msdn training

Module 12: Operators, Delegates, and Events

Contents

This course is based on the prerelease Beta 1 version of Microsoft® Visual Studio .NET. Content in the final release of the course may be different from the content included in this prerelease version. All labs in the course are to be completed with the Beta 1 version of Visual Studio .NET.

Microsoft

Overview

- Introduction to Operators
- Operator Overloading
- Creating and Using Delegates
- Defining and Using Events

This module covers three areas of useful functionality that can be implemented in a class or **struct**: operators, delegates, and events.

Operators are the basic components of a language. You use operators to perform manipulations and comparisons between variables that may be logical, relational, or conditional in nature.

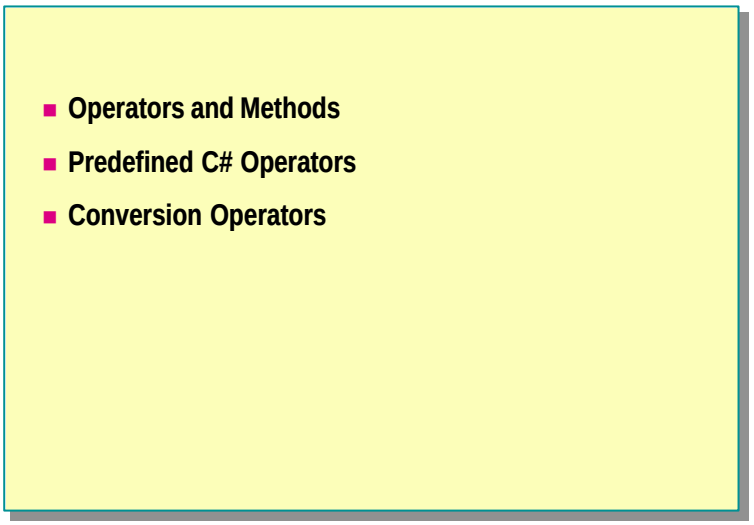
Delegates specify a contract between an object that issues calls to a function and an object that implements the called function.

Events provide the way for a class to notify its clients when a change occurs in the state of any of its objects.

After completing this module, you will be able to:

- Define operators, to make a class or **struct** easier to use.
- Use delegates to decouple a method call from a method implementation.
- Add event specifications to a class to allow subscribing classes to be notified of changes in object state.

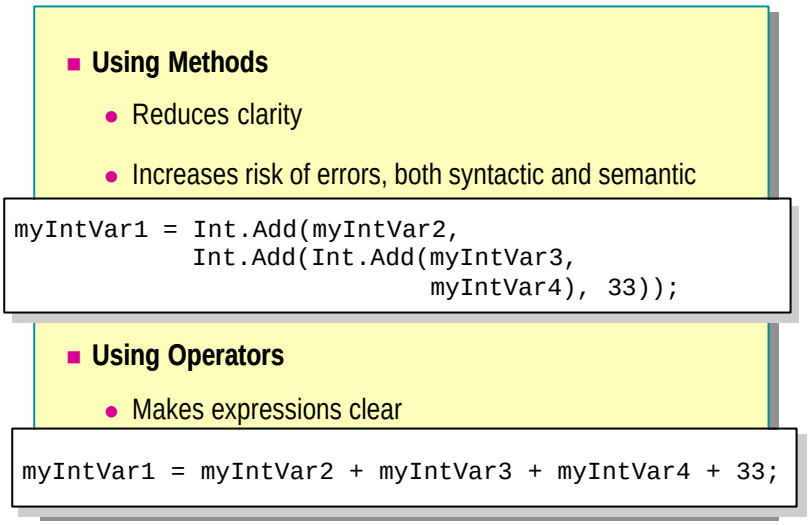
Introduction to Operators



Operators are different from methods. They have special requirements that enable them to function as expected. C# has a number of predefined operators that you can use to manipulate the types and classes supplied with the Microsoft® .NET Framework.

In this section, you will see why C#, like most languages, has operators. You will be presented with the complete list of operators that C# supports. You will learn to use operators to convert data from one type to another, and you will be introduced to the concept of defining your own operators.

