

On the left, there is a "Mortality Tables" section with three radio buttons:
 

- UK Assured Lives
- UK Immediate Annuitant
- UK Pension Annuitant

On the right, there are input fields:
 

- Mortality Table: A1967-70(2)select
- Interest Rate: 3.25
- Initial Age: 30
- Initial Duration: 0
- Endowment Term: 10

 A "Calculate" button is located below these fields.

Below the input fields, there are two radio buttons for "Table Format":
 

- Age x, durs t-t+10
- Ages x - x+10, dur t

The main data table is as follows:

x	t	x+t	$\ddot{a}_{[x]+t}$	$A_{[x]+t}$	$\ddot{a}_{[x]+t:n-t}$	$A_{[x]+t:n-t}$	n-t
30	0	30	23.7359	0.252864	8.6708	0.727068	10
30	1	31	23.4851	0.260758	7.9236	0.750589	9
30	2	32	23.2292	0.268813	7.1527	0.774854	8
30	3	33	22.9677	0.277045	6.3571	0.799897	7
30	4	34	22.6984	0.285521	5.5353	0.825765	6
30	5	35	22.4214	0.294243	4.6864	0.852486	5
30	6	36	22.1365	0.303210	3.8095	0.880089	4
30	7	37	21.8439	0.312420	2.9035	0.908606	3
30	8	38	21.5436	0.321872	1.9674	0.938072	2
30	9	39	21.2357	0.331565	1.0000	0.968523	1
30	10	40	20.9202	0.341494	0.0000	0.000000	0

### The result of choosing *Tabulate single life insurance and annuity values*

When you choose the first option, the system loads `sla_tab.aspx`. This defines the screen layout in terms of ASP.NET controls, including the `DataGrid` control for tabulating the results. The `sla_tab.aspx` script contains the declarations `Inherits="actuarial" src="actfns.dws`, so ASP.NET loads the `actuarial` class from this workspace (via a call to Dyalog APL). When the page is loaded, it generates a `Page_Load` event, which in turn calls its `Page_Load` method. This populates the ASP controls with data, and the resulting web page is displayed. The mechanism is described below.

For further details, see the `sla_tab.aspx` script and `ACTFNS.DWS` workspace.



## Converting an Existing Workspace

The steps involved in converting the workspaces were as follows:

1. Replace the Dyalog APL GUI with the equivalent HTML Forms, which are defined in one or more separate `.aspx` web pages. To retain consistency, it is helpful to give the ASP controls the same names as the original GUI controls, which they are replacing.
2. Attach the names of APL callback functions to the appropriate ASP controls; essentially, any controls that will be involved in a postback operation, such as the Submit button.
3. Starting with a `CLEAR WS`, create a `Class` that represents a .NET class based upon `System.Web.UI.Page`. For example, in converting the ACTFNS workspace, we started by creating the class:

```
)edit o actuarial
```

4. then defining `⎕USING` as follows:

```
:Using System
:Using System.Web.UI,system.web.dll
:Using System.Web.UI.WebControls
:Using System.Web.UI.HtmlControls
:Using System.Data,system.data.dll
```

The name you choose for this class will replace `classname` in the `Inherits="classname"` declaration in the `.aspx` web page(s) that call it.

5. Create a namespace, change into it, and copy the workspace to be converted; in this case, the starting point was a workspace named `DH_ACTFNS`:

```
)NS actuarial_utils
)CS actuarial_utils
#.actuarial_utils
)COPY DH_ACTFNS
DHACTFNS saved ...
```

6. Modify the code as appropriate, inserting a `Page_Load` function and whatever callback functions that are required.
7. Make sure the class 'actuarial' has an `:Include actuarial_utils` statement

## The Page\_Load function

The `Page_Load` function must be declared as `:Access Public`. `Page_Load` must be spelled correctly as it is this name that causes the function to supercede the base class `Page_Load` method of the same name.

For example, the `Page_Load` function of the `actuarial` class in `ACTFNS.DWS` is shown below:

```

▽ Page_Load;INT;AGE;DUR;TERM;TAB_DURS;MPC1;INT1;INT2;
  INTY;RUN_OPTION;OPT
  :Access public
  :Signature Page_Load
  A Overrides Page_Load method of Page class
  A Called when Page is loaded or re-loaded after postback
  A Initialise fields and calculate on initial load only
  :If 0=IsPostBack
    RUN_OPTION←GET_RUN_OPTION
    :Select RUN_OPTION
    :Case 1
      EINT.Text←⌘INT←3.25
      EAGE.Text←⌘AGE←30
      EDUR.Text←⌘DUR←0
      ETRM.Text←⌘TERM←10
      TA.Checked←TAB_DURS←1
      CHANGE_TABLES ⍉
    :Case 2
      CPLAN.Items.Clear
      :For OPT :In ↓OPTSPLAN
      CPLAN.Items.Add{82ε□DR 1ρω:ω ⍉ ω}DETRAIL OPT
      :EndFor
      EMPC1.Text←⌘MPC1←100
      EINT1.Text←⌘INT1←3.25
      EINT2.Text←⌘INT2←3.25
      EINTY.Text←⌘INTY←99
      EAGE.Text←⌘AGE←30
      EDUR.Text←⌘DUR←0
      ETRM.Text←'N/A'
      CHANGE_TABLES ⍉
    :EndSelect
  :EndIf
▽

```

If exported correctly, `Page_Load` will be called every time the calling web page is loaded. This occurs when the page is loaded for the first time, and whenever the page is submitted back to the web server by the browser (postback). A postback will occur whenever a callback function is involved, and potentially at other times.

The `Page_Load` function may determine whether it is being invoked by a first time load, or by a postback, from the value of the `IsPostBack` property. This is a property that it inherits from its base class `System.Web.UI.Page`.

The `Page_Load` example shown above uses this property to control the initialisation of the controls in the calling web page. The names `EINT`, `EAGE`, `EDUR` and so forth refer to names of controls in the calling web page. When `Page_Load` is executed, the `actuarial` object is associated with the web page itself, and so the names of all its controls are visible as sub-objects within it.

Note that the `actuarial` class is used by two different web pages, and the function `GET_RUN_OPTION` function determines which of these are involved. (It does so by detecting the presence or otherwise of a particular control on the page).

## Callback functions

The `actuarial` class in `ACTFNS.DWS` provides four callback functions named `CALC_FSLTAB_RESULTS`, `CALC_FSL_RESULTS`, `CHANGE_TABLES` and `CHANGE_TABLE_FORMAT`. The first two of these functions are attached as callbacks to the *Calculate* button in each of two separate web pages `sla_tab.aspx` and `sla_disp.aspx`. For example, the statement that defines the button in `sla_tab.aspx` is:

```
<asp:Button id=Button1 runat="server" Text="Calculate"
onClick="CALC_FSLTAB_RESULTS"></asp:Button>
```

The third callback, `CHANGE_TABLES`, is called by `sla_tab.aspx` when the user selects a different set of Mortality Tables from the three provided. `CHANGE_TABLE_FORMAT` is called when the user clicks either of the two radio buttons that select how the output is to be displayed.

Like the `Page_Load` function, callback functions must be declared as being *Public* methods. This is done using the `:Access` statement.

In addition, and this is **essential**, APL callback functions must be declared to have the correct signature expected of .NET callback functions. This means that they must be monadic, and their argument must be declared to be a 2-element nested array containing two .NET objects; the object that generated the event, and an object that represents the arguments to the event.

Specifically, these parameters must be of type `System.Object` and `System.EventArgs` respectively. However, as our `USING` contains `System`, it is not necessary to include the `System` prefix.

For example, the statements for the function `CALC_FSLTAB_RESULTS` is shown below:

```
:Access Public
:Signature CALC_FSLTAB_RESULTS Object obj, EventArgs ev
```

## Validation functions

In a Dyalog APL web page application, there are basically two approaches to validation. You can handle it entirely yourself, or you can exploit the various validation controls that come with ASP.NET. The sample application uses the latter approach by way of illustration. For example:

```
<asp:TextBox id=EINT runat="server"></asp:TextBox>
<asp:RequiredFieldValidator id="RFVINT"
    ControlToValidate="EINT"
    ErrorMessage="Interest Rate must be a number
        between 0 and 20"
    Text="*"
    runat="server"/></td>
```

These ASP.NET statements associate a `RequiredFieldValidator` named `RFVINT` with the `EINT` field, the field used to enter *Interest Rate*. If the user leaves this field blank, the system will automatically generate the specified error message. The page defines a separate `ValidationSummary` control as follows:

```
<asp:ValidationSummary id="Summary1"
    HeaderText="Please enter a value in the following
        fields"
    Font-Size="smaller"
    ShowSummary="false"
    ShowMessageBox="true"
    EnableClientScript="true"
    runat="server"/>
```

The `ValidationSummary` control collects error messages from all the other validation controls on the page, and displays them together. In this case, a pop-up message box is used. One advantage of this approach is that this type of validation can be carried out client-side by local JavaScript that is generated automatically on the server and incorporated in the HTML that is sent to the browser.

Logical field validation for this page is carried out on the server by APL functions that are attached to `CustomValidator` controls. For example:

```
<asp:CustomValidator id="CustomValidator_INT"
  OnServerValidate="VALIDATE_INT"
  ControlToValidate="EINT"
  Display="Dynamic"
  ErrorMessage="Interest Rate must be a number between
    0 and 20"
  runat="server"/>
```

These ASP.NET statements associate a `CustomValidator` control named *CustomValidator\_INT* with the *Interest Rate* field *EINT*. The statement `OnServerValidate="VALIDATE_INT"` specifies that `VALIDATE_INT` is the validation function for the *CustomValidator\_INT* object.

The `VALIDATE_INT` function and its .Net Properties page are shown below.

```

  ▾ VALIDATE_INT MSG;source;args
[1]  A Validates Interest Rate
[2]  :Access Public
[3]  :Signature VALIDATE_INT Object source,
      ServerValidateEventArgs args
[4]  source args←MSG
[5]  :Trap 0
[6]  INT←Convert.ToDouble args.Value
[7]  :Else
[8]  args.IsValid←0
[9]  :Return
[10] :EndTrap
[11] args.IsValid←(0≤INT)^20≥INT
  ▾
```

To make the `VALIDATE_INT` function available to the calling web page, it is exported as a method. Its *calling signature*, namely that it takes two parameters of type `System.Object` and `System.Web.UI.WebControls.ServerValidateEventArgs` respectively, identifies it as a validation function. All these factors are essential in making it recognizable and callable.

`VALIDATE_INT[4]` assigns its (2-element) argument to `source` and `args` respectively. Both are namespace references to .NET objects. `source` is the object that fired the event (*CustomValidator\_INT*). `args` is an object that represents the event. Its `Value` property returns the text in the control being validated, in this case the control named *EINTI*.

`VALIDATE_INT[6]` converts the text in the `EINT` control to a number, using the `ToDouble` method of the `System.Convert` class. You could of course use `¶VFI`, but the `Convert` methods automatically cater for National Language numerical formats. This statement is executed within a `:Trap` control structure because the method will generate a .NET exception if the data in the field is not a valid number.

`VALIDATE_INT[8 11]` set the `IsValid` property of the `ServerValidateEventArgs` object `args` to 0 or 1 accordingly. This also sets the `IsValid` property of the validation control represented by `source`. The system will automatically display the error message associated with any validation control whose `IsValid` property is 0. Furthermore, the page itself has an `IsValid` property, which is the logical-and of all the `IsValid` properties of all the validation controls on the page. This is used later by the calculation function `CALC_FSLTAB_VALUES`.

In this case, the validation function stores the numeric value of the control in a variable `INT`, which will subsequently be used by the calculation functions.

When the page is posted back to the server, ASP.NET executes its own built-in validation controls and then calls the functions associated with the `CustomValidator` controls, in the order they are defined on the page. In addition to the `VALIDATE_INT` function, there are eight other custom validation functions. Three of these, which validate the *Initial Age*, *Endowment Term* and *Initial Duration* fields, are listed below. Note that all of the `VALIDATE_XXX` functions have the same .NET signature as `VALIDATE_INT`.

```

    ▽ VALIDATE_AGE MSG;source;args
[1]   A Validates Age
[2]   :Access Public
[3]   :Signature VALIDATE_AGE Object source,
        ServerValidateEventArgs args
[4]   source args←MSG
[5]   :Trap 0
[6]   AGE←Convert.ToInt32 args.Value
[7]   :Else
[8]       args.IsValid←0
[9]       :Return
[10]  :EndTrap
[11]  args.IsValid←(10≤AGE)^80≥AGE
    ▽

```

`VALIDATE_AGE` is similar to `VALIDATE_INT`, except that, because it expects an integer value, it uses the `ToInt32` method instead of the `ToDouble` method.

`VALIDATE_TERM`, which validates the *Endowment Term* field, is slightly more interesting because there are two levels of checking involved. The first check that the user has entered an integer number, is performed by lines [10-15] in the same way as in the previous examples, using the `ToInt32` method of the `System.Convert` class within a `:Trap` control structure. However, validation of the *Endowment Term* field depends upon the value of another field, namely *Initial Age*.

Not only must the user enter an integer, but also its value must be between 10 and (90-AGE) where AGE is the value in the *Initial Age* field. However, if the user has entered an incorrect value in the *Initial Age* field, this, the second level of validation cannot be performed.

```

    ▽ VALIDATE_TERM MSG;source;args
[1]   A Validates Endowment Term
[2]   :Access Public
[3]   :Signature VALIDATE_TERM Object source,
      ServerValidateEventArgs args
[4]   source args←MSG
[5]   :If ^/(RFVAGE CustomValidator_AGE).IsValid
[6]       source.ErrorMessage←'Endowment Term must
      be an integer between 10 and ',(90-AGE),
      ' (90-Age)'
[7]   :Else
[8]       source.ErrorMessage←'Endowment Term must
      be an integer between 10 and (90-Age)'
[9]   :EndIf
[10]  :Trap 0
[11]  TERM←Convert.ToInt32 args.Value
[12]  :Else
[13]  args.IsValid←0
[14]  :Return
[15]  :EndTrap
[16]  :If ^/(RFVAGE CustomValidator_AGE).IsValid
[17]  args.IsValid←(TERM≥10)^TERM≤90-AGE
[18]  :EndIf
    ▽
```

At this stage it is worth reviewing the sequence of events that occurs when a user action in the browser causes a *postback* to the server.

1. The page, including all the contents of its fields, is sent back to the ASP.NET server using an http POST command.
2. The postback causes the creation of a new instance of the page; which is represented by a new clone of the `actuarial` namespace.
3. The creation of a new page instance raises the `Page_Load` event which in turn invokes the `Page_Load` method associated with the Page class, or an override method if one is specified. In this case, it calls our `Page_Load` function in the newly cloned instance of the `actuarial` namespace. The `Page_Load` function typically deals with initialisation, such as opening a component file or establishing a connection to a data source. In this case, it does nothing on a postback.
4. Because the *Calculate* button was pressed (see *Forcing Validation*), each of the `CustomValidator` controls on the page raises an `OnServerValidate` event, which in turn calls the associated function in the current instance of the page. These events occur in the order the controls are defined within the page. Note that built-in validation controls, including any `RequiredFieldValidator` controls, are invoked first, potentially in the browser prior to the postback.
5. Because the *Calculate* button was pressed (see *Forcing Validation*), each of the `CustomValidator` controls on the page raises an `OnServerValidate` event, which in turn calls the associated function in the current instance of the page. These events occur in the order the controls are defined within the page. Note that built-in validation controls, including any `RequiredFieldValidator` controls, are invoked first, potentially in the browser prior to the postback.
6. The control that caused the postback raises an appropriate event, which in turn fires the associated callback function.
7. After all the control events have been raised and processed the `Page_UnLoad` event is raised and the associated function (if any) is invoked. This function is a good place to implement termination code, such as closing a component file or data source.
8. The instance of the page is destroyed. Any global variables in the namespace, that were defined by the `Page_Load` function, the validation functions and the callback function, are lost because the clone of the `actuarial` namespace disappears.



This means that within the life of the cloned instance of the actuarial namespace, the system runs our `Page_Load` function followed by `VALIDATE_INT`, followed by `VALIDATE_AGE`, `VALIDATE_TERM`, `VALIDATE_DUR` etc. and finally by `CALC_FSLTAB_RESULTS`. These functions take their input from the values passed in their arguments (as in the case of the `VALIDATE_XXX` functions) or from the properties of any of the controls on the Page. They perform output by modifying these properties, or by invoking standard methods on the Page.

Notice that, if successful, the `VALIDATE_INT` function set up a global variable (strictly speaking, only global within the current instance of the actuarial namespace) called `INT` that contains the value in the *Interest Rate* field. Similarly, `VALIDATE_AGE` defines a variable called `AGE`. These variables are subsequently available for use by the calculation function.

This technique, of having each validation function define a variable for its associated field, saves repeating the conversion work in the calculation routine `CALC_FSLTAB_RESULTS` that will be called when the validation is complete. It also saves repeating the conversion work in a validation routine that needs to know the value of a previously validated field.

Returning to the explanation of `VALIDATE_TERM`, line [16] checks to see that both the `RequiredFieldValidator` and `CustomValidator` controls for the *Initial Age* field register that the value in the field is valid, before attempting to perform the second stage of the validation which depends upon `AGE`. Note that `AGE` must exist (and be a reasonable value) if `CustomValidator_AGE.IsValid` is true. Notice too that it is insufficient just to check the `CustomValidator` control, because its validation function will not be invoked (and the control will register that the field is valid) if the field is empty.

Line [5] uses similar logic to set up an appropriate error message, which is assigned to the `ErrorMessage` property of the corresponding `CustomValidator` control, represented by `source`.

`VALIDATE_DUR`, which validates the *Initial Duration* field, uses similar logic to check that the value in the *Endowment Term* field is correct and that `TERM`, on which it depends, is therefore defined. In addition, in line [8] it refers to the `Checked` property of the `RadioButton` controls named `TA` and `TB` respectively.

```

▽ VALIDATE_DUR MSG;source;args;DT
[1]  ⍺ Validates Initial Duration
[2]  :Access Public
[3]  :Signature VALIDATE_DUR Object source,
      ServerValidateEventArgs args
[4]  source args←MSG
[5]  :If 2=GET_RUN_OPTION
[6]  DT←1
[7]  :Else
[8]  DT←+/10 1×(TA TB).Checked
[9]  :EndIf
[10] :If ^/(RFVTRM CustomValidator_TERM).IsValid

[11] source.ErrorMessage←'Initial Duration must be an
      integer between 0 and ',(⊘TERM-DT),
      ' (TERM-',(⊘DT),')'
[12] :Else
[13] source.ErrorMessage←'Initial Duration must be an
      integer between 0 and (Term-',(⊘DT),')'
[14] :EndIf
[15] :Trap 0
[16] DUR←Convert.ToInt32 args.Value
[17] :Else
[18] args.IsValid←0
[19] :Return
[20] :EndTrap
[21] :If ^/(RFVTRM CustomValidator_TERM).IsValid
[22] args.IsValid←(0≤DUR)^DUR≤TERM-DT
[23] :EndIf
▽

```

## Forcing Validation

Validation controls are automatically invoked when the user activates a Button control, but not when other postbacks occur. For example, when the user selects a different Mortality Table (represented by a RadioButtonList control), the page calls the `CHANGE_TABLES` function.

```

<asp:RadioButtonList id=MT runat="server"
  RepeatDirection="Vertical" RepeatRows="3" tabIndex=1
  onSelectedIndexChanged="CHANGE_TABLES"
  AutoPostBack="true">
<asp:ListItem Value="UK Assured Lives">
  Selected="True">UK Assured Lives</asp:ListItem>
<asp:ListItem Value="UK Immediate Annuitant">
  UK Immediate Annuitant</asp:ListItem>
<asp:ListItem Value="UK Pension Annuitant">
  UK Pension Annuitant</asp:ListItem>
</asp:RadioButtonList>

```

A `RadioButtonList` control does not cause validation to occur, so this must be done explicitly. This is easily achieved by calling the `Validate` method of the Page itself as shown in `CHANGE_TABLES[11]` below.

```

    ▽ CHANGE_TABLES ARGS;TableNames;TableName;OPTSMORT;
      MORT_OPTION;RUN_OPTION
[1]   :Access public
[2]   :Signature CHANGE_TABLES Object obj, EventArgs ev
[3]   RUN_OPTION←GET_RUN_OPTION
[4]   MORT_OPTION←1+MT.SelectedIndex
[5]   OPTSMORT←MORT_OPTION⇒OPTSMORT_ASS OPTSMORT_ANNI
      OPTSMORT_ANNP
[6]   TableNames←⇒OPTSMORT      A Assured lives/term
      assurance tables
[7]   TableNames←↓(2=□NC 0 1↓3⇒OPTSMORT)÷TableNames
[8]   TableNames←TableNames~'' '
[9]   CMTAB.Items.Clear
[10]  :For TableName :In TableNames
[11]  CMTAB.Items.Add TableName
[12]  :EndFor
[13]  Page.Validate A Force page validation
[14]  :Select RUN_OPTION
[15]  :Case 1
[16]  CALC_FSLTAB_RESULTS 0
[17]  :Case 2
[18]  CALC_FSL_RESULTS 0
[19]  :EndSelect

```

▽

## Calculating and Displaying Results

The function `CALC_FSLTAB_RESULTS`, which for brevity is only partially shown below, is used by the `sla_tab.aspx` page to calculate and display results.

```

▽ CALC_FSLTAB_RESULTS ARGs;X;ULT;MORTOPT;QTAB;TABLE;
  TAB_DURS;RUN_OPTION;MORT_OPTION;UNIX;DOS;
  CURRENTDATE;CURRENTTIME;OPTSMORT;TABLES;MSG;data
[1]   :If IsValid A Is page valid ?
  ...
[6]   MORT_OPTION←1+MT.SelectedIndex
[7]   OPTSMORT←MORT_OPTION>OPTSMORT_ASS
      OPTSMORT_ANNI
      OPTSMORT_ANNP

[8]
[9]   TABLES←↓3>OPTSMORT
[10]  MORTOPT←(ρTABLES)ρ0
[11]  MORTOPT[1+CMTAB.SelectedIndex]←1
[12]  TABLE←>MORTOPT/TABLES
  ...
[15]  TAB_DURS←TA.Checked
  ...
[41]  FSLT←((ρX)ρ(3 0)(3 0)(3 0)(11 4)(11 6)(12 4)
      (11 6)(8 0))⌈X
[42]  FSLT←FSLT~'' '
[43]  :With data←[]NEW DataTable
[44]    cols←Columns.Add''##.FSL_HEADER
[45]    {
[46]      row←NewRow 0
[47]      row.ItemArray←ω
[48]      Rows.Add row
[49]    }''↓##.FSLT
[50]  :EndWith
[51]  fsl.DataSource←[]NEW DataView data
[52]  fsl.DataBind
[53]  fsl.Visible←1
[54]  :Else
[55]    fsl.Visible←0
[56]  :EndIf

```

▽

The results of the calculation are displayed in a DataGrid object named `fsl`. This is defined within the `sla_tab.aspx` page as follows:

```
<asp:DataGrid id="fsl" runat="server" Width="700"
  AllowPaging="false" BorderColor="black" CellPadding="3"
  CellSpacing="0" Font-Size="9pt" PageSize="10">
  <ItemStyle HorizontalAlign="right" Width="100">
  </ItemStyle>
  <HeaderStyle HorizontalAlign="center"
  Font-Size="12pt" Font-Bold="true" BackColor="#17748A"
  ForeColor="FFFFFF"></HeaderStyle>
</asp:DataGrid>
```

`CALC_FSLTAB_RESULTS[1]` checks to see if the user input is valid. If not, [55] hides the DataGrid object `fsl` so that no results are displayed in the page. The display of error messages is handled separately, and automatically, by the ValidationSummary control on the page.

`CALC_FSLTAB[11-15]` obtain the values of the *CMTAB* (DropDownList) and *TA* (RadioButton) controls on the page.

`CALC_FSLTAB[43-53]` store the calculated data table `FSLT` in the DataGrid `fsl`.



---

# Chapter 9:

## Writing Custom Controls for ASP.NET

### Introduction

The previous chapter showed how you can build ASP.NET Web Pages by combining APL code with the Web Controls provided in the .NET Namespace `System.Web.UI.WebControls`. These controls are in fact just ordinary .NET classes. In particular, they are extensible components that can be used to develop more complex controls that encapsulate additional functionality.

This chapter describes how you can go about building custom server-side controls, for deployment in ASP.NET Web Pages.

A custom control is simply a .NET class that inherits from the `Control` class in the .NET Namespace `System.Web.UI`, or inherits from a higher class that is itself based upon the `Control` class. Like any other .NET class, a custom control is implemented in an assembly, physically as a DLL file. This chapter explores three different ways to implement a custom control.

The `Control` class provides a `Render` method whose job is to generate the HTML that defines appearance of the control. The first example, the `SimpleCtl` control, overrides the `Render` method to display a simple string "Hello World" in the browser.

The `TemperatureConverterCtl1` control is an example of a compositional control, i.e. one that is composed of other standard controls packaged with special functionality. The `TemperatureConverterCtl2` control, uses the basic approach of the `SimpleCtl` control, but provides the same functionality as `TemperatureConverterCtl1`. The `TemperatureConverterCtl3` control illustrates how to generate events for the hosting page to catch and process.

These examples, which are based upon a series of articles called *Advanced ASP.NET Server-Side Controls* by George Shepherd that appeared in the *msdn magazine* (October 2000, January 2001 and March 2001 issues), are implemented in a namespace called `DyalogSamples` in the workspace `samples\asp.net\Temp\Bin\Temp.dws`. The corresponding .NET Assembly `samples\asp.net\Temp\Bin\Temp.dll` was generated from this workspace.

## The SimpleCtl Control

```
)CLEAR
clear ws
```

Starting with a `clear ws`, the first step is to make the `DyalogSamples` container namespace, and then change into it.

```
)NS DyalogSamples
#.DyalogSamples

)CS DyalogSamples
#.DyalogSamples
```

Next we can build the first of the three example classes `SimpleCtl`, specifying its base class to be `Control` (actually, `System.Web.UI.Control`):

```
)ed o SimpleCtl
:Class SimpleCtl: Control
```

we must define `⎕USING` to include all of the .NET Namespaces that will be needed (this could also have been implemented with the `:Using` statement, but the examples in this section were originally written for version 10.1 of Dyalog APL):

```
⎕USING←,←'System'
⎕USING,←←'System.Collections.Specialized,system.dll'
⎕USING,←←'System.Web,System.Web.dll'
⎕USING,←←'System.Web.UI'
⎕USING,←←'System.Web.WebControls'
⎕USING,←←'System.Web.HtmlControls'
```

Having changed into the `SimpleCtl` namespace, we can define a function called `Render` that supercedes the `Render` method that `SimpleCtl` has inherited from its base class, `System.Web.UI.Control`.



The `Render` method defined by the `System.Web.UI.Control` base class is `void` and takes a parameter of type `HtmlTextWriter`. When the `SimpleCtl` control is referenced in a Web Page, ASP.NET creates an instance of it and calls its `Render` method because it is a `Control` and is expected to have one. Moreover, ASP.NET supplies an object of type `HtmlTextWriter` as its parameter. You do not need to worry where this object came from, or what it actually represents. You need only know that an `HtmlTextWriter` provides a method called `WriteLine` that may be used to output a text string to the browser. The mechanics of how this actually happens are handled by the `HtmlTextWriter` object itself.

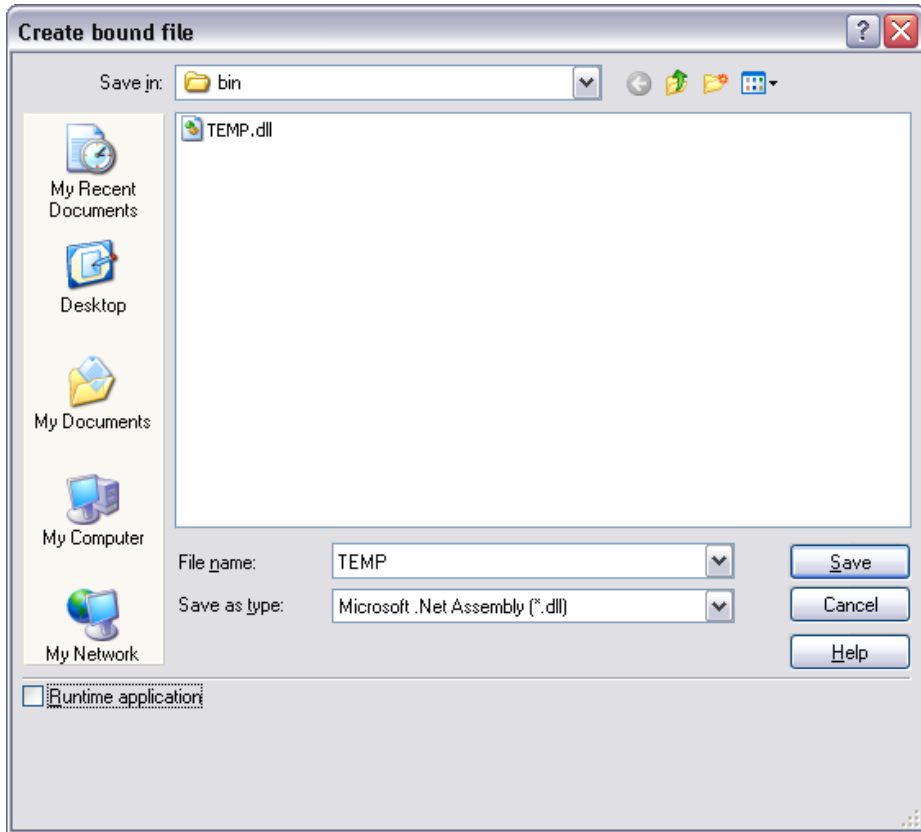
In APL terms, the argument to our `Render` function, `output`, will be a namespace reference, and the function can simply call its `WriteLine` method with a character vector argument. This argument can contain any valid HTML string and defines the appearance of the `SimpleCtl` control.

The next step is to define the `Render` function. The function is defined to be `void` (i.e. it does not return a result) and to take a single parameter of type `HtmlTextWriter`. Note that to successfully replace the base class method method, the `Render` function must have exactly this *Signature*.

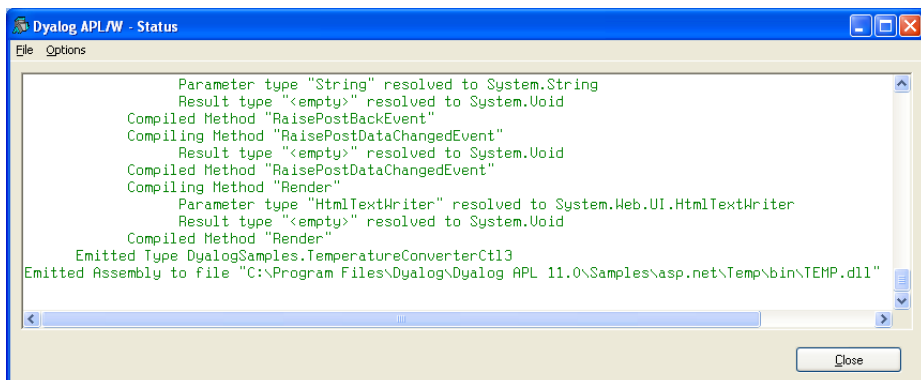
```
    ▽ Render output;HTML
[1]   :Access public
[2]   :Signature Render HtmlTextWriter output
[3]   HTML←' <h3>Hello World</h3>'
[4]   output.WriteLine <HTML
    ▽
```

Finally, we can save the workspace and generate the .NET Assembly. This must be located in the `Bin` subdirectory of `samples\asp.net\Temp` which itself is mapped to the IIS Virtual Directory `localhost/dyalog.net/Temp`.

```
    )SAVE
C:\Dyalog\samples\ASP.NET\TEMP\BIN\TEMP saved...
```



When we select *Export...* from the *File* menu, the information displayed in the Status window confirms that the `SimpleCtl` class has been successfully emitted and saved.



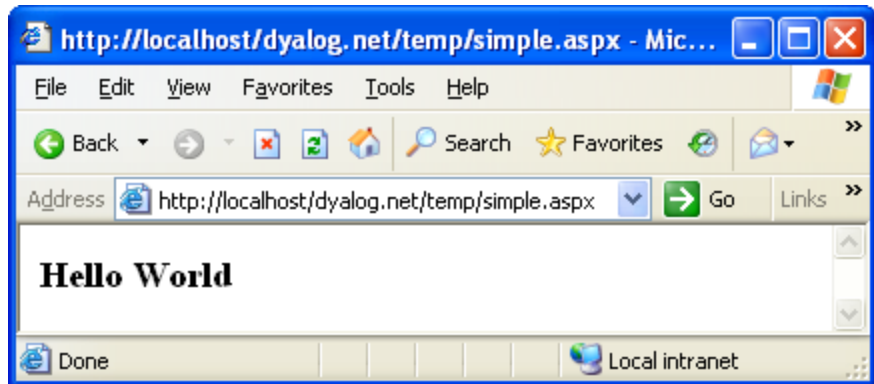
## Using SimpleCtl

Our `SimpleCtl` control may now be included in any .NET Web Page from which `Temp.dll` is accessible. The file `samples\asp.net\Temp\Simple.aspx` is simply an example. The fact that this control is written in Dyalog APL is immaterial.

```
<%@ Register TagPrefix="Dyalog"
           Namespace="DyalogSamples" Assembly="TEMP" %>

<html>
<body>
<Dyalog:SimpleCtl runat=server/>
</body>
</html>
```

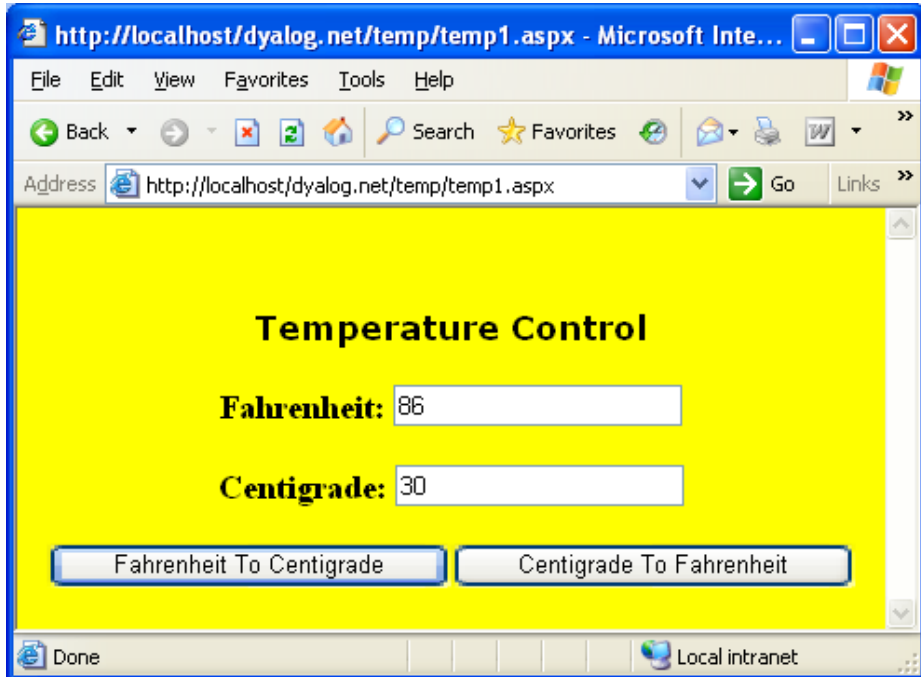
The first line of the script specifies that any controls referenced later in the script that are prefixed by `Dyalog:`, refer to custom controls in the .NET Namespace called `DyalogSamples`. In this case, `DyalogSamples` is located by searching the Assembly `TEMP.dll` in the `Bin` subdirectory.