Operators and Methods



The purpose of operators is to make expressions clear and easy to understand. It would be possible to have a language with no operators, relying instead on well-defined methods, but this would most likely have an adverse affect on the clarity of the language.

Using Methods

For example, suppose the arithmetic addition operator was not present, and the language instead provided an **Add** method of the **Int** class that took parameters and returned a result. Then, to add two variables, you would write code similar to the following:

```
myIntVar1 = Int.Add(myIntVar2, myIntVar3);
myIntvar2 = Int.Add(myIntVar2, 1);
```

Using Operators

By using the arithmetic addition operator, you can write the more concise lines of code that follow:

```
myIntVar1 = myIntVar2 + myIntVar3;
myIntVar2 = myIntVar2 + 1;
```

Code would become almost indecipherable if you were to add a series of values together by using the **Add** method, as in the following code:

```
myIntVar1 = Int.Add(myIntVar2, Int.Add(Int.Add(myIntVar3,
➥myIntVar4), 33));
```

If you use methods in this way, the likelihood of errors, both syntactic and semantic, is enormous. Operators are actually implemented as methods by C#, but their syntax is designed to make them easy to use. The C# compiler and runtime automatically convert expressions with operators into the correct series of method calls.

Predefined C# Operators

Operator Categories

Arithmetic	Member access
Logical (Boolean and bitwise)	Indexing
String concatenation	Cast
Increment and decrement	Conditional
Shift	Delegate concatenation and removal
Relational	Object creation
Assignment	Type information
Overflow exception control	Indirection and address

The C# language provides a large set of predefined operators. Following is the complete list.

Operator category	Operators
Arithmetic	+, -, *, /, %
Logical (Boolean and bitwise)	&, |, ^, !, ~, &&, ||, true, false
String concatenation	+
Increment and decrement	++, --
Shift	<<, >>
Relational	==, !=, <, >, <=, >=
Assignment	=, +=, -=, *=, /=, %=, &=, |=, <<=, >>=
Member access	.
Indexing	[ ]
Cast	( )
Conditional	?:
Delegate concatenation and remo val	+, -
Object creation	new
Type information	is, sizeof, typeof
Overflow exception control	checked, unchecked
Indirection and address	*, ->, [ ], &

You use operators for building expressions. The function of most operators is well understood. For example, the addition operator (+) in the expression `10 + 5` will perform arithmetic addition, and in this example the expression will yield the value of 15.

Some of the operators may not be as familiar as others, and some are defined as keywords rather than symbols, but their functionality with the data types and classes supplied with the .NET Framework is completely defined.

Operators with Multiple Definitions

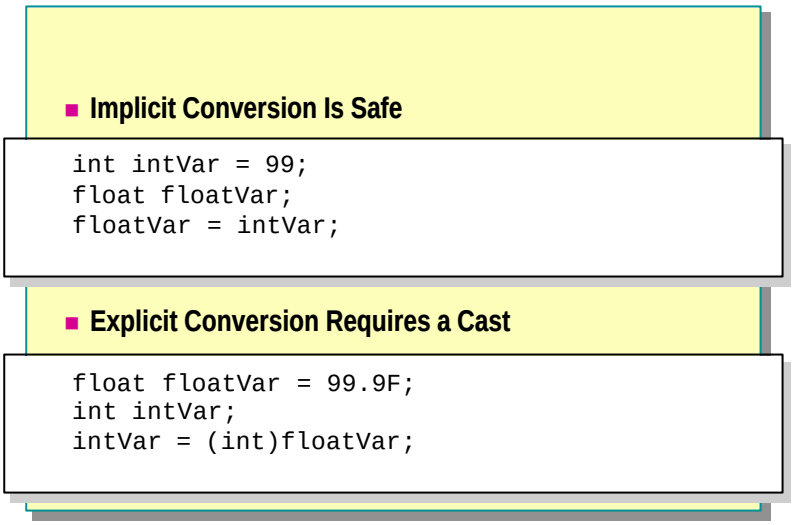
A confusing aspect of operators is that the same symbol may have several different meanings. The + in the expression `10 + 5` is clearly the arithmetic addition operator. You can determine the meaning by the context in which it is used—no other meaning of + makes sense.

However, the following example uses the + operator to concatenate strings:

```
"Adam " + "Barr"
```

It is the function of the parser, when the program is compiled, to determine the meaning of an operator in any given context.

Conversion Operators



By using the predefined C# operators, you can convert data of one type to another type. Data conversion can be implicit or explicit.

An implicit conversion is one that is guaranteed not to lose information. An explicit conversion may lose information. An explicit conversion is specified by using a cast, and it becomes the programmers' responsibility to handle any lost data.

Implicit Conversions

When an implicit conversion is performed, you may not even be aware that it has happened. The following code provides an example:

```
int intVar = 99;
float floatVar;
floatVar = intVar;   // Implicit conversion from int to float
```

In this example, the compiler generates code that automatically converts the value in *intVar* into a floating-point value before storing the result in *floatVar*. Converting from an **int** to a **float** is considered a safe conversion by C# because there will be no loss of data.

Explicit Conversions

Some types of conversions are not considered to be safe by the compiler. For example, converting from a **float** to an **int** is not safe:

```
float floatVar = 99.9F;
int intVar;
intVar = (int)floatVar; // Explicit – a cast is needed
```

In this case, you must use casting to perform explicit data conversion. The conversion could result in some loss of data. In the preceding code, the value stored in *intVar* will be 99 and the 0.9 will be lost. Without the cast, the program will not compile.

◆ Operator Overloading

- Introduction to Operator Overloading
- Overloading Relational Operators
- Overloading Logical Operators
- Overloading Conversion Operators
- Overloading Operators Multiple Times
- Quiz: Spot the Bugs

Many predefined operators in C# perform well-defined functions on classes and other data types. This clear definition widens the scope of expression for the user. You can redefine some of the operators provided by C# and use them as operators that work only with classes and structs that you have defined. In a sense, this is the same as defining your own operators. This process is known as operator overloading.

Not all predefined C# operators can be overloaded. The unary arithmetic and logic operators can be overloaded freely, as can the binary arithmetic operators. The assignment operators cannot be overloaded directly, but they are all evaluated using the arithmetic, logical, and shift operators, which in turn can be overloaded.

In this section, you will learn how to overload relational, logical, and conversion operators. You will also learn how to overload an operator multiple times.

Introduction to Operator Overloading

- **Operator Overloading**
  - Define your own operators only when appropriate
- **Operator Syntax**
  - Operator**op**, where **op** is the operator being overloaded
- **Example**

```
public static Time operator+(Time t1, Time t2)
{
      int newHours = t1.hours + t2.hours;
      int newMinutes = t1.minutes + t2.minutes;
      return new Time(newHours, newMinutes);
}
```

Though operators make expressions simpler, you should only define operators when it makes sense to do so. Operators should only be overloaded when the class or **struct** is a piece of data (like a number), and will be used in that way. An operator should always be unambiguous in usage; there should be only one possible interpretation of what it means. For example, you should not define an increment operator (++) on an **Employee** class (`emp1++;`) because the semantics of such an operation on an **Employee** are not clear. What does it actually mean to " increment an employee" ? Would you be likely to use this as part of a larger expression? If by increment you mean "give the employee a promotion," define a **Promote** method instead (`emp1.Promote();`).

Syntax for Overloading Operators

All operators are public static methods and their names follow a particular pattern. All operators are called operator**op**, where **op** specifies exactly which operator is being overloaded. For example, the method for overloading the addition operator is **operator+**.

The parameters that the operator takes and the types of parameters it returns must be well defined. All arithmetic operators return an instance of the class and manipulate objects of the class.

Example

As an example, consider the **Time struct** shown in the following code. A **Time** value consists of two parts: a number of hours and a number of minutes. The code in bold shows how to implement the binary addition operator (+) for adding two **Time**s together, and the binary subtraction operator (-) for subtracting one **Time** from another.