## The TemperatureConverterCtl1 Control

The `TemperatureConverterCtl1` control is an example of a *compositional* control, i.e. a server-side custom control that is composed of other standard controls.

In this example, The `TemperatureConverterCtl1` control gathers together two textboxes and two push buttons into a single component as illustrated below. Type a number into the *Centigrade* box, click the *Centigrade To Fahrenheit* button, and the control converts accordingly. If you click the *Fahrenheit To Centigrade* button, the reverse conversion is performed.



Starting with the TEMP workspace, the first step is to change into the `DyalogSamples` container namespace.

```
)LOAD SAMPLES\ASP.NET\TEMP\BIN\TEMP
C:\Dyalog\samples\ASP.NET\TEMP\BIN\TEMP saved...
```

```
)CS DyalogSamples
#.DyalogSamples
```

The `TemperatureConverterCtl1` control is going to *contain* other standard controls as *child controls*. A control that acts as a container should implement an interface called `INamingContainer`.

This interface does not in fact require any methods; it merely acts as a marker. When we create a `class` to represent the control, we need to specify that it provides this interface:

```
:Class TemperatureConverterCtl1: Control,
    System.Web.UI.INamingContainer
```

## Child Controls

Whenever ASP.NET initialises a `Control`, it calls its `CreateChildControls` method (the default `CreateChildControls` method does nothing). So to make the appropriate child controls, we simply define a function called `CreateChildControls` with the appropriate public interface (no arguments and no result) as shown below.

```
▽ CreateChildControls
:Access    public override
:Signature CreateChildControls

Controls.Add [NEW LiteralControl, <<'<h3>Fahrenheit: '
m_FahrenheitTextBox←[NEW TextBox
m_FahrenheitTextBox.Text←,'0'
Controls.Add m_FahrenheitTextBox
Controls.Add [NEW LiteralControl, <<'</h3>'

Controls.Add [NEW LiteralControl, <<'<h3>Centigrade: '
m_CentigradeTextBox←[NEW TextBox
m_CentigradeTextBox.Text←,'0'
Controls.Add m_CentigradeTextBox
Controls.Add [NEW LiteralControl, <<'</h3>'

F2CButton←[NEW Button
F2CButton.Text←'Fahrenheit To Centigrade'
F2CButton.onClick←[OR'F2CConvertBtn_Click'
Controls.Add F2CButton

C2FButton←[NEW Button
C2FButton.Text←'Centigrade To Fahrenheit'
C2FButton.onClick←[OR'C2FConvertBtn_Click'
Controls.Add C2FButton
▽
```

Line[2] creates an instance of a `LiteralControl` (a label) containing the text "Fahrenheit" with an HTML tag "<H3>". `Controls` is a property of the `Control` class (from which `TemperatureConverterCtl1` inherits) that returns a `ControlCollection` object. This has an `Add` method whose job is to add the specified control to the list of child controls managed by the object.

Lines[3-4] create a `TextBox` child control containing the text "0", and Line[5] adds it to the child control list.

Line[6] adds a second `LiteralControl` to terminate the "<H3>" tag.

Lines [8-12] do the same for Centigrade.

Lines[14-15] create a `Button` control labelled "Fahrenheit To Centigrade". Line[16] associates the callback function `F2CConvertBtn_Click` with the button's `onClick` event. Note that it is necessary to assign the `⌈OR` of the function rather than its name. Line[17] adds the button to the list of child controls.

Lines[19-22] create a Centigrade button in the same way.

This function is run every time the page is loaded; however in a postback situation, other code steps in to modify the values in the textboxes, as we shall see.

The public interface for the `CreateChildControls` function is defined on line [1] using the `:Access public` statement.

## Fahrenheit and Centigrade Values

The `TemperatureConverterCtl1` maintains two public properties named `CentigradeValue` and `FahrenheitValue`, which may be accessed by a client application. These properties are not exposed directly as variables, but are obtained and set via *property get* (or *accessor*) and *property set* (or *mutator*) functions. (This is recommended practice for C#, so the example shows how it is done in APL.) In this case, the values are simply stored in or obtained directly from the corresponding textboxes set up by `CreateChildControls`.

```

:Property CentigradeValue
  ▽ C←get
    :Access    public
    :Signature  Double←get_CentigradeValue
    C←m_CentigradeTextBox.Text
  ▽

  ▽ set C
    :Access    public
    :Signature  set_CentigradeValue Double Value
    m_CentigradeTextBox.Text←C.NewValue
  ▽
:EndProperty A CentigradeValue

```

Notice that the `Get` function uses `double` to convert the text in the textbox to a numeric value. Clearly something more robust would be called for in a real application

Similar functions to handle the `Fahrenheit` property are provided but are not shown here.

## Responding to Button presses

We have seen how APL callback functions have been attached to the `onClick` events in the two buttons. The `C2FConvertBtn_Click` callback function simply obtains the `CentigradeValue` property, converts it to Fahrenheit using `C2F`, and then sets the `FahrenheitValue` property.

```

    ▽ C2FConvertBtn_Click args
      :Access    public
      :Signature C2FConvertBtn_Click Object ,EventArgs
      FahrenheitValue←C2F CentigradeValue
    ▽

    ▽ f←C2F c
  [1]   f←32+c×1.8
    ▽
    ▽ F2CConvertBtn_Click args
      :Access    public
      :Signature  F2CConvertBtn_Click Object ,EventArgs
      CentigradeValue←F2C FahrenheitValue
    ▽

    ▽ c←F2C f
  [1]   c←(f-32)÷1.8
    ▽

```

These functions are all internal functions that are private to the control, and it is therefore not necessary to define public interfaces for them.

## Using the Control on the Page

The text of the script file `samples\Temp\Temp1.aspx` is shown below. There is really no difference between this example and the `simple.aspx` described earlier.

```
<%@ Register TagPrefix="Dyalog" Namespace="DyalogSamples"
      Assembly="TEMP"%>
<html>
<body bgcolor="yellow">
<br><br>
<center>
<h3><font face="Verdana" color="black">Temperature
Control</font></h3>

<form runat=server>
<Dyalog:TemperatureConverterCtl1 id=TempCvtCtl1 runat=server/>
</form>
</center>
</body>
</html>
```

The HTML generated by the control at run-time is shown below. Notice that in place of the server-side control declaration in `temp1.aspx`, there are two edit controls with numerical values in them, and two push buttons to submit data entered on the form to the server.

```
<html>
<body bgcolor="yellow">
<br><br>
<center>
<h3><font face="Verdana" color="black">Temperature
Control</font></h3>

<form name="ctrl1" method="post" action="temp1.aspx" id="ctrl1">
<input type="hidden" name="__VIEWSTATE"
value="YTB6MTc3MzAxNzYxNF9fX3g=03f01d88" />

<h3>Fahrenheit: <input name="TempCvtCtl1:ctrl1" type="text"
value="32" /></h3><h3>Centigrade: <input name="TempCvtCtl1:ctrl4"
type="text" value="0" /></h3><input type="submit"
name="TempCvtCtl1:ctrl6" value="Fahrenheit To Centigrade"
/><input type="submit" name="TempCvtCtl1:ctrl7" value="Centigrade
To Fahrenheit" />
</form>

</center>
</body>
</html>
```



## The TemperatureConverterCtl2 Control

The previous example showed how to compose an ASP.NET custom control from other standard controls. This example shows how you can instead generate standard form elements on the browser by rendering the HTML for them directly.

Starting with the TEMP workspace, the first step is to change into the `DyalogSamples` container namespace.

```
)LOAD SAMPLES\ASP.NET\TEMP\BIN\TEMP
C:\Dyalog\samples\ASP.NET\TEMP\BIN\TEMP saved...
```

```
)CS DyalogSamples
#.DyalogSamples
```

In the composite temperature control `TemperatureConverterCtl1`, discussed previously, all the data transfers between the browser and the server, relating to the standard child controls that it contains, are handled automatically by the controls themselves. Rendered controls require a bit more programming because it is up to the control developer to do the data transfer. The data transfer is managed through two interfaces, namely `IPostBackDataHandler` and `IPostBackEventHandler`. We will see how these interfaces are used later.

When we create a `class` to represent the control, we need to specify that it provides these interfaces.

```
:Class TemperatureConverterCtl2: Control,
    System.Web.UI.IPostBackDataHandler,
    System.Web.UI.IPostBackEventHandler
```

### Fahrenheit and Centigrade Values

Like the previous `TemperatureConverterCtl2` control, the `TemperatureConverterCtl2` maintains two public properties named `CentigradeValue` and `FahrenheitValue` using property *get* and property *set* functions.

This time, the control manages the current temperature values in two internal variables named `_CentigradeValue` and `_FahrenheitValue`, which we must initialise.

```
_CentigradeValue←0
_FahrenheitValue←0
```

The `CentigradeValue`'s *get* function simply returns the current value of `_CentigradeValue`. Its .NET Properties are defined as shown so that it is exported as a *property get* function for the `CentigradeValue` property, and returns a `Double`.

```

▽ C←get
:Access public
:Signature Double←get
C←_CentigradeValue
▽

```

The `CentigradeValue`'s `set` function simply resets the value of `_CentigradeValue` to that of its argument. Its .NET Properties are defined as shown so that it is exported as a *property set* function for the `CentigradeValue` property, and takes a `Double`.

```

▽ set C
:Access public
:Signature set Double Value
_CentigradeValue←C.NewValue
▽

```

The property *get* and property *set* functions for the `FahrenheitValue` property are similarly defined. The .signatures for these functions are similar to those for the `CentigradeValue` functions and are not shown.

## Rendering the Control

Like the `SimpleCtl` example described earlier in this Chapter, the `TemperatureConverterCtl2` control has a **Render** function that generates the HTML to represent its appearance, and in this case its behaviour too.

As we saw in the `SimpleCtl` example, the `Render` method will be called by ASP.NET with a parameter that represents an `HtmlTextWriter` object. This is represented by the APL local name `output`.

Lines[3-8] and lines [10-15] generate HTML that defines two text boxes in which the user may enter the Fahrenheit and centigrade values respectively. Lines[8+15] use the `Write` method of the `HtmlTextWriter` object to output the HTML.

Lines[4+11] obtain the fully qualified identifier for this particular instance of the `TemperatureConverterCtl2` control from its `UniqueID` property. This is a property, which it inherits from `Control` and is therefore also a property of the current (APL) namespace.

Lines[17-21] and Lines[23-27] generate and output the HTML to represent the two buttons that convert from Fahrenheit to Centigrade and from Centigrade to Fahrenheit respectively.

```

▽ Render output;C;F;BF;CF
:Access public override
:Signature Render HtmlTextWriter output

F←'<h3>Fahrenheit <input name='
F,←UniqueID
F,←' id=FahrenheitValue type=text value='
F,←_FahrenheitValue
F,←'></h3>'
output.Write=F

C←'<h3>Centigrade <input name='
C,←UniqueID
C,←' id=CentigradeValueKey type=text value='
C,←_CentigradeValue
C,←'></h3>'
output.Write=C

BF←'<input type=button value=FahrenheitToCentigrade '
BF,←' onClick="jscript:'
BF,←Page.GetPostBackEventReference
    □THIS'FahrenheitToCentigrade'
BF,←'">'
output.Write=BF

CF←'<input type=button value=CentigradeToFahrenheit '
CF,←' onClick="jscript:'
CF,←Page.GetPostBackEventReference
    □THIS'CentigradeToFahrenheit'
CF,←'">'
output.Write=CF

output.WriteLine◦<' ' <br>' <br>'
▽

```

Lines[17-27] generate HTML that wires the buttons up to JavaScript handlers to be executed *by the browser*. The JavaScript simply causes the browser to execute a post-back, i.e. send the page contents back to the server.

`GetPostBackEventReference` is a (shared) method provided by the `System.Web.UI.Page` class that generates a reference to a client-side script function. In this case it is called with two parameters, an object that represents the current instance of the `TemperatureConverterCtl2` control, and a string that will be passed to the server to indicate the cause of the postback (i.e. which button was pressed). The first parameter is a reference to the current object, which is returned by the system function `□THIS`.

The client-side script is itself generated, and inserted into the HTML stream automatically.

To help to understand this process fully, it is instructive to examine the HTML that is generated by these functions. We will do this a bit later in the Chapter.

## Loading the Posted Data

Once the server-side control has rendered the HTML for the browser, the user is free to type numbers into the text boxes and to press the buttons.

When the user presses a button, the browser runs the client-side JavaScript code that in turn generates a postback to the server.

When we created `TemperatureConverterCtl2` we specified that it supported the `IPostBackDataHandler` interface. This interface must be implemented by controls that want to receive postback data (i.e., the contents of Form fields that the user may have entered or changed). `IPostBackDataHandler` has two methods `LoadPostData` and `RaisePostDataChangedEvent`. `LoadPostData` is automatically invoked when a postback occurs, and the postback data is supplied as a parameter.

So when the postback occurs, the server reloads the original page and, because this is a postback situation and our control has advertised the fact that it implements `IPostBackDataHandler`, ASP.NET invokes its `LoadPostBack` method. This method is called with two parameters. The first is a key and the second is a collection of name/value pairs. This contains the names of all the Form fields on the page (and there may be others not directly associated with our custom control) and the values they had when the user pressed the button. The key provides the means to extract the relevant part of this collection. The `LoadPostData` function is shown below.

```

▽ R←LoadPostData args;postDataKey;values;controlValues;new
  :Signature Boolean←IPostBackDataHandler.LoadPostData
    String postDataKey,
    NameValueCollection values
  postDataKey values←args
  controlValues←values[⊢postDataKey]
  new←ParseControlValues controlValues
  R←v/new=_FahrenheitValue _CentigradeValue
  _FahrenheitValue _CentigradeValue←new
▽

```

Line[3] obtains the two parameters from the argument and Line[4] uses the key to extract the appropriate data from the collection. `ControlValues` is a comma-delimited string containing name/value pairs. The function `ParseControlValues` simply extracts the values from this string, i.e. the contents of the Fahrenheit and Centigrade text boxes.

## Postback Events

The result of `LoadPostData` is Boolean and indicates whether or not any of the values in a control have changed. If the result is `True` (1), ASP.NET will next call the `RaisePostDataChanged` method. This method is called with no parameters and merely signals that something has changed. The control knows *what* has changed by comparing the old with the new, as in `LoadPostData` [10].

Finally, the page framework calls the `RaisePostBackEvent` method, passing it a string that identifies the page element that caused the post back.

The objective of these calls is to provide the control with the information it requires to synchronise its internal state with its appearance in the browser.

In this case, we are not interested in which of the two text box values the user has altered; what matters is which of the two buttons *FahrenheitToCentigrade* or *CentigradeToFahrenheit* was pressed. Therefore, in this case, the control uses `RaisePostBackEvent` rather than `RaisePostDataChanged` (or indeed, `LoadPostData` itself, which is another option). The reason is that `RaisePostBackEvent` receives the name of the button as its argument.

So in our case, the `RaisePostDataChanged` function does nothing. Nevertheless, it is essential that the function is provided and essential that it supports the correct public interface, namely that it takes no arguments and returns no result (`Void`).

```

    ▽ RaisePostDataChangedEvent
[1] :Access public
[2] :Signature RaisePostDataChangedEvent
[3] A Do nothing
    ▽

```

The `RaisePostBackEvent` function simply switches on its argument, which is the name of the button that the user pressed, and recalculates `_CentigradeValue` or `_FahrenheitValue` accordingly.

```

    ▽ RaisePostBackEvent eventArgument
[1] :Access public
[2] :Signature RaisePostBackEvent String eventArg
[3] :Select eventArgument
[4] :Case 'FahrenheitToCentigrade'
[5]     _CentigradeValue←F2C _FahrenheitValue
[6] :Case 'CentigradeToFahrenheit'
[7]     _FahrenheitValue←C2F _CentigradeValue
[8] :EndSelect
    ▽

```

Finally, the page framework calls the **OnPreRender** and **Render** functions again, which generate new HTML for the browser.

## Using the Control on a Page

Once all the functions, and their public interfaces for the `TemperatureConverterCtl2` have been defined, the workspace is saved and `TEMP.DLL` is remade using *Export* from the *Session File* menu. For brevity, this process is not shown pictorially here.

So long as it has access to this DLL, our custom control may be accessed from any ASP.NET Web Page, and a simple example is shown below.

```
<%@ Register TagPrefix="Dyalog" Namespace="DyalogSamples"
      Assembly="TEMP" %>

<html>
<body bgcolor="yellow">
<center>
<h3><font face="Verdana" color="black">
Temperature Control</font></h3>
<h4><font face="Verdana" color="black">
Server-Side Noncompositional control</font></h4>

<form runat=server>
<Dyalog:TemperatureConverterCtl2 id=TempCvtCtl2
runat=server/>
</form>

</center>
</body>
</html>
```

The HTML that is generated by the control is illustrated below. Notice the presence of a JavaScript function named `__doPostBack`. This is generated by the `RegisterPostBackScript` method called from the **OnPreRender** function. The code that wires the buttons to this function was generated by the `GetPostBackEventReference` method called from the **Render** function.

```
<html>
<body bgcolor="yellow">
<center>
<h3><font face="Verdana" color="black">Temperature
Control</font></h3>
<h4><font face="Verdana" color="black">Server-Side
Noncompositional control</font></h4>

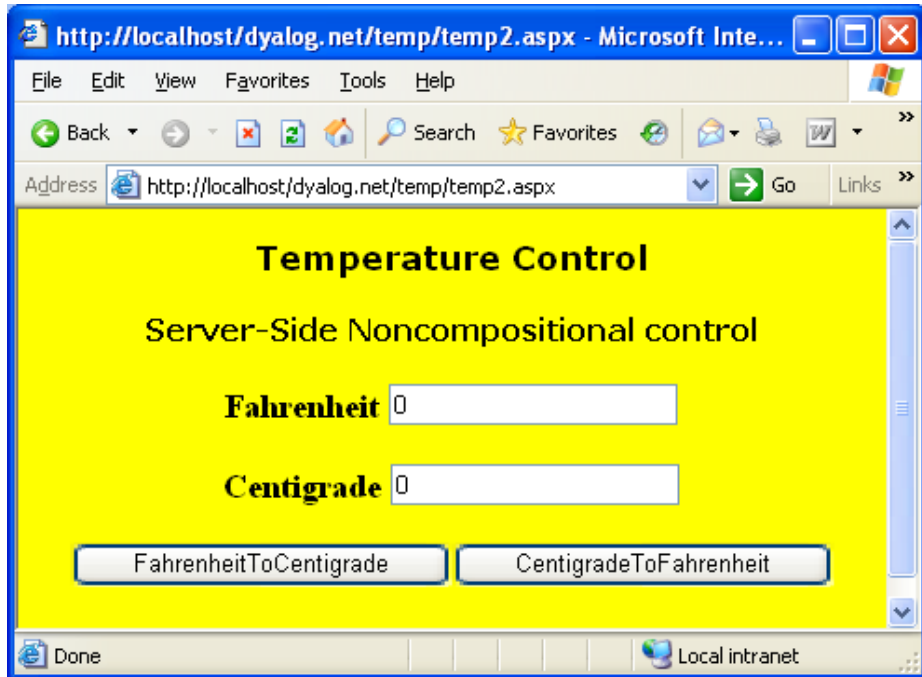
<form name="ctrl1" method="post" action="temp2.aspx" id="ctrl1">
<input type="hidden" name="__EVENTTARGET" value="" />
<input type="hidden" name="__EVENTARGUMENT" value="" />
<input type="hidden" name="__VIEWSTATE"
value="YTB6MTc3MzAxNzYxMl9fX3g=9cfcfa5c" />

<script language="javascript">
<!--
        function __doPostBack(eventTarget, eventArgument) {
            var theform = document.ctrl1
            theform.__EVENTTARGET.value = eventTarget
            theform.__EVENTARGUMENT.value = eventArgument
            theform.submit()
        }
// -->
</script>

<h3>Fahrenheit <input name=TempCvtCtl2 id=FahrenheitValue
type=text value=0></h3><h3>Centigrade <input name=TempCvtCtl2
id=CentigradeValueKey type=text value=0></h3><input type=button
value=FahrenheitToCentigrade onClick="jscrip:__
doPostBack('TempCvtCtl2','FahrenheitToCentigrade')"><input
type=button value=CentigradeToFahrenheit onClick="jscrip:__
doPostBack('TempCvtCtl2','CentigradeToFahrenheit')">
<br>
<br>

</form>

</center>
</body>
</html>
```



## The TemperatureConverterCtl3 Control

In the previous examples, events generated by control have been internal events, i.e. events that have been detected and processed internally by the control itself.

A separate requirement is to be able to design a custom control that generates *external* events, i.e. events that can be detected and handled by the page that is hosting the control. This example illustrates how to do this.

The TemperatureConverterCtl3 namespace is a copy of TemperatureConverterCtl2 with a couple of changes.

The first change is to describe an event that the control is going to generate. This is done using `⎕NQ` inside TemperatureConverterCtl3 like this:

```
2 ⎕NQ '' 'SetEventInfo' 'Export'
      (('Double' 'Fahrenheit')
      ('Double' 'Centigrade'))
```



To define an event, enter its name after the 'SetEventInfo' string. Then enter the list of parameter type/name pairs that the event will include when it is generated. In this case, the name of the event is *Export* and it will report two parameters named *Fahrenheit* and *Centigrade* which are both of data type *Double*.

This version of the control will present a slightly different appearance to the previous one. The control itself is wrapped up in an HTML *Table*, with the conversion buttons arranged in a column. These buttons generate internal events that are caught and handled by the control itself. The third row of the table contains an additional button labelled *Export* which will generate the *Export* event when pressed. The Render function is shown below.

```

▽ Render output;TableRow;HTML;SET
:Access public override
:Signature Render HtmlTextWriter output
TableRow←{
    HTML←'<tr><td>',α,'</td><td><input name=',UniqueID
    HTML,←' id=',α,'Value type=text '
    HTML,←' value=',(αω),'></td>'
    HTML,←'<td><input type=button value=Convert '
    HTML,←' onClick="jscript:'
    HTML,←'(Page.GetPostBackEventReference □THIS α),
    '></td></tr>'
    HTML
}

HTML←' '
HTML←'<table>'
HTML,←'Fahrenheit'TableRow _FahrenheitValue
HTML,←'Centigrade'TableRow _CentigradeValue

SET←'<tr><td><input type=button value=Export '
SET,←' onClick="jscript:'
SET,←Page.GetPostBackEventReference □THIS'Export '
SET,←'"></td></tr>'
HTML,←SET,'</table>'
output.Write<HTML
▽

```

Notice that `Render [ 18 ]` causes the *Export* button to generate a Postback event which will call `RaisePostBackEvent` with the argument 'Export'. Up to now, this is just an internal event just like the events generated by the conversion buttons.

The final stage is to modify `RaisePostBackEvent` to propagate this event to the host page.

```

▽ RaisePostBackEvent eventArgument
:Signature IPostBackEventHandler.RaisePostBackEvent
      String eventArg
:Select eventArgument
:Case 'Fahrenheit'
    _CentigradeValue←F2C _FahrenheitValue
:Case 'Centigrade'
    _FahrenheitValue←C2F _CentigradeValue
:Case 'Export'
    4 □NQ'' 'Export' _FahrenheitValue
      _CentigradeValue
:EndSelect
▽

```

This is simply done by adding a third `:Case` statement, so that when the function is invoked with the argument `'Export'`, it fires an `Export` event. This is done by line [7] using `4 □NQ`. The elements of the right argument are:

[1]	''	Specifies that the event is generated by this instance of the control
[2]	'Export'	The name of the event to be generated
[3]	_FahrenheitValue	The value of the first parameter, <i>Fahrenheit</i>
[4]	_CentigradeValue	The value of the second parameter, <i>Centigrade</i>

It is then up to the page that is hosting the control to respond to the event in whatever way it deems appropriate.

## Hosting the Control on a Page

The following example illustrates an ASP.NET web page that hosts the `TemperatureConverterCtl3` custom control and responds to its `Export` event. The page uses a `<script>` written in APL, but it could just as easily be written in VB.NET.

```
<%@ Register TagPrefix="Dyalog" Namespace="DyalogSamples"
    Assembly="TEMP"%>

<script language="Dyalog" runat="server">
    ▽ ExportCB args;sender;e
[1]     sender e←args
[2]     (Flab Clab).Text←⌘`e.(Fahrenheit Centigrade)
    ▽
</script>

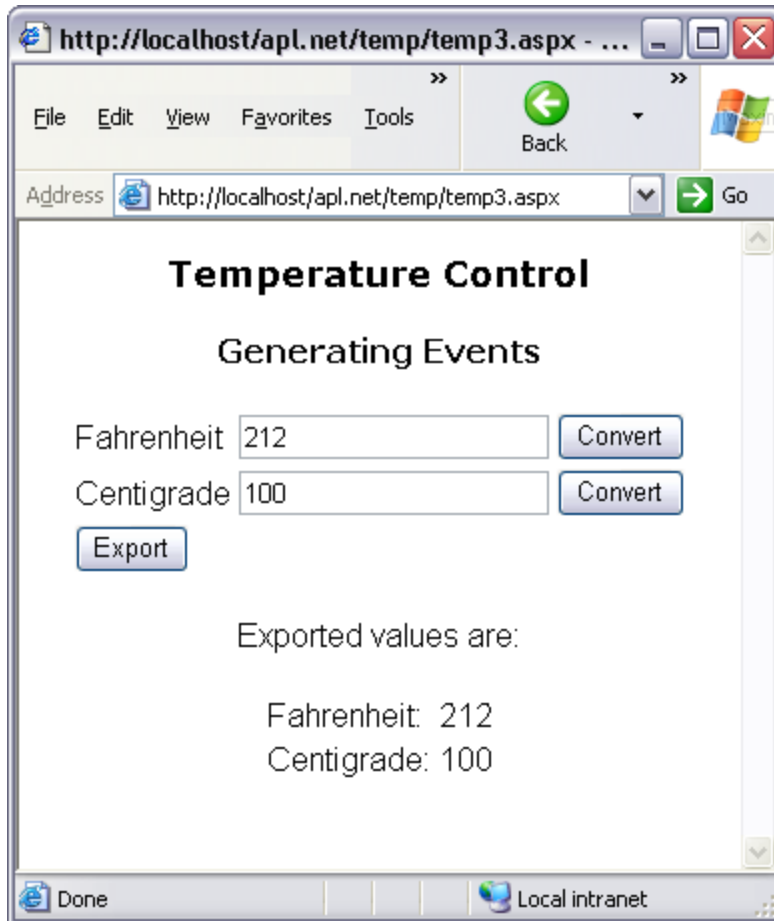
<html>
<body>
<center>
<h3><font face="Verdana">Temperature Control
    </font></h3>
<h4><font face="Verdana">Generating Events
    </font></h4>

<form runat=server>
<Dyalog:TemperatureConverterCtl3 id="TempcvtCtl3"
    onExport="ExportCB"
runat=server/>
</form>

<p>Exported values are:</p>
<table>
<tr><td>Fahrenheit:</td>
    <td><asp:Label id="Flab" Text="" runat="server">
        </asp:Label></td>
</tr>
<tr><td>Centigrade:</td>
    <td><asp:Label id="Clab" Text="" runat="server">
        </asp:Label></td>
</tr>
</table>
</center>
</body>
</html>
```

In this example, the host page associates a callback function `ExportCB` with the `Export` event. The `ExportCB` callback function is defined within the `<script></script>` section of the page. It simply sets the `Text` property of two `Label` controls to display the parameters reported by the event.

The picture below illustrates what happens when you run the page. Notice that the user can independently convert values between the two temperature scales and export these values from the control, to the host page, by pressing the Export button.



---

# Chapter 10:

## APLScript

### Introduction

APLScript is a Dyalog APL scripting language. It was originally designed specifically to program ASP.NET Web Pages and Web Services, but it has been extended to be of more general use outside the Microsoft .NET environment.

APLScript is not workspace oriented (although you can call workspaces from it) but is simply a character file containing function bodies and expressions.

APLScript files may be viewed and edited using any character-based editor which supports Unicode text files, such as Notepad. APLScript files may also be edited using Microsoft Word, although they must be saved as text files without any Word formatting.

APLScript files employ Unicode encoding so you need a Unicode font with APL symbols, such as APL385 Unicode, to view them. In order to type Dyalog APL symbols into an APLScript file, you also need the Dyalog APL Input Method Editor (IME), or other APL compatible keyboard.

If you choose to use the Dyalog APL IME it can be configured using *Control panel/Keyboard*. In particular, you may change the associated *.DIN* file from the dialog box obtained by pressing *IME Settings* in the *Input Locales* tab. Under Windows XP for example, this is done using *Control panel/Regional and Language Options*.

There are basically three types of APLScript files that may be identified by three different file extensions. APLScript files with the extension *.aspx* and *.asmx* specify .NET classes that represent ASP.NET Web Pages and Web Services respectively. APLScript files with the extension *.apl* may specify .NET classes or may simply represent an APL application in a script format as opposed to a workspace format. Such applications do not necessarily require the Microsoft .NET Framework.

## The APLScript Compiler

APLScript files are *compiled* into executable code by the APLScript compiler whose name is given in the table below.

	Unicode Edition	Classic Edition
<b>32-Bit</b>	dyalogc_unicode.exe	dyalogc.exe
<b>64-Bit</b>	dyalogc64_unicode.exe	dyalogc64.exe

This program is called automatically by ASP.NET when a client application requests a Web Page (.aspx) or Web Service (.asmx) and in these circumstances always generates the corresponding .NET class. However, the Script Compiler may also be used to:

- Compile an APLScript into a workspace (.dws) that you may subsequently run using DYALOG.EXE or DYALOGRT.EXE in the traditional manner.
- Compile an APLScript into a .NET class (.dll) which may subsequently be used by any other .NET compatible host language such as C# or Visual Basic.
- Compile an APLScript into a native Windows executable program (.exe), which may be run as a stand-alone executable. This program may be distributed, along with the Dyalog APL runtime DLL, as a packaged application, and does not require any of the additional support files and registry entries that are typically needed by the Dyalog APL run-time DYALOGRT.EXE. Note too that the Dyalog APL dynamic link library does not use MAXWS but instead allocates workspace dynamically as required. See the User Guide for further details.
- Compile a Dyalog APL Workspace (.dws) into a native Windows executable program, with the same characteristics and advantages described above.

The Script is designed to be run from a command prompt. If in the 32-bit Classic Edition you type `dyalogc /?` (to query its usage) the following output is displayed:

---

Dyalog APLScript compiler 32 bit. Classic Mode. Version  
13.1.12350.0  
Copyright Dyalog Ltd 2012

dyalogc.exe command line options:

/?	Usage
/r:file	Add reference to assembly
/o[ut]:file	Output file name
/x:file	Read source files from Visual Studio.Net
project file	
/res:file	Add resource to output file
/icon:file	File containing main program icon
/q	Operate quietly
/v	Verbose
/s	Treat warnings as errors
/nonet	Creates a binary that does not use Microsoft
.Net	
/runtime	Build a non-debuggable binary
/lx:expression	Specify entry point (Latent Expression)
/t:library	Build .Net library (.dll)
/t:nativeexe	Build native executable (.exe). Default
/t:workspace	Build dyalog workspace (.dws)
/nomessages	Process does not use windows messages. Use when
creating	
	a process to run under IIS
/console	Creates a console application
/c	Creates a console application
/unicode	Creates an application that runs in a Unicode
intepreter	
/wx:[0 1 3]	Sets WX for default code

## Creating an APLScript File

Conceptually, the simplest way to create an `APLScript` file is with Notepad, although you may use many other tools including Microsoft Visual Studio as described in the next Chapter.

1. Start Notepad
2. *Choose Format/Font* from the Menu Bar and select an appropriate Unicode font that contains APL symbols, such as *APL 385 Unicode* or *Arial Unicode MS*.
3. Select an APL keyboard by clicking on your keyboard selector in the System Tray. Note that this keyboard setting (and button) is associated only with the current instance of Notepad. If you start another instance of Notepad, or another editor, you will have to select the APL keyboard for it separately and there will be two floating toolbars on your display.
4. Now type in your APL code. If you use a Ctrl keyboard, you will discover that Ctrl+ keystrokes generate APL symbols For example, Ctrl+n generates  $\tau$ .
5. Choose *File/Save*. When the *Save As* dialog appears, ensure that *Encoding* is set to *Unicode* and *Save as type:* is set to *All Files*. Enter the name of the file, adding the extension `.asmx` or `.aspx`, and then click *Save*. Note that you have to save the `.asmx` file somewhere in an IIS Virtual Directory structure.



## Transferring code from the Dyalog APL Session

You may find it easier to write APL code using the Dyalog APL function or class editor that is provided by the Dyalog APL Session. Or you may already have code in a workspace that you want to copy into an `APLScript` file.

If so, you can transfer code from the Session into your `APLScript` editor (e.g. Notepad) using the clipboard. Notice that because `APLScript` requires Unicode encoding (for APL symbols), you must ensure that character data is written to the clipboard in Unicode.

In the Unicode interpreter this is always done. In the Classic interpreter this is controlled by a parameter called `UnicodeToClipboard` that specifies whether or not data is transferred to and from the Windows clipboard as Unicode. This parameter may be changed using the Trace/Edit page of the Configure dialog box.

If set (the default), APL text pasted to the clipboard from the Session is written as Unicode and APL requests Unicode data back from the clipboard when it is required. This makes it easy to transfer APL code between the Session and an `APLScript` editor, which is using the Arial Unicode MS font.

In the Classic interpreter when pasting code *into* the Dyalog editor, there are two menu items under the Edit menu, which allow you to explicitly select whether the Unicode mapping should be used, or the old mapping which corresponds to the Dyalog Std TT or Dyalog Alt TT fonts. You should use "Paste non-Unicode" when transferring text from the on line help, or text copied from earlier versions of Dyalog APL without the Unicode option.