The unary increment (++) and decrement (–) operators are also shown. They add or subtract one minute from a **Time**.

```
public struct Time
{
   public Time(int minutes) : this(0, minutes)
   {
   }

   public Time(int hours, int minutes)
   {
      this.hours = hours;
      this.minutes = minutes;
      Normalize( );
   }

   // Arithmetic

   public static Time operator+(Time lhs, Time rhs)
   {
        return new Time(lhs.hours + rhs.hours,
                        lhs.minutes + rhs.minutes
                       );
   }

   public static Time operator-(Time lhs, Time rhs)
   {
        return new Time(lhs.TotalMinutes( )
                      – rhs.TotalMinutes( )
                        );
   }

   ...

   // Helper methods

   private void Normalize( )
   {
      if (hours < 0 || minutes < 0) {
           throw new ArgumentException("Time too small");
      }
      hours += (minutes / 60);
      minutes %= 60;
   }

   private int TotalMinutes( )
   {
       return hours * 60 + minutes;
   }

   private int hours;
   private int minutes;
}
```

Overloading Relational Operators

- **Relational Operators Must Be Paired**
  - < and >
  - <= and >=
  - == and !=
- **Override the Equals Method If Overloading == and !=**
- **Override the GetHashCode Method If Overriding Equals Method**

You must overload the relational or comparison operators in pairs. Each relational operator must be defined with its logical antonym. This means that if you overload <, you must also overload >, and vice versa. Similarly, != must be overloaded with ==, and <= must be overloaded with >=.

Tip For consistency, create a **Compare** method first and define all the relational operators by using **Compare**. The code example on the following page shows you how to do this.

Overriding the Equals Method

If you overload == and !=, you should also override the **Equals** virtual method that your class inherits from **Object**. This is to ensure consistency when two objects of this class are compared, whether by == or the **Equals** method, so that a situation in which == returns **true** and the **Equals** method returns **false** is avoided.

Overriding the GetHashCode Method

The **GetHashCode** method (also inherited from **Object**) is used to identify an instance of your class if it is stored in a hash table. Two instances of the same class for which **Equals** returns **true** should also hash to the same integer value. By default, this is not the case. Therefore, if you override the **Equals** method, you should also override the **GetHashCode** method.

Example

The following code shows how to implement the relational operators, the **Equals** method, and the **GetHashCode** method for the **Time struct**:

```
public struct Time
{

    ...

    // Equality

    public static bool operator==(Time lhs, Time rhs)
    {
        return lhs.Compare(rhs) == 0;
    }

    public static bool operator!=(Time lhs, Time rhs)
    {
        return lhs.Compare(rhs) != 0;
    }

    // Relational

    public static bool operator<(Time lhs, Time rhs)
    {
        return lhs.Compare(rhs) < 0;
    }

    public static bool operator>(Time lhs, Time rhs)
    {
        return lhs.Compare(rhs) > 0;
    }

    public static bool operator<=(Time lhs, Time rhs)
    {
        return lhs.Compare(rhs) <= 0;
    }

    public static bool operator>=(Time lhs, Time rhs)
    {
        return lhs.Compare(rhs) >= 0;
    }
```

(Code continued on following page.)

```
    // Inherited virtual methods (from Object)

    public override bool Equals(object obj)
    {
        return obj is Time && Compare((Time)obj) == 0;
    }

    public override int GetHashCode( )
    {
        return TotalMinutes( );
    }

    private int Compare(Time other)
    {
        int lhs = TotalMinutes( );
        int rhs = other.TotalMinutes( );

        int result;
        if (lhs < rhs)
            result = -1;
        else if (lhs > rhs)
            result = +1;
        else
            result = 0;

        return result;
    }
    ...
}
```

Overloading Logical Operators

- **Operators && and || Cannot Be Overloaded Directly**
  - They are evaluated in terms of &, |, **true**, and **false**, which can be overloaded
  - **x && y** is evaluated as **T.false(x) ? x : T.&(x, y)**
  - **x || y** is evaluated as **T.true(x) ? x : T.|(x, y)**

You cannot overload the logical operators && and || directly. However, they are evaluated in terms of the &, |, **true**, and **false** operators, which you can overload.