Unless you explicitly want to have line numbers in your `APLScript`, the simplest way to paste APL code from the Session into an `APLScript` text editor is as follows:

1. open the function in the function editor
2. select all the lines of code, or just the lines you want to copy
3. select *Edit/Copy* or press Ctrl+Ins
4. switch to your `APLScript` editor and select *Edit/Paste* or press Shift+Ins.
5. Insert del (▼) symbols at the beginning and end of the function.

If you want to preserve line numbers (this is allowed, but not recommended in APLScript files), you may use the following technique:

1. In the Session window, type a del (▼) symbol followed by the name of the function, followed by another del (▼) and then press Enter. This causes the function to be displayed, with line numbers, in the Session window.
2. Select the function lines, including the surrounding dels (▼) and choose *Edit/Copy* or press Ctrl+Insert.
3. switch to your APLScript editor and select *Edit/Paste* or press Shift+Ins.

## General principles of APLScript

The layout of an APLScript file differs according to whether the script defines a Web Page, a Web Service, a .NET class, or an APL application that may have nothing to do with the .NET Framework. However, within the APLScript, the code layout rules are basically the same.

An APLScript file contains a sequence of function bodies and executable statements that assign values to variables. In addition, the file typically contains statements that are directives to the APLScript compiler. If the script is a Web Page or Web Service, it may also contain directives to ASP.NET. The former all start with a colon symbol (:) in the manner of control structures. For example, the **:Namespace** statement tells the APLScript compiler to create, and change into, a new namespace. The **:EndNamespace** statement terminates the definition of the contents of a namespace and changes back from whence it came.

Assignment statements are used to set up system variables, such as `⌈ML`, `⌈IO`, `⌈USING` and arbitrary APL variables. For example:

```
⌈ML←2
⌈IO←0
⌈USING⍣←'System.Data'

A←88
B←'Hello World'

⌈CY'MYWS'
```

These statements are extracted from the APLScript and executed by the compiler in the order that they appear. It is important to recognise that they are executed at compile time, and not at run-time, and may therefore only be used for initialisation.

Notice that it is acceptable to execute `⌈CY` to bring in functions and variables from a workspace that are to be incorporated into the code. This is especially useful to import a set of utilities. Note also that it is possible to export these functions as methods of .NET classes if the functions contain the appropriate colon statements.

The APLScript compiler will in fact execute any valid APL expression that you include. However, the results may not be useful and may indeed simply terminate the compiler. For example, it is not sensible to execute statements such as `LOAD`, or `OFF`.

Function bodies are defined between opening and closing del (`▽`) symbols. These are fixed by the APLScript compiler using `FX`. Line numbers and white space formatting are ignored.

## Creating Programs (.exe) with APLScript

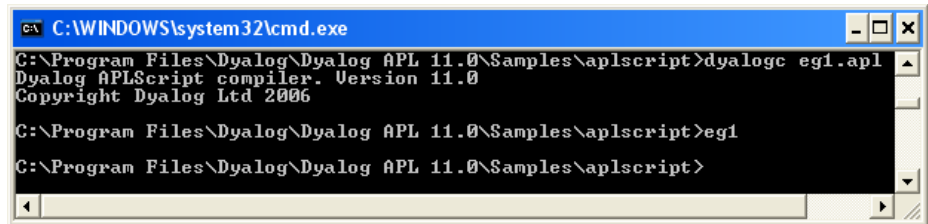
The following examples, which illustrate how you can create an executable program (.exe) direct from an APLScript file, may be found in the directory `samples\aplscript`.

### A simple GUI example

The following APLScript illustrates the simplest possible GUI application that displays a message box containing the string "Hello World".

```
:Namespace N
  LX←'N.RUN'
  ▽RUN;M
    'M'WC'MsgBox' 'A GUI exe' 'Hello World'
  DQ'M'
  ▽
:EndNamespace
```

This example, which is saved in the file `eg1.apl`, is compiled to a Windows executable (.exe) using `dyalogc.exe` and run from the same command window as shown below. Notice that it is essential to surround the code with `:Namespace / :EndNamespace` statements and to define a `LX` either in the APLScript itself, or as a parameter to the `dyalogc` command.



```
C:\WINDOWS\system32\cmd.exe
C:\Program Files\Dyalog\Dyalog APL 11.0\Samples\aplscript>dyalogc eg1.apl
Dyalog APLScript compiler. Version 11.0
Copyright Dyalog Ltd 2006
C:\Program Files\Dyalog\Dyalog APL 11.0\Samples\aplscript>eg1
C:\Program Files\Dyalog\Dyalog APL 11.0\Samples\aplscript>
```



You can associate the `.exe` with a desktop icon, and it will run stand-alone, without a (DOS) command window. Furthermore, any default APL output that would normally be displayed in the session window will simply be ignored.

## A simple console example

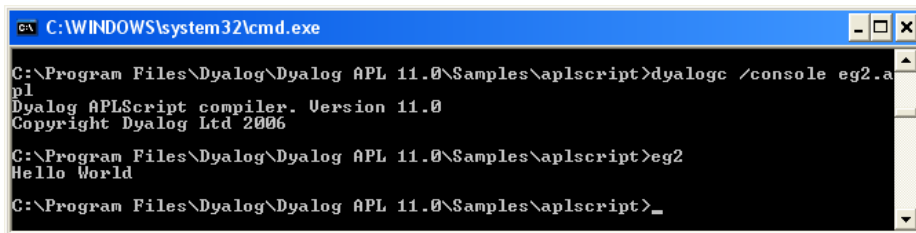
The following APLScript illustrates the simplest possible application that displays the text "Hello World".

This example, which is saved in the file `eg2.apl`, is compiled to a Windows executable (`.exe`) and run from a command window as shown below. Notice that the `/console` flag is used to tell the APLScript compiler to create a *console* application that runs from a command prompt. In this case, default APL output that would normally be displayed in the session window turns up in the command window from which the program was run.

```
:Namespace N
⌋LX←'N.RUN'
▽RUN
'Hello World'
▽
:EndNamespace
```

Once more, it is essential to surround the code with

`:Namespace / :EndNamespace` statements and to define a `⌋LX` either in the APLScript itself, or as a parameter to the `dyalogc` command.



## Defining Namespaces

Namespaces are specified in an APLScript using the `:Namespace` and `:EndNamespace` statements. Although you may use `⍋NS` and `⍋CS` within functions inside an APLScript, you should not use these system functions outside function bodies. Note that such use is not *prevented*, but that the results will be unpredictable.

`:Namespace Name`

introduces a new namespace called `Name` relative to the current space.

`:EndNamespace`

terminates the definition of the current namespace. Subsequent statements and function bodies are processed in the context of the original space.

It is imperative that at least ONE namespace be specified.

All functions specified between the `:Namespace` and `:EndNamespace` statements are fixed in that namespace. Similarly, all assignments define variables inside that namespace.

The following example illustrates how APL namespace usage is handled in APLScript. The program, contained in the file `eg3.apl`, is as follows:

```

:Namespace N
⍋LX←'N.RUN'

▽RUN
⍋PATH←'↑'
NS.START
END
▽
▽R←CURSPACE
R←⇒⍋NSI
▽
▽END
'Ending in ',CURSPACE
▽

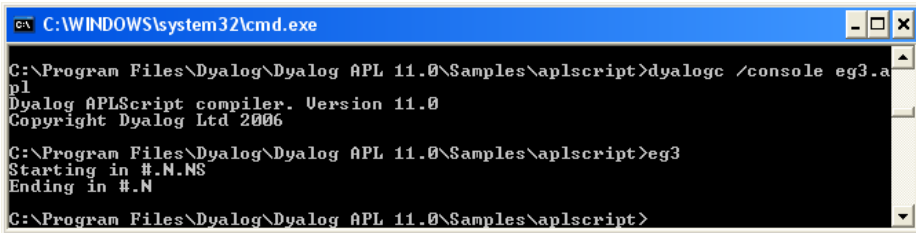
:NameSpace NS
▽START
'Starting in ',CURSPACE
▽
:EndNameSpace
:EndNameSpace

```

This somewhat contrived example illustrates how a namespace is defined inside another namespace using `:NameSpace` and `:EndNameSpace` statements. The namespace `NS` contains a single function called `START`, which is called from the main function `RUN`.

Notice that `⍶PATH` is defined *dynamically* in function `RUN`. If it were defined outside a function in a static statement in the script (say, after the statement that sets `⍶LX`), it would not be honoured when the application was run.

This program is shown, compiled and run as a console application, below.



```

C:\WINDOWS\system32\cmd.exe
C:\Program Files\Dyalog\Dyalog APL 11.0\Samples\aplscript>dyalogc /console eg3.apl
Dyalog APLScript compiler. Version 11.0
Copyright Dyalog Ltd 2006
C:\Program Files\Dyalog\Dyalog APL 11.0\Samples\aplscript>eg3
Starting in #.N.NS
Ending in #.N
C:\Program Files\Dyalog\Dyalog APL 11.0\Samples\aplscript>

```

## Creating .NET Classes with APLScript

It is possible to define and use new .NET classes within an APLScript.

A class is defined by `:Class` and `:EndClass` statements. The methods provided by the class are defined as function bodies enclosed within these statements. Please see the Language Reference for a complete discussion of writing classes in Dyalog APL. This chapter will only provide a brief introduction to the subject, aimed specifically at APLScript.

You may also define sub-classes or nested classes using nested `:Class` and `:EndClass` statements.

`:Class Name: Type`

Declares a new class called `Name`, which is based upon the Base Class `Type`, which may be any valid .NET Class.

`:EndClass`

Terminates a class definition block

A class specified in this way will automatically support the methods, properties and events that it inherits from its Base Class, together with any new public methods that you care to specify.

However, the new class only inherits a default constructor (which is called with no parameters) and does not inherit all of the other private constructors from its Base Class. You can define a method to be a constructor using the `:Implements Constructor` declarative comment. Constructor overloading is supported and you may define any number of different constructor functions in this way, but they must have unique parameter sets for the system to distinguish between them.

You can create and use instances of a class by using the `NEW` system function in statements elsewhere in the APLScript.

## Exporting Functions as Methods

Within a `:Class` definition block, you may define private functions and public functions. A public function is one that is exposed as a method and may be called by a client that creates an instance of your class. Public functions must have a section of *declaration* statements. Other functions are purely internal to the class and are not directly accessible by a client application.

The declaration statements for public functions perform the same task for an APLScript that is performed using the .NET Properties dialog box, or by executing `SetMethodInfo` in the Dyalog APL Session, prior to creating a .NET assembly. The following declaration statements may be used.

`:Access Public`

Specifies that the function is callable. This statement applies only to a .NET class or to a Web Page and is not applicable to a Web Service.

`:Access WebMethod`

Specifies that the function is callable as a Web Method. This statement applies only to a Web Service (.asmx). From version 11.0, the statement is equivalent to:

```
:Access Public  
:Attribute System.Web.Services.WebMethodAttribute
```

`:Implements Constructor`

Specifies that the function is a constructor for a new .NET class. This function must appear between `:Class` and `:EndClass` statements and this applies only to a Web Page (.aspx). See *Defining Classes in APLScript* for further details. A constructor is called when you execute the `New` method in the class.

```
:Signature result←fn type1 Name1, type2 Name2,..
```

Declares the result of the method to have a given data type, if any. It also declares parameters to the method to have given data types and names. **Name<sub>x</sub>** is optional and may be any well-formed name that identifies the parameter. This name will appear in the metadata and is made available to a client application as information. It is therefore sensible to choose meaningful names. The names you allocate to parameters have no other meaning and are not associated with the names of local variables that you may choose to receive them. However, it is not a bad idea to use the same local names as the public names of your parameters.

## A .NET Class example

The following APLScript illustrates how you may create a .NET Class using APLScript. The example class is the same as *Example 1* in Chapter 5. The APLScript code, saved in the file `samples\aplclasses\aplclasses6.apl`, is as follows:

```
:Namespace APLClasses

:Class Primitives: Object
⊞USING←,c'System'
:Access public

▽ R←IndexGen N
:Access Public
:Signature Int32[]←IndexGen Int32 number
R←ιN
▽
:EndClass

:EndNamespace
```

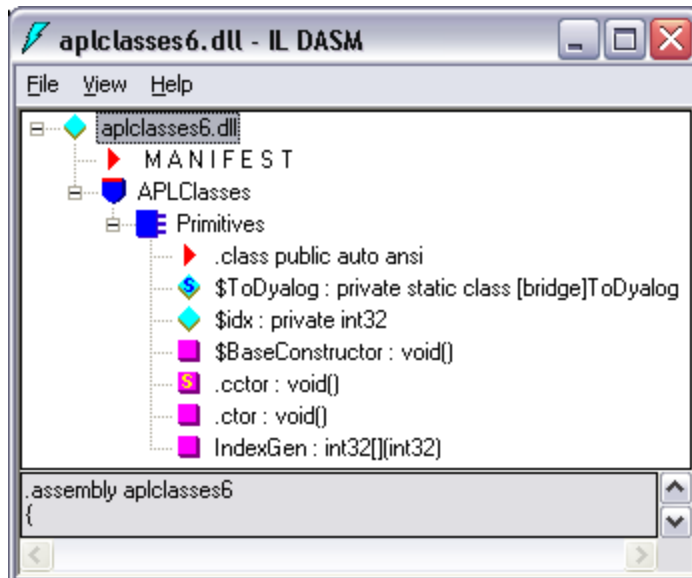
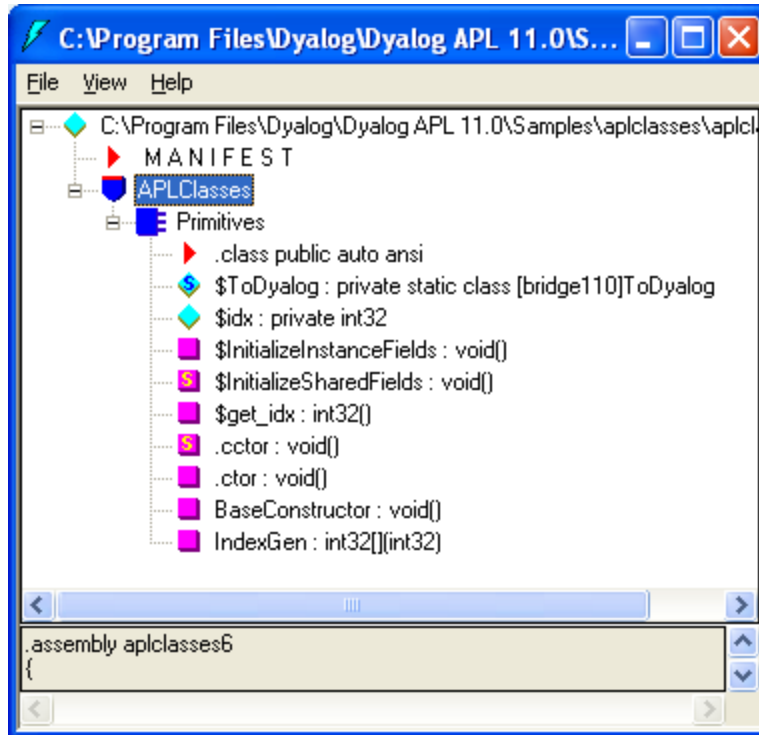
This APLScript code defines a namespace called **APLClasses**. This simply acts as a container and is there to establish a .NET namespace of the same name within the resulting .NET assembly. Within **APLClasses** is defined a .NET class called **Primitives** whose base class is `System.Object`. This class has a single public method named **IndexGen**, which takes a parameter called **number** whose data type is `Int32`, and returns an array of `Int32` as its result.

The following command shows how `aplclasses6.apl` is compiled to a .NET Assembly using the `/t:library` flag.

```
APLClasses>dyalogc /t:library aplclasses6.apl
Dyalog APLScript compiler 32bit Classic Mode Version 13.0.8690.0
Copyright Dyalog Limited 2011
APLClasses>
```



The next picture shows a view of the resulting `aplclasses6.dll` using ILDASM.



This .NET Class can be called from APL just like any other. For example:

```

)CLEAR
clear ws

    □USING←'APLClasses,Samples\APLClasses\
                                aplclasses6.dll'
    APL←□NEW Primitives
    APL.IndexGen 10
1 2 3 4 5 6 7 8 9 10

```

## Defining Properties

Properties are defined by `:Property` and `:EndProperty` statements. A property pertains to the class in which it is defined.

```

:Property Name
    ▽ C←get
[1]    :Access public
[2]    :Signature Double←get
[3]    C←...
    ▽

```

Declares a new property called `Name` whose data type is `System.Double`. The latter may be any valid .NET type which can be located through `□USING`.

`:EndProperty`

Terminates a property definition block

Within a `:Property` block, you must define the *accessors* of the property. The accessors specify the code that is associated with referencing and assigning the value of the property. No other function definitions or statements are allowed inside a `:Property` block.

The accessor used to reference the value of the property is represented by a function named `get` that is defined within the `:Property` block. The accessor used to assign a value to the property is represented by a function named `set` that is defined within the `:Property` block.

The `get` function is used to retrieve the value of the property and must be a niladic result returning function. The data type of its result determines the `Type` of the property. The `set` function is used to change the value of the property and must be a monadic function with no result. The argument to the function will have a data type `Type` specified by the `:Signature` statement. A property that contains a `get` function but no `set` function is effectively a read-only property.

The following APLScript, saved in the file `samples\aplclasses\aplclasses7.apl`, shows how a property called `IndexOrigin` can be added to the previous example. Within the `:Property` block there are two functions defined called `get` and `set` which are used to reference and assign a new value respectively. These functions have the fixed names and syntax specified for *property get* and *property set* functions as described above.

```

:Namespace APLClasses

:Class Primitives: Object
  ⍎USING←,c'System'
  :Access public

  ▽ R←IndexGen N
  :Access Public
  :Signature Int32[]←IndexGen Int32 number
  R←ιN
  ▽

  :Property IndexOrigin
  ▽io←get
  :Signature Int32←get Int32 number
  io←⍎IO
  ▽

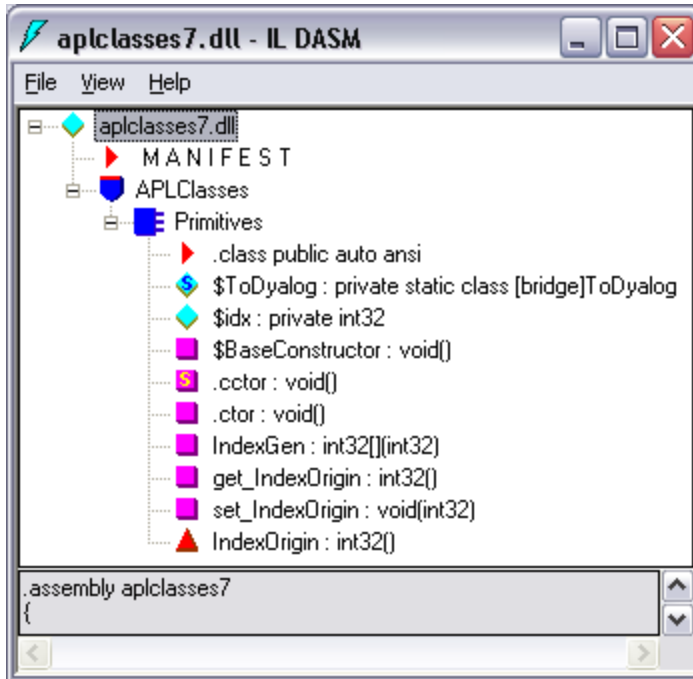
  ▽set io
  :Signature set Int32 number
  :If io∈0 1
    ⍎IO←io
  :EndIf
  ▽
  :EndProperty

:EndClass

:EndNamespace

```

The ILDASM view of the new `aplclasses7.dll`, with the addition of an `IndexOrigin` property, is illustrated below.



For other examples of the use of property definitions, see *The Component File Solution* in Chapter 11.

This .NET Class can be called from APL just like any other. For example:

```

)CLEAR
clear ws

⎕USING←'APLClasses,Samples\APLClasses\
                                     APLClasses7.DLL'

APL←⎕NEW Primitives
APL.IndexGen 10
1 2 3 4 5 6 7 8 9 10
APL.IndexOrigin
1
    APL.IndexOrigin←0
    APL.IndexGen 10
0 1 2 3 4 5 6 7 8 9

```

## Indexers

An *indexer* is a property of a class that enables an instance of that class (an object) to be indexed in the same way as an array, if the host language supports this feature. Languages that support object indexing include C# and Visual Basic. Dyalog APL does also allow indexing to be used on objects. This means that you can define an APL class that exports an indexer and you can use the indexer from C#, Visual Basic or Dyalog APL.

Indexers are defined in the same way as properties, between `:Property Default` and `:EndProperty` statements. An There may be only one indexer defined for a class.

Note: the `:Property Default` statement in Dyalog APL is closely modelled on the indexer feature in C# and employs similar syntax. If you use `ILDASM` to browse a .NET class containing an indexer, you will see the indexer as the *default property* of that class, which is how it is actually implemented.

## Creating ASP.NET Classes with APLScript

As mentioned previously, the original purpose of APLScript was to provide the ability to write ASP.NET Web Pages and Web Services in Dyalog APL. Both these applications are based upon script files.

### Web Page Layout

An ASP.NET Web Page typically consists of a mixture of HTML and code written in a scripting language. The script code is separated from the HTML by being embedded within `<script>` and `</script>` tags and normally appears in the `<head>` `</head>` section of the page. Only one block of script is allowed in a page. The script block normally consists of a collection of functions, which are invoked by some event on the page, or on an element of the page.

APLScript code starts with a statement:

```
<script language="Dyalog" runat=server>
```

and finishes with:

```
</script>
```

Typically, the APLScript code consists of callback functions that are attached to server-side events on the page.

## Web Service Layout

The first line in a Web Service script must be a declaration statement such as:

```
<%@ WebService Language="Dyalog" Class="ServiceName" %>
```

where `ServiceName` is an arbitrary name that identifies your Web Service.

The next statement must be a `:Class` statement that declares the name of the Web Service and its Base Class from which it inherits. The base class will normally be `System.Web.Services.WebService`. For example:

```
:Class ServiceName: System.Web.Services.WebService
```

The last line in the script must be:

```
:EndClass
```

Although it may appear awkward to have to specify the name of your Web Service twice, this is necessary because the two statements are being processed quite separately by different software components. The first statement is processed by ASP.NET. When it sees `Language="Dyalog"`, it then calls the Dyalog APLScript compiler, passing it the remainder of the script file. The `:Class` statement tells the APLScript compiler the name of the Web Service and its base class. `:Class` and `:EndClass` statements are private directives to the APLScript compiler and are not relevant to ASP.NET.

## How APLScript is processed by ASP.NET

Like any other Web Page or Web Service, an APLScript file is processed by ASP.NET.

The first time ASP.NET processes a script file, it first performs a compilation process whose output is a .NET assembly. ASP.NET then calls the code in this assembly to generate the HTML (for a Web Page) or to run a method (for a Web Service).

ASP.NET associates the compiled assembly with the script file, and only recompiles it if/when it has changed.

ASP.NET does not itself compile a script; it delegates this task to a specialised compiler that is associated with the language declared in the script. This association is made either in the application's `web.config` file or in the global `machine.config` file. Dyalog installs a default `web.config` file which includes these settings in the `samples\asp.net` folder.

The APLScript compiler is itself written in Dyalog APL.

Although the compilation process takes some time, it is typically only performed once, so the performance of an APLScript Web Service or Web Page is not compromised. Once it has been compiled, ASP.NET redirects all subsequent requests for an APLScript to its compiled assembly.

Please note that the use of the word *compile* in this process does not imply that your APL code is actually compiled into Microsoft Intermediate Language (MSIL). Although the process does in fact generate *some* MSIL, your APL code will still be interpreted by the Dyalog APL DLL engine at run-time. The word *compile* is used only to be consistent with the messages displayed by ASP.NET when it first processes the script.

## The web.config file

The default web.config file (installed with Dyalog) includes all the settings to associate Language = "dyalog" with the Dyalog APLScript compiler dyalogc.exe. In addition the file includes an <appSettings> section, as follows:

```
<appSettings>
  <add key="DyalogIsolationMode"
value="DyalogIsolationProcess" />
  <add key="DyalogCompilerEncoding" value="Unicode" />
</appSettings>
```

The "DyalogIsolationMode" setting is used to provide the isolation method which is discussed in chapter 12. It can have one of the following values:

- "DyalogIsolationAssembly"
- "DyalogIsolationApplication"
- "DyalogIsolationProcess" (the default)

The DyalogCompilerEncoding setting determines which version of the script compiler is used, and this in turn determines if the application will run in a Classic or Unicode interpreter. It can have one of the following values:

- "Unicode"
- "Classic" (the default)

The web.config file also enables debugging so that compiled assemblies use the development version of the dyalog interpreter.





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# Chapter 11:

## Visual Studio Integration

### Introduction

Dyalog APL supports loose integration with Microsoft Visual Studio.NET. Loose integration allows you to create Visual Studio projects using APLScript, and build .EXEs and .DLLs using Visual Studio as the front-end tool.

Dyalog APL is not yet tightly integrated with Visual Studio, and does not, for example, permit you to use the Visual Studio User Interface design tools directly. However, you can create class libraries in APL and easily call them from VB, C# or VC++ applications which have been created using the designers.

The Dyalog APL installation program adds some sample APL applications in the appropriate Visual Studio directory, which are described in this Chapter.

To begin with, the Hello World example shows you how to go about creating a .EXE program file using Visual Studio and APLScript.

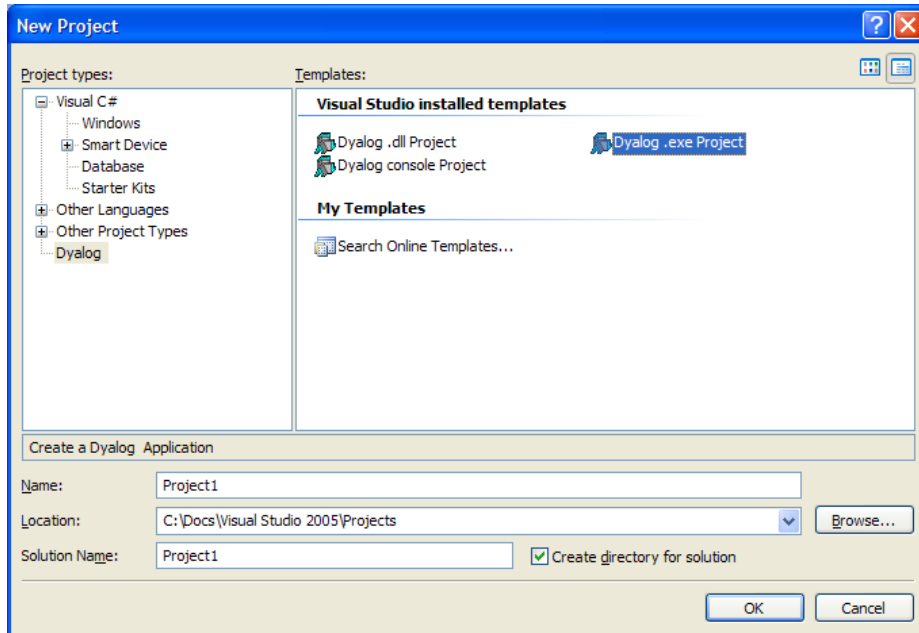
### Hello World Example

This example illustrates what is involved how you go about creating an application program (.exe) using APLScript with Visual Studio. The examples use Visual Studio 2005.

#### Creating an APL.EXE Project

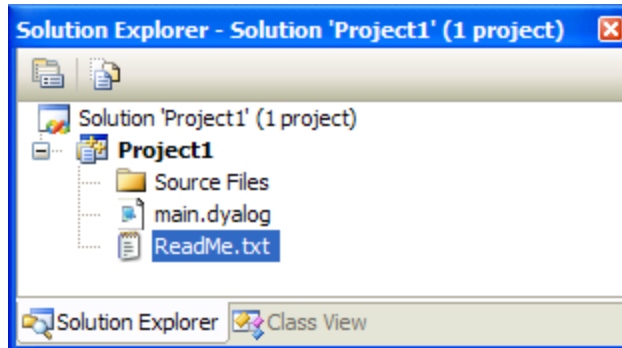
Start Visual Studio and click *New Project*, or select *File/New/Project* from the menu bar. This gives you a choice of three APL templates as shown below.

- *Dyalog .exe Project* for building GUI applications.
- *Dyalog console Project* to build a runtime application which will send output to the console (command line program, will not be able to use the APL session for debugging).
- *Dyalog .dll Project* to build an assembly containing APL classes which will be used by other .Net tools or applications.



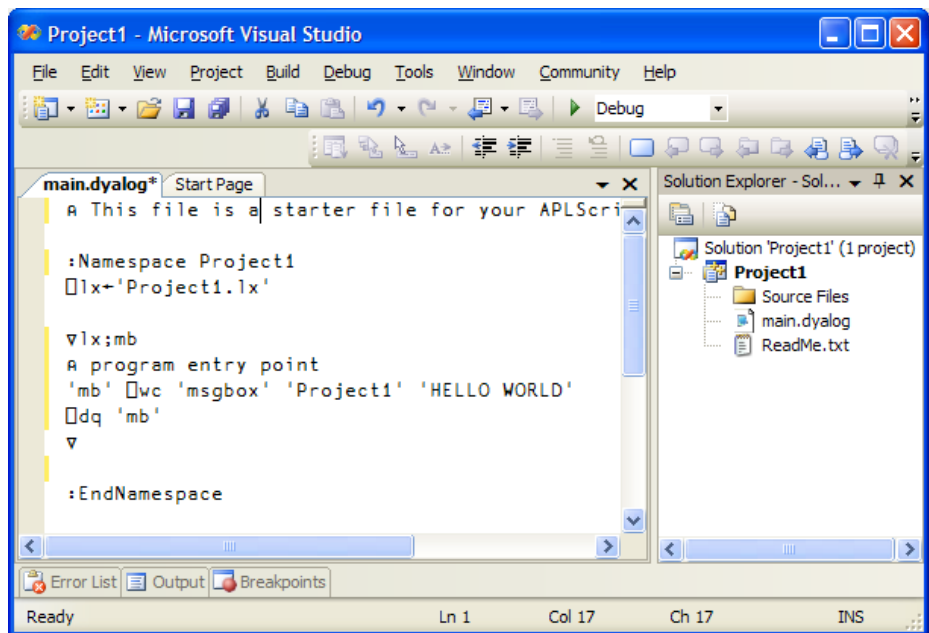
In this case, Select *Dyalog.exe Project*, and click *OK*.

Visual Studio will now create a new Project, in this case named `Project1`, containing a single source code file named `main.dyalog` and a `ReadMe.txt` as shown below. The latter contains instructions about using Visual Studio with Dyalog APL.



We recommend that you select *Tools|Options|Environment|Fonts and Colours*, and select the *APL385 Unicode* font for use with APL projects.

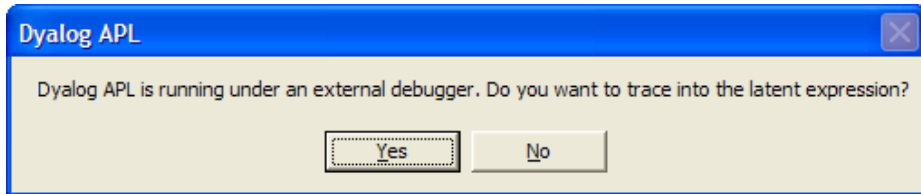
`main.dyalog` is an APLScript file containing a single comment. Select the APL keyboard (see *Input Method Editor*), and enter the following simple APLScript program.



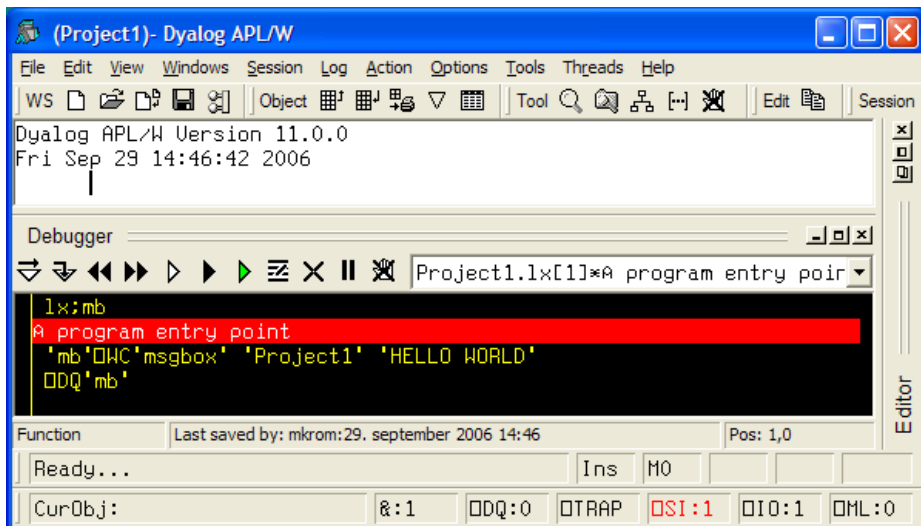
When it runs, the example should display a simple message box. Notice that:

- Your APL code must be surrounded by a `:Namespace ... :EndNamespace` block.
- You must set `⎕LX` to start your application, but you do not have to explicitly call `⎕OFF` to end it.

To run your application, press F5 (Start Debugging), or click on the "play" icon shown below the Community menu item on the previous screen.<sup>1</sup>



You can avoid this pop-up by using ctrl-F5 (run without debugging). If you confirm that you would like to trace the latent expression, the next thing you see should be:



<sup>1</sup>If you get a warning that the project is out of date, ignore it.

If you continue to last line of the function, the program displays the dialog box shown below, waits for you to click *OK*, and then exits.