If variables *x* and *y* are both of type **T**, the logical operators are evaluated as follows:

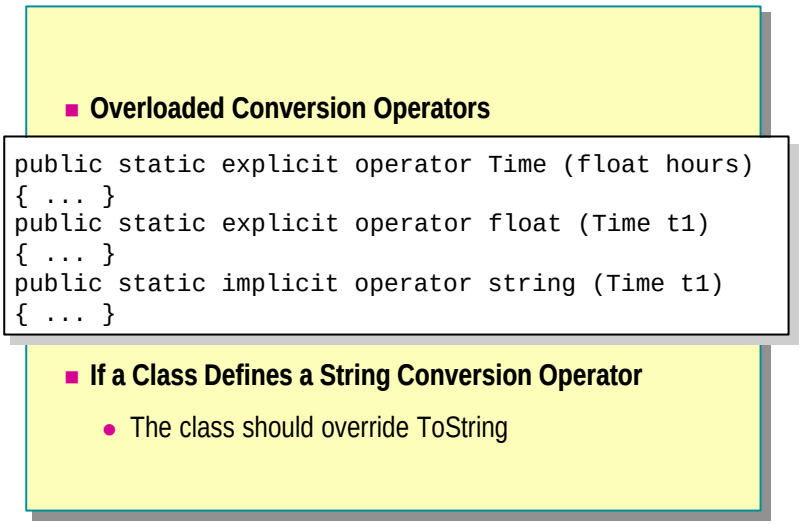
- **x && y** is evaluated as **T.false(x) ? x : T.&(x, y)**

  This expression translates as "if *x* is false as defined by the **false** operator of **T**, the result is *x*; otherwise it is the result of using the & operator of **T** over *x* and *y*."

- **x || y** is evaluated as **T.true(x) ? x : T.|(x, y)**

  This expression means "if *x* is true as defined by the **true** operator of **T**, the result is *x*; otherwise it is the result of using the | operator of **T** over *x* and *y*."

Overloading Conversion Operators



You can define implicit and explicit conversion operators for your own classes and create programmer-defined cast operators that can be used to convert data from one type to another. Some examples of overloaded conversion operators are:

- `explicit operator Time (int minutes)`

  This operator converts an **int** into a **Time**. It is explicit because not all ints can be converted; a negative argument results in an exception being thrown.
- `explicit operator Time (float minutes)`

  This operator converts a **float** into a **Time**. Again, it is explicit because a negative parameter causes an exception to be thrown.
- `implicit operator int (Time t1)`

  This operator converts a **Time** into an **int**. It is implicit because all **Time** values can safely be converted to **int**.
- `explicit operator float (Time t1)`

  This operator converts a **Time** into a **float**. In this case the operator is explicit because, although all Times can be converted to **float**, the floating-point representation of some values may not be exact. (You always take this risk with computations involving floating-point values.)
- `implicit operator string (Time t1)`

  This operator converts a **Time** into a **string**. This is also implicit because there is no danger of losing any information in the conversion.

Overriding the ToString Method

Design guidelines recommend that, for consistency, if a class has a string conversion operator, it should override the **ToString** method, which should perform the same function. Many classes and methods in the **System** namespace – **Console.WriteLine** for example – use **ToString** to create a printable version of an object.

Example

The following code shows how to implement the conversion operators. It also shows one way to implement the **ToString** method. Note how the **Time struct** overrides **ToString**, which is inherited from **Object**.

```
public struct Time
{
  ...

  // Conversion operators
  public static explicit operator Time (int minutes)
  {
      return new Time(0, minutes);
  }

  public static explicit operator Time (float minutes)
  {
     return new Time(0, (int)minutes);
  }

  public static implicit operator int (Time t1)
  {
      return t1.TotalMinutes( );
  }

  public static explicit operator float (Time t1)
  {
      return t1.TotalMinutes( );
  }

  public static implicit operator string (Time t1)
  {
      return t1.ToString( );
  }

  // Inherited virtual methods (from Object)

  public override string ToString( )
  {
      return String.Format("{0}:{1:00}", hours, minutes);
  }
  ...
}
```

Tip If a conversion operator could throw an exception or return a partial result, make it explicit. If a conversion is guaranteed to work without any loss of data, you can make it implicit.

Overloading Operators Multiple Times

- **The Same Operator Can Be Overloaded Multiple Times**

```
public static Time operator+(Time t1, int hours)
{...}

public static Time operator+(Time t1, float hours)
{...}

public static Time operator-(Time t1, int hours)
{...}

public static Time operator-(Time t1, float hours)
{...}
```

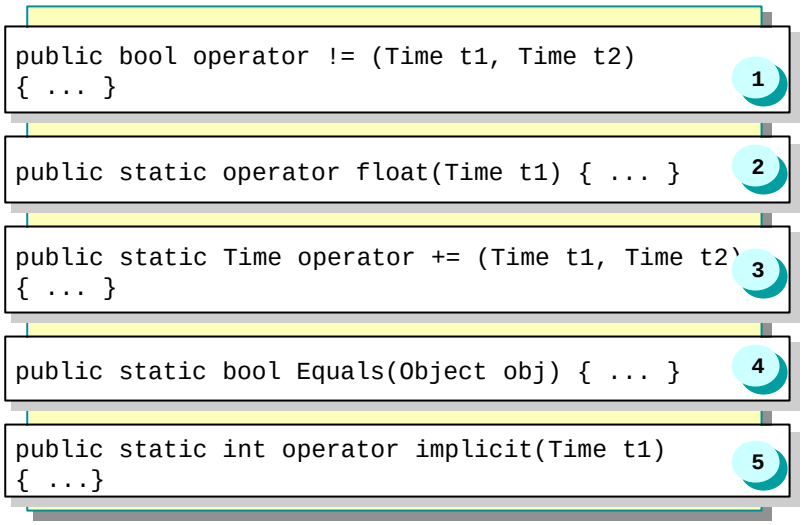
You can overload the same operator multiple times to provide alternative implementations that take different types as parameters. At compile time, the system establishes the method to be called depending upon the types of the parameters being used to invoke the operator.

Example

The following code shows more examples of how to implement the + and – operators for the **Time struct**. Both examples add or subtract a specified number of hours from the supplied **Time**:

```
public struct Time
{
    ...
    public static Time operator+(Time t1, int hours)
    {
        return t1 + new Time(hours, 0);
    }

    public static Time operator+(Time t1, float hours)
    {
        return t1 + new Time((int)hours, 0);
    }

    public static Time operator-(Time t1, int hours)
    {
        return t1 – new Time(hours, 0);
    }

    public static Time operator-(Time t1, float hours)
    {
        return t1 – new Time((int)hours, 0);
    }
    ...
}
```

Quiz: Spot the Bugs



In this quiz, you can work with a partner to spot the bugs in the code on the slide. To see the answers to this quiz, turn the page.

Answers

1. Operators must be static because they belong to the class rather than an object. The definition for the != operator should be:

```
public static bool operator != (Time t1, Time t2) { ... }
```

2. The "type" is missing. Conversion operators must either be implicit or explicit. The code should be as follows:

```
public static implicit operator float (Time t1) { ... }
```

3. You cannot overload the += operator. However, += is evaluated by using the + operator, which you can overload.

4. The **Equals** method should be an instance method rather than a class method. However, if you remove the **static** keyword, this method will hide the virtual method inherited from **Object** and not be invoked as expected, so the code should use **override** instead, as follows:

```
public override bool Equals(Object obj) { ... }
```

5. The **int** and **implicit** keywords have been transposed. The name of the operator should be **int**, and its type should be implicit, as follows:

```
public static implicit operator int(Time t1) { ... }
```

Note All the cases listed above will result in compile-time errors.