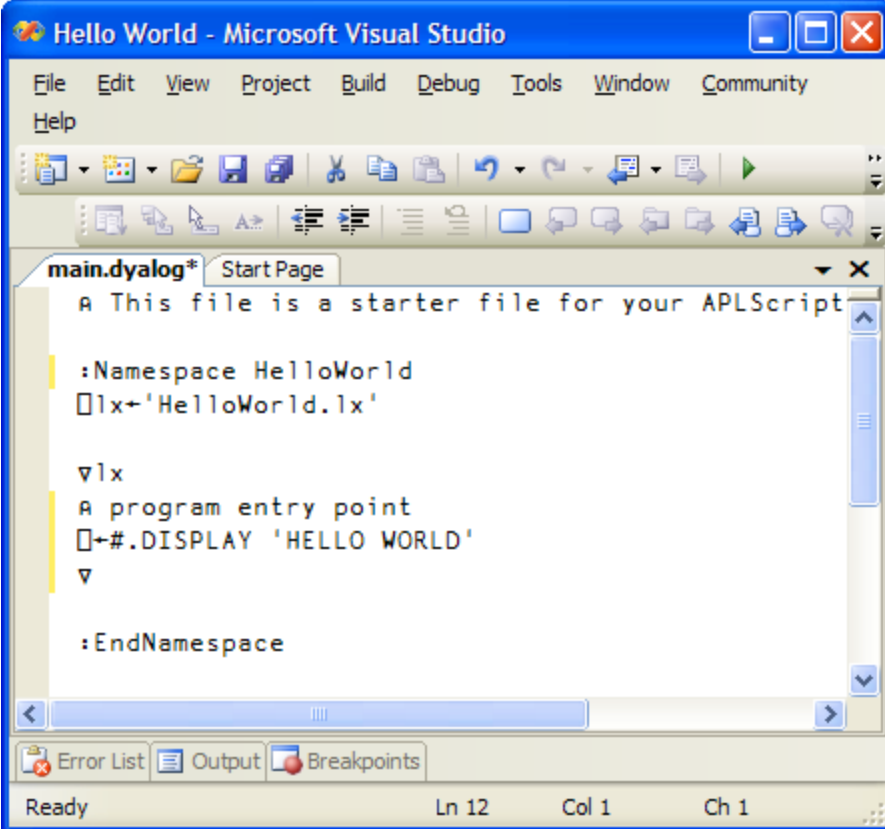
As a result of building the project, you will also have an executable program named `Project1.exe`.

## Using an Existing Workspace

The next example takes the approach a stage further and illustrates how an application built using Visual Studio can access an existing workspace.

Go to the *Start* page and click *New Project*.

This time, create a *Dyalog console Project* and name the project *Hello World*. Edit the contents of `main.dyalog` so that the `lx` function calls the function `DISPLAY` that is not itself defined in the script.



```
main.dyalog* Start Page
A This file is a starter file for your APLScript

:Namespace HelloWorld
  lx←'HelloWorld.lx'

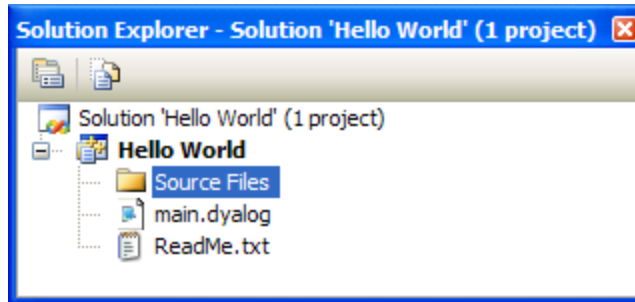
  ∇lx
  A program entry point
  □→#.DISPLAY 'HELLO WORLD'
  ∇

:EndNamespace
```

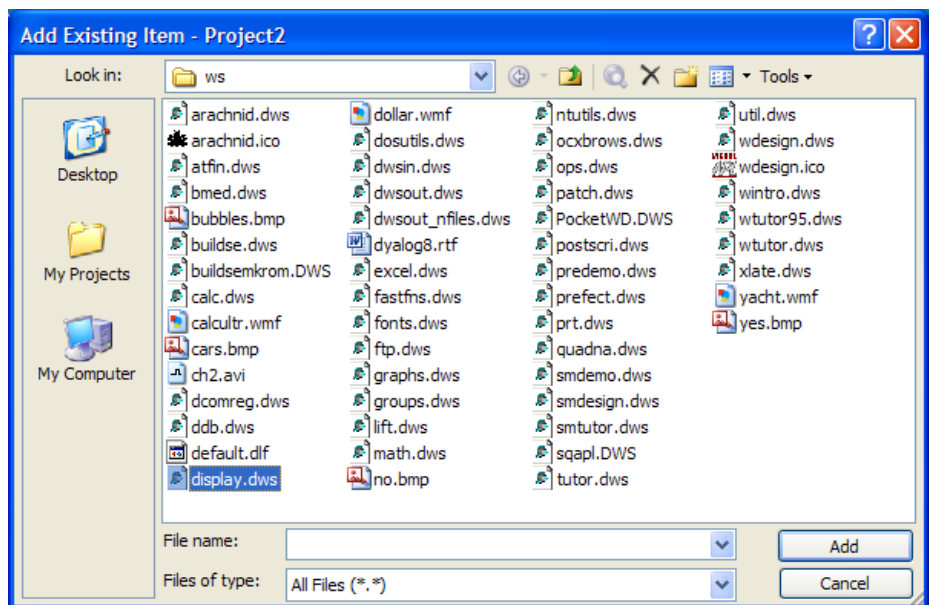
Ready Ln 12 Col 1 Ch 1

The `DISPLAY` function will be provided by the `DISPLAY` workspace, which you can add to the project as follows.

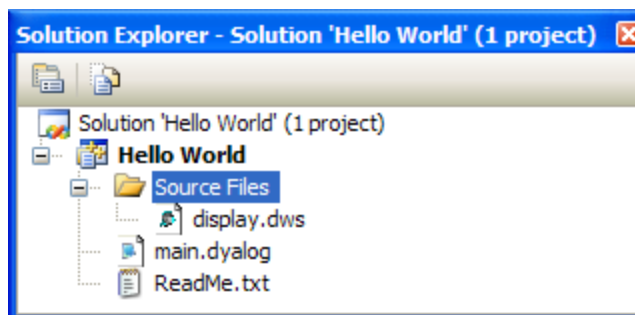
In the *Solution Explorer* window, select *Source Files* and click the right button to bring up the context menu.



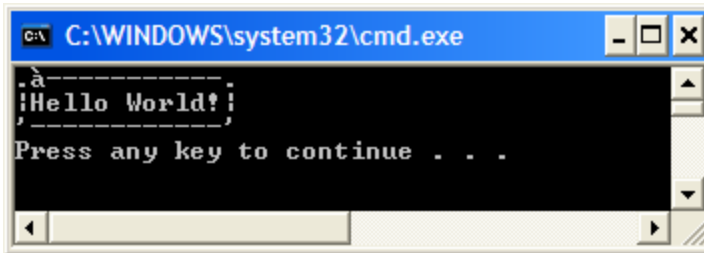
Select *Add*, and then *Add Existing Item...*. This brings up a file selection dialog. Navigate to the *ws* folder below the main Dyalog folder and choose *display.dws*.



This file is then added to the project as shown below.



If you run the solution without debugging, Visual Studio will pause after it completes execution, and allow you to see the output. Press *ctrl+F5* or use the menu item *Debug|Start without Debugging*.



Console applications always run using a runtime APL engine, so any errors in the application will cause a *Runtime Violation*. You can debug console applications by temporarily switching to session output, by changing the command line used to build the application as follows:

In the solution explorer, right click on *Hello World* and select properties. Under *Configuration Properties*, select the *NMake* page and edit the *Build Command Line*, which should be:

```
"%DYALOGNETDIR130%\dyalogc.exe" /console /o:"Hello World.exe"  
/x:"Hello World.vcproj"
```

Remove the */console* switch to debug your application, and put it back again when you are done and would like it to use the session again.



# Chapter 12:

## Implementation Details

### Classic and Unicode Versions

Dyalog 13.0 exists in two versions, the Classic version, and the Unicode version. The Unicode version has full support for Unicode characters. The Classic version is less compatible with Unicode and is provided for compatibility with existing Dyalog applications.

There are a number of files that have different names depending on their Classic or Unicode flavour. For example the "Classic" `dyalog130.dll` has a `dyalog130_unicode.dll` counterpart; the "Classic" `dyalogc.exe` has a `dyalogc_unicode.exe` counterpart.

This document typically refers to the "Classic" variant but this should be read as meaning the Unicode variant where appropriate.

### Introduction

`dyalog130.dll` is the Dyalog APL *engine* that hosts the execution of all .NET classes that have been written in Dyalog APL, including APL Web Pages and APL Web Services. `dyalog130` provides the interface between client applications (such as ASP.NET) and your APL code. It receives calls from client applications, and executes the appropriate APL code. It also works the other way, providing the interface between your APL code and any .NET classes that you may call.

`dyalog130` is the full developer version of the DLL that contains the APL Session, Editor, Tracer and so forth, and may be used to develop and debug an APL .NET class while it is executing

`dyalog130rt.dll` is the re-distributable run-time version of `dyalog130.dll` and contains no debugging facilities.

## Isolation Mode

For *each* application which uses a class written in Dyalog APL, at least one copy of either `dyalog130.dll` or `dyalog130rt.dll` will be started in order to host and execute the appropriate APL code. Each of these *engines* will have an APL workspace associated with it, and this workspace will contain classes and instances of these classes. The number of engines (and associated workspaces) which are started will depend on the Isolation Mode which was selected when the APL assemblies used by the application were generated. Isolation modes are:

- Each host process has a single workspace
- Each appdomain has its own workspace
- Each assembly has its own workspace

The last two Isolation Modes are new in version 11.0. Previously, each application always used a single engine to run all classes and instances used by that application.

Note that, in this context, Microsoft Internet Information Services (IIS) is a *single* application, even though it may be hosting a large number of different web pages. Each ASP.Net application will be running in a separate *AppDomain*, a mechanism used by .NET to provide isolation within an application. Other .NET applications may also be divided into different AppDomains.

In other words, if you use the first option, ALL classes and instances used by any IIS web page will be hosted in the same workspace and share a single copy of the interpreter. The second option will start a new Dyalog engine for each ASP.Net application. The final option an engine for each assembly containing APL classes.

## Structure of the Active Workspace

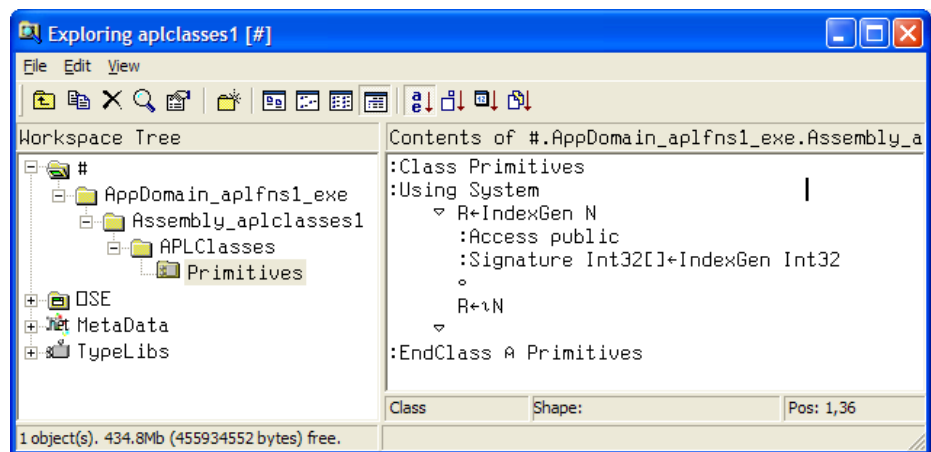
Each engine which is started has a workspace associated with it that contains all the APL objects it is currently hosting.

Unless the highest isolation mode, "Each assembly has its own workspace", has been selected, the workspace will contain one or more namespaces associated with .NET *AppDomains*. When .NET calls Dyalog APL to process an APL class, it specifies the *AppDomain* in which it is to be executed. To maintain *AppDomain* isolation and scope, Dyalog APL associates each different *AppDomain* with a namespace whose name is that of the *AppDomain*, prefixed by `AppDomain_`.

Within each `AppDomain_` namespace, there will be one or more namespaces associated with the different Assemblies from which the APL classes have been loaded. These namespaces are named by the Assembly name prefixed by `Assembly_`. If the APL class is a Web Page or a Web Service, the corresponding Assembly is created dynamically when the page is first loaded. In this case, the name of the Assembly itself is manufactured by .NET. Below the `Assembly_` namespace is a namespace that corresponds to the .NET Namespace that represents the container of your class. If the APL class is a Web Page or Web Service, this namespace is called `ASP`. Finally, the namespace tree ends with a namespace that represents the APL class. This will have the same name as the class. In the case of a Web Page or Web Service, this is the name of the `.aspx` or `.asmx` file.

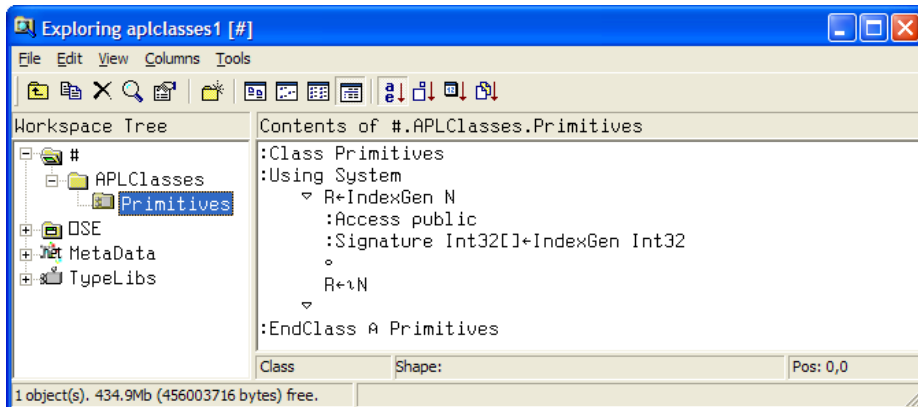
Note that in the manufactured namespace names, characters that would be invalid symbols in a namespace name are replaced by underscores.

The following picture shows the namespace tree that exists in the `dyalog130.DLL` workspace when the `aplfn1.exe` program is executed. This example is discussed as Example 1 in Chapter 5. To cause the suspension, an error has been introduced in the method `IndexGen`.



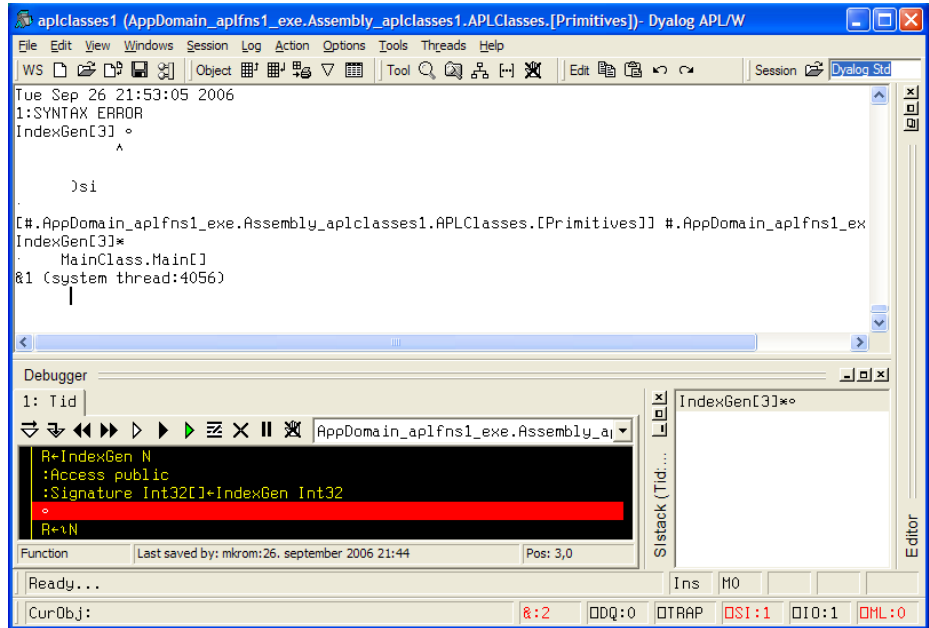
In the above example case, there is a single AppDomain involved whose name, `aplfnsl.exe`, is specified by .NET. APL has made a corresponding namespace called `AppDomain_aplfnsl_exe`. Next, there is a namespace associated with the Assembly `aplclasses1`, named `Assembly_APLCLASSES1`. Beneath this is a namespace called `APLClasses` associated with the .NET Namespace of the same name. Finally, there is a namespace called `Primitives` that represents the APL class of that name. This namespace contains all the code associated with the class; in this case, just a single function called `IndexGen`.

Note that, if the assembly had been generated with isolation mode (Each assembly has its own workspace), the AppDomain and Assembly structure is not created above the classes which are in the workspace, so the workspace structure is much simpler:



The next picture shows the APL Session window that is displayed with execution suspended on `IndexGen [ 1 ]`. Notice that the State Indicator in Dyalog APL has been extended to display the entire .NET calling structure, and not just the APL stack. In this case, the State Indicator shows that `IndexGen` was called from `MainClass.Main`, which combines the class and method names specified in `aplfnsl.cs`. Note that .NET calls are slightly indented.

This extension to )SI applies also to DIALOG.EXE. For example, if you attach an APL callback function to a Winforms Button object, the callback is executed as a result of a call from the Button object back into the APL environment. The State Indicator will show the entire call stack, including methods in the .NET components.



Notice too that `IndexGen` has been started on APL thread 1 which, in this case, is associated with system thread 4056. If the client application were to call `IndexGen` on multiple system threads, this would be reflected by multiple APL threads in the workspace. This topic is discussed in further detail below.

The possibility for the client to execute code in several instances of an object at the same time requires that each executing instance is separated from all the others. Each instance will be created as an **unnamed** object in the workspace, within the relevant appdomain and assembly namespaces.

## Threading

The .NET Framework is inherently a multi-threaded environment. For example, ASP.NET runs its own thread pool from which it allocates system threads to its clients. Calls from ASP.NET into APL Web Pages and Web Services will typically be made from different system threads. This means that APL will receive calls from .NET while it is processing a previous call. The situation is further complicated when you write an APL Web Page that calls an APL Web Service, both of which may be hosted by a single `dyalog130.dll` inside ASP.NET. In these circumstances, ASP.NET may well allocate different system threads to the .NET calls, which are made into the two separate APL objects. Although in the first example (multiple clients) APL could theoretically impose its own queuing mechanism for incoming calls, it cannot do so in the second case without causing a deadlock situation.

It is important to remember that whether running as `DYALOG.EXE`, or as `dyalog130.dll`, the Dyalog APL interpreter executes in a *single system thread*. However, APL does provide the ability to run several APL threads at the same time. If you are unfamiliar with APL threads, see *Language Reference, Chapter 1* for an introduction to this topic.

To resolve this situation, Dyalog APL automatically allocates APL threads to .NET system threads and maintains a thread synchronisation table so that calls on the same system thread are routed to the same APL thread, and vice versa. This is important because a GUI object (cf. `System.Windows`) is owned by the system thread that created it and can only be accessed by that thread.

The way that system threads are allocated to APL threads differs between the case where APL is running as the primary executable (`DYALOG.EXE`) or as a DLL hosted by another program (`dyalog130.dll`). The latter is actually the simpler of the two and will be considered first.

### DYALOG130.DLL Threading

In this case, all calls into `dyalog130.dll` are initiated by Microsoft .NET.

When a .NET system thread first needs to run an APL function, APL starts a new APL thread for it, and executes the function in that APL thread. For example, if the first call is a request to create a new instance of an APL .NET object, its constructor function will be run in APL thread 1. An entry is made in the internal thread table that associates the originating system thread with APL thread 1. When the constructor function terminates, the APL thread is retained so that it is available for a subsequent call on its associated system thread. In this respect, the automatically created APL thread differs from an APL thread that was created using the spawn operator `&` (See Language Reference).

When a subsequent call comes in, APL locates the originating system thread in its internal thread table, and runs the appropriate APL function in the corresponding APL thread. Once again, when the function terminates, the APL thread is retained for future use. If a call comes in on a new system thread, a new APL thread is created.

Notice that under normal circumstances, APL thread 0 is never used in `dyalog130.dll`. It is only ever used if, during debugging, the APL programmer explicitly changes to thread 0 by executing `)TID 0` and then runs an expression.

Periodically, APL checks the existence of all of the system threads in the internal thread table, and removes those entries that are no longer running. This prevents the situation arising that all APL threads are in use.

## DYALOG.EXE Threading

In these cases, all calls to Microsoft .NET are initiated by Dyalog APL. However, these calls may well result in calls being made back from .NET into APL.

When you make a .NET call from APL thread 0, the .NET call is run on **the same system thread** that is running APL itself.

When you make a .NET call from any other APL thread, the .NET call is run on a different system thread. Once again, the correspondence between the APL thread number and the associated system thread is maintained (for the duration of the APL thread) so that there are no thread/GUI ownership problems. Furthermore, APL call-backs invoked by .NET calls back into APL will automatically be routed to the appropriate APL thread. Notice that, unlike a call to a DLL via `□NA`, there is no way to control whether or not the system uses a different system thread for a .NET call. It will always do so if called from an APL thread other than APL thread 0.

## Thread Switching

Dyalog APL will potentially *thread switch*, i.e. switch execution from one APL thread to another, at the start of any line of APL code. In addition, Dyalog APL will potentially thread switch when a .Net method is called or when a .Net property is referenced or assigned a value. If the .NET call accesses a relatively slow device, such as a disk or the internet, this feature can improve overall throughput by allowing other APL code while a .NET call is waiting. On a multi-processor computer, APL may truly execute in parallel with the .NET code.

Note that when running DYALOG.EXE, .NET calls made from APL thread 0 will prevent any switching between APL threads. This is because the .NET code is being executed in the same system thread as APL itself. If you want to use APL multi-threading in conjunction with .NET calls, it is therefore advisable to perform all of the .NET calls from threads other than APL thread 0.

## Debugging an APL.NET Class

All DYALOG.NET objects are executed by the Dyalog APL dynamic link library `dyalog130.dll` or `dyalog130rt.dll`. The former contains all of the development and debug facilities of the APL Session, including the Editors and Tracer. The latter contains no debugging facilities at all. The choice of which DLL is used is made when the assembly is exported from APL using the *File|Export* menu, or compiled using `dyalogc.exe`.

If an APL .NET object that is bound to `dyalog130.dll` generates an untrapped APL error (such as a **VALUE ERROR**) **and** the client application is configured so that it is allowed to interact with the desktop, the APL code will suspend and the APL Session window will be displayed. Otherwise, it will throw an exception.

If an APL .NET object that is bound to `dyalog130.dll` generates an untrapped APL error it will throw an exception.

### Specifying the DLL

There are a number of different ways that you choose to which of the two DLLs your DYALOG.NET class will be bound. Note that the appropriate DLL must be available when the class is subsequently invoked. If the DLL to which the APL .NET class is bound is not present, it will throw an exception.

If you build a .NET class from a workspace using the *File/Export* menu item, you use the *Runtime application* checkbox. If *Runtime application* is unchecked, the .NET Class will be bound to `dyalog130.dll`. If *Runtime application* is checked, the .NET Class will be bound to `dyalog130rt.dll`.

If you build a .NET class using the APLScript compiler, it will by default be bound to `dyalog130.dll`. If you specify the `/runtime` flag, it will be bound to `dyalog130rt.dll`.

If your APL .NET class is a Web Page or a Web Service, you specify to which of the two DLLs it will be bound using the *Debug* attribute. This is specified in the opening declaration statement in the `.aspx`, `.asax` or `.asmx` file. If the statement specifies `"Debug=true"`, the Web Page or Web Service will be bound to `dyalog130.dll`. If it specifies `"Debug=false"`, the Web Page or Web Service will be bound to `dyalog130rt.dll`.

If you omit the `Debug=` attribute in your Web page, the value will be determined from the various .NET `config` files on your computer.



## Forcing a suspension

If an APL error occurs in an APL .NET object, a suspension will occur and the Session will be available for debugging. But what if you want to force this to happen so that you can Trace your code and see what is happening?

If your APL class is built directly from a workspace, you can force a suspension by setting stops in your code before using *Export* to build the DLL. If your class is a Web Page or Web Service where the code is contained in a workspace using the *workspace behind* technique (See Chapter 8), you can set stops in this workspace before you )SAVE it.

If your APL class is defined entirely in a Web Page, Web Service, or an APLScript file, the only way to set a break point is to insert a line that sets a stop explicitly using `⌈STOP`. It is essential that this line appears after the definition of the function in the script. For example, to set a stop in the `Intro\intro1.aspx` example discussed in Chapter 8, the script section could be as follows:

```
<script language="dyalog" runat="server">
∇Rotate args
:Access Public
:Signature Reverse Object,EventArgs

(>args).Text←ϕPressme.Text
∇

3 ⌈STOP 'Rotate'

</script>
```

As an alternative, you can always insert a deliberate error into your code!

Finally, you can usually force a suspension by generating a Weak Interrupt. This is done from the pop-up menu on the APL icon in the System Tray that is associated with `dyalog130.dll`. Note that selecting Weak Interrupt from this menu will not have an immediate effect, but it sets a flag that will cause Dyalog APL to suspend when it next executes a line of APL code. You will need to activate your object in some way, e.g. by calling a method, for this to occur. Note that this technique may not work if `dyalog130.dll` is busy because a thread switch automatically resets the Weak Interrupt flag. In these circumstances, try again.

The run-time version of the Dyalog APL DLL does not display an icon in the System Tray.

## Using the Session, Editor and Tracer

When an DYALOG.NET object suspends execution, all other active APL .NET objects bound to `dyalog130.dll` that are currently being executed by the same client application will also suspend. Furthermore, all the classes currently being hosted by `dyalog130.dll` are visible to the APL developer whether active (an instance is currently being executed) or not. Note that if a client application, such as ASP.NET, is also hosting APL .NET objects bound to the *runtime* DLL, these objects will be hosted in a separate workspace attached to `dyalog130rt.dll` and will not be visible to the developer.

Debugging a running DYALOG.NET object is substantially the same process as debugging a stand-alone multi-threaded APL application. However, there are some important things to remember.

Firstly, the namespace structure above your APL class should be treated as being inviolate. There is nothing to prevent you from deleting namespaces, renaming namespaces, or creating new ones in the workspace. However, you do so at your peril!

Similarly, you should not alter, delete or rename any functions that have been automatically generated on your behalf by the APLScript compiler. These functions are also inviolate.

If execution in `dyalog130.dll` is suspended, you may not execute `)CLEAR` or `)RESET`. You may execute `)OFF` or `⎕OFF`, but if you do so, the client application will terminate. If you attempt to close the APL Session window, you will be warned that this will terminate the client application and you may cancel the operation or continue (and exit).

If you fix a problem in a suspended function and then press *Resume* or *Continue* (Tracer) or execute a branch, and the execution of the currently invoked method succeeds, you will be left with an empty State Indicator (assuming that no other threads are actively involved). The Dyalog APL DLL is at this stage idle, waiting for the next client request and the State Indicator will be empty.

If, at this point, you close the APL Session window, a dialog box will give you the option of terminating the (client) application, or simply hiding the APL Session Window. If you execute `)OFF` or `⎕OFF` the client application will terminate.

Note that in the discussion above, a reference to terminating the client application means that APL executes `Application.Exit()`. This may cause the application to terminate cleanly (as with ASP.NET) or it may cause it to crash.

# Index

- .NET Classes
  - exploring 13
  - using 10
  - writing 41
- .NET namespaces 7
  
- A**
- Access:Constructor statement 185
- accessors 188
- ACTFNS workspace 135
- Active Server Pages 65
- adding .NET objects 21
- APL language extensions
  - for .NET objects 21
- aplc.exe 176
- APLScript 175
  - Access:Constructor statement 185
  - Access:Public statement 78, 128, 185
  - Access:WebMethod statement 185
  - Class statement 133, 184, 192
  - compiler 176, 192
  - copying from workspaces 181
  - defining classes 184
  - defining properties 188
  - editing 178
  - EndClass statement 133, 184, 192
  - EndIndexer statement 191
  - EndNamespace statement 183
  - EndProperty statement 188
  - example of a .NET Class 186
  - example of a console application 182
  - example of a GUI application 181
  - importing code 179
  - Indexer statement 191
  - layout 180
  - Namespace statement 183
  - ParameterList statement 128, 186
  - Property statement 188
  - Returns statement 78, 186
  - specifying namespaces 183
  - Web Page 191
  - Web Service 192
- AppDomain 204
- Application.Run method 39
- Application\_End method 89
- Application\_Start method 89
- ASP.NET.config files 89
- assemblies
  - browsing 117
  - creating 41
  - exploring 13
- AsyncCallback class 121
- asynchronous use
  - of a Web Service 119
- AutoPostBack property 131
  
- B**
- base class 7, 28, 41, 47, 76, 84, 117, 130, 132-133, 154, 184-186, 192
- BRIDGE.DLL 3, 29
- Browse .Net Assembly dialog box 14
- Button class 35, 160
- ByRef class 29
  
- C**
- C# 45, 49-50, 54, 58, 60, 62
- child controls
  - of a custom control 159
- class constructor 17
- Class Methods 21
- Class statement 133, 184, 192
- code behind 132
- Common Language Runtime 2
- Common Operators 21
- Common Type System 2, 7
- comparing .NET objects 21

compositional control	158	FileStream class	31
config files		Font class	29
for ASP.NET	89	FontStyle class	29
constructor	35, 47	Form.ControlCollection class	36
constructor methods	11	FormBorderStyle class	28, 36
constructor overloading	55	FormStartPosition class	36
Constructor statement	185		
Constructors	11	<b>G</b>	
Constructors folder	17	GDIPlus workspace	40
Control class	153	GetPostBackEventReference method	165, 168
ControlCollection class	159	GetType method	12
Convert class	29, 143	global.asax file	89
CreateChildControls method	159	GOLF function	40, 113
creating GUI objects	33	GolfService	
custom controls	153, 158	calling from C#	105
		testing from a browser	99
<b>D</b>		using from Dyalog APL	113
DataGrid class	151	writing	88
examples	39	GraphicsUnit class	29
DataGrid control	138	GUI objects	33
debugging	51		
Directory class	24	<b>H</b>	
DivRem method	29	hidden fields	126
DropDownList class	129	HtmlTextWriter class	164
DYALOG APL.DLL	42, 79, 176	HttpRequest class	26
DYALOG APL.RUNTIME.DLL	4, 203	HttpResponse class	27
Dyalog namespace	29		
dyalog.exe.config	5	<b>I</b>	
		IIS	65
<b>E</b>		application	66
EndClass statement	133, 184, 192	virtual directory	66-68, 72-73, 75, 80, 83, 106, 124, 155, 178
enumeration	36-37	ILDASM	13, 187, 190-191
enumerations	28	INamingContainer Interface	158
ErrorMessage property	147	Indexers	191
EventArgs class	141	Input Method Editor (IME)	175
exception	23, 52	Interfaces	63
Exception class	23	intrinsic controls	125-126
Export	41, 48	IPostBackDataHandler Interface	166
		IPostBackDataHandler Interface	163
<b>F</b>			
File class	24		

- 
- |   |                    |  |  |
|---|--------------------|--|--|
| IPostBackEventHandler Interface         | 163                |  |  |
| Isolation Mode                          | 204                |  |  |
| IsPostBack property                     | 130, 141           |  |  |
| IsValid property                        | 144                |  |  |
| <b>J</b>                                |                    |  |  |
| JavaScript                              | 165, 168           |  |  |
| <b>L</b>                                |                    |  |  |
| LiteralControl class                    | 159                |  |  |
| LoadPostData method                     | 166                |  |  |
| LoanService                             |                    |  |  |
| exploring                               | 117                |  |  |
| testing from a browser                  | 85                 |  |  |
| using asynchronously                    | 119                |  |  |
| using from Dyalog APL                   | 112                |  |  |
| writing                                 | 83                 |  |  |
| <b>M</b>                                |                    |  |  |
| MailMessage class                       | 25                 |  |  |
| MakeProxy function                      | 111, 113           |  |  |
| manipulating files.                     | 24                 |  |  |
| Math class                              | 29                 |  |  |
| MAXWS parameter                         | 176                |  |  |
| Metadata                                | 13, 15, 117        |  |  |
| method overloading                      | 59                 |  |  |
| method signature                        | 128                |  |  |
| Methods folder                          | 19                 |  |  |
| Microsoft Internet Information Services | 65                 |  |  |
| modal dialog box                        | 34-35              |  |  |
| <b>N</b>                                |                    |  |  |
| namespace reference array expansion     | 25, 113            |  |  |
| Net Classes                             | 13                 |  |  |
| NET classes                             | 7                  |  |  |
| New method                              | 17, 35, 185        |  |  |
| New system function                     | 11                 |  |  |
| non-modal Forms                         | 39                 |  |  |
| Notepad                                 | 175                |  |  |
| <b>O</b>                                |                    |  |  |
| object hierarchy                        | 34                 |  |  |
| OnServerValidate event                  | 146                |  |  |
| Overloading                             | 11                 |  |  |
| overriding                              | 41                 |  |  |
| <b>P</b>                                |                    |  |  |
| Page_Load event                         | 129, 138           |  |  |
| Page_Load function                      | 139-140            |  |  |
| Page_Load method                        | 138                |  |  |
| ParameterList statement                 | 186                |  |  |
| PATH:in APLScript                       | 184                |  |  |
| Point class                             | 34-35              |  |  |
| Pointers                                | 29                 |  |  |
| positioning Forms and controls          | 34                 |  |  |
| post back                               | 126, 140, 160, 166 |  |  |
| post back events                        | 167                |  |  |
| private                                 | 17, 161            |  |  |
| PROJ workspace                          | 135                |  |  |
| properties                              |                    |  |  |
| defining                                | 160                |  |  |
| property get function                   | 163                |  |  |
| property set function                   | 163-164            |  |  |
| Properties folder                       | 18                 |  |  |
| proxy class                             | 40, 111-113        |  |  |
| ProxyData class                         | 26                 |  |  |
| <b>R</b>                                |                    |  |  |
| RadioButton control                     | 147                |  |  |
| RadioButtonList control                 | 148-149            |  |  |
| RaisePostBackEvent method               | 167                |  |  |
| RaisePostDataChangedEvent method        | 166                |  |  |
| RegisterPostBackScript method           | 168                |  |  |
| Render method                           | 154, 164, 168      |  |  |
| RequiredFeildValidator control          | 142                |  |  |
| RequiredFieldValidator control          | 146                |  |  |
| Returns statement                       | 186                |  |  |
| runat attribute                         | 125                |  |  |

**S**

Sending an email	25
server controls	125
signature statement	43, 78
Size class	34
sizing Forms and controls	34
SmtpMail class	25
State Indicator	206
Stream class	27
StreamReader class	27
subtracting .NET objects	21

**T**

TestAsyncLoan function	120
TETRIS workspace	40
TextBox class	160
thread switching	209
ToDouble method	143
ToInt32 method	144
ToString method	10, 12

**U**

Unicode	175
Unicode font	178
UnicodeToClipboard parameter	179
URI class	26
Using statement	9
USING system variable	8, 26, 35, 63, 128

**V**

Validate method	149
Validation	
of ASP.NET web pages	142
ValidationSummary control	142, 151
virtual directory	66
Visual Studio	
Hello World example	195
Visual Studio.NET	
and APLScript	195

**W**

Weak Interrupt	
in dyalog101.dll	211
web pages	
code behind	132
custom controls	153
writing	123
web scraping	26
Web Services	2
asynchronous use	119
WEBSERVICES workspace	40, 89, 111, 113
WFGOLF function	40
Windows.Forms	33
WINFORMS workspace	33, 39
Workspace Explorer	
browsing assemblies	117
WSDL.EXE	111