Lab 12.1: Defining Operators

Objectives

After completing this lab, you will be able to:

- Create operators for addition, subtraction, equality testing, multiplication, division, and casting.
- Override the **Equals**, **ToString,** and **GetHashCode** methods.

Prerequisites

Before working on this lab, you must be familiar with the following:

- Using inheritance in C#
- Defining constructors and destructors
- Compiling and using assemblies
- Basic C# operators

Estimated time to complete this lab: 30 minutes

Exercise 1
Defining Operators for the BankAccount Class

In previous labs, you created classes for a banking system. The **BankAccount** class holds customer bank account details, including the account number and balance. You also created a **Bank** class that acts as a factory for creating and managing **BankAccount** objects. The bank classes were wrapped in a single class library: bank.dll. Completed code is supplied as part of this lab, in case you did not finish the earlier labs.

In this exercise, you will define the == and != operators in the **BankAccount** class. The default implementation of these operators, which is inherited from **Object**, tests to check whether the references are the same. You will redefine them to examine and compare the information in two accounts.

You will then override the **Equals** and **ToString** methods. The **Equals** method is used by many parts of the runtime and should exhibit the same behavior as the equality operators. Many classes in the .NET Framework use the **ToString** method when they need a string representation of an object.

↙ To define the == and != operators

1. Open the Bank.sln project in the *install folder*\Labs\Lab12\Starter\Bank folder.
2. Add the following method to the **BankAccount** class:

```
public static bool operator == (BankAccount acc1,
➥BankAccount acc2)
{
    ...
}
```

3. In the body of **operator ==**, add statements to compare the two **BankAccount** objects. If the account number, type, and balance of both accounts are the same, return **true**; otherwise return **false**.
4. Compile the project. You will receive an error.

   (Why will you receive an error when you compile the project?)
5. Add the following method to the **BankAccount** class:

```
public static bool operator != (BankAccount acc1,
➥BankAccount acc2)
{
    ...
}
```

6. Add statements in the body of **operator !=** to compare the contents of the two **BankAccount** objects. If the account number, type, and balance of both accounts are the same, return **false**; otherwise return **true**. You can achieve this by calling **operator ==** and inverting the result.
7. Save and compile the project. The project should now compile successfully. The previous error was caused by having an unmatched **operator ==** method. (If you define **operator ==**, you must also define **operator !=**, and vice versa.)

The complete code for both of the operators is as follows:

```
public class BankAccount
{
   ...
   public static bool operator == (BankAccount acc1,
➥BankAccount acc2)

   {
       if ((acc1.accNo == acc2.accNo) &&
          (acc1.accType == acc2.accType) &&
          (acc1.accBal == acc2.accBal)) {
          return true;
       } else {
          return false;
       }
   }

   public static bool operator != (BankAccount acc1,
➥BankAccount acc2)

   {
       return !(acc1 == acc2);
   }
   ...
}
```

↙ To test the operators

1. Open the TestHarness.sln project in the *install folder*\Labs\Lab12\Starter\TestHarness folder.
2. Create a reference to the **Bank** component that you created in the previous labs. To do this:
   a. Expand the TestHarness project in Solution Explorer.
   b. Right-click **References**, and click **Add Reference**.
   c. Click **Browse**, and navigate to the *install folder*\Labs\Lab12\Starter\Bank\bin\debug folder.
   d. Click **Bank.dll**, and then click **Open**.
   e. Click **OK**.
3. Create two **BankAccount** objects in the **Main** method of the **CreateAccount** class. To do this:
   a. Use **Bank.CreateAccount()**, and instantiate the **BankAccount** objects with the same balance and account type.
   b. Store the account numbers generated in two long variables called *accNo1* and *accNo2*.
4. Create two **BankAccount** variables called *acc1* and *acc2*. Populate them with the two accounts created in the previous step by calling **Bank.GetAccount()**.
5. Compare *acc1* and *acc2* by using the **==** operator. This test should return **false** because the two accounts will have different account numbers.
6. Compare *acc1* and *acc2* by using the **!=** operator. This test should return **true**.
7. Create a third **BankAccount** variable called *acc3*. Populate it with the account that you used to populate *acc1* by calling **Bank.GetAccount(),** using *accNo1* as the parameter.
8. Compare *acc1* and *acc3* by using the **==** operator. This test should return **true**, because the two accounts will have the same data.

9. Compare *acc1* and *acc3* by using the **!=** operator. This test should return **false**.

   If you have problems, a utility function called **Write** is available that you can use to display the contents of a **BankAccount** that is passed in as a parameter.

   Your completed code for the test harness should be as follows:

```
class CreateAccount
{
    static void Main( )
    {

      // Create two bank accounts. Use Bank.CreateAccount(...)
       // with the same balance and type.
      // Store the numbers of these two accounts in long
       //variables accNo1 and accNo2 long accNo1 =
     ➥       Bank.CreateAccount(AccountType.Checking, 100);
      long accNo2 =
     ➥       Bank.CreateAccount(AccountType.Checking, 100);

      // Create two BankAccount variables, acc1 and acc2.
      // Use Bank.GetAccount( ) to populate them with the
      // two accounts just created.
      BankAccount acc1 = Bank.GetAccount(accNo1);
      BankAccount acc2 = Bank.GetAccount(accNo2);

      // Compare acc1 and acc2 by using the == operator.
      // (Should be false because the account numbers will be
      // different.)
      if (acc1 == acc2) {
          Console.WriteLine(
     ➥    "Both accounts are the same. They should not be!");
      } else {
          Console.WriteLine(
     ➥     "The accounts are different. Good!");
      }

      // Compare acc1 and acc2 by using the != operator.
      // (Should be true because the account numbers will be
      // different.)
      if (acc1 != acc2) {
          Console.WriteLine(
     ➥     "The accounts are different. Good!");
      } else {
          Console.WriteLine(
     ➥     "Both accounts are the same. They should not be!");
      }
```

(Code continued on following page.)

```
        // Create a third BankAccount variable, acc3, and
        // populate it with the account whose
        // account number is in accNo1. Use Bank.GetAccount
        BankAccount acc3 = Bank.GetAccount(accNo1);
        if (acc1 == acc3) {
            Console.WriteLine(
        ➥    "The accounts are the same. Good!");
        } else {
            Console.WriteLine(
        ➥    "The accounts are different. They should not be!");
        }

        // Compare acc1 and acc3 by using the == operator.
        // (Should be true because all the data will be the
        // same.)
        // Compare acc1 and acc3 by using the != operator.
        // (Should be false.)
        if (acc1 != acc3) {
            Console.WriteLine(
        ➥    "The accounts are different. They should not be!");
        } else {
            Console.WriteLine(
        ➥    "The accounts are the same. Good!");
        }
    }
    ...
}
```

10. Compile and run the test harness.

↙ To override the Equals, ToString, and GetHashCode methods

1. Open the Bank.sln project in the *install folder*\Labs\Lab12\Starter\Bank folder.
2. Add the **Equals** method to the **BankAccount** class:

```
public override bool Equals(Object acc1)
{
    ...
}
```

   The **Equals** method should perform the same function as the == operator, except that it is an instance rather than a class method. Use the == operator to compare **this** to *acc1*.

3. Add the **ToString** method as follows:

```
public override string ToString( )
{
    ...
}
```

   The body of the **ToString** method should return a string representation of the instance.

4. Add the **GetHashCode** method as follows:

```
public override int GetHashCode( )
{
  ...
}
```

   The **GetHashCode** method should return a unique value for each different account, but different references to the same account should return the same value. The easiest solution is to return the account number. (You will need to cast it to an **int** first.)

5. The completed code for **Equals**, **ToString**, and **GetHashCode** is as follows:

```
public override bool Equals(Object acc1)
{
   return this == acc1;
}

public override string ToString( )
{
   string retVal =  "Number: " + this.accNo + "\tType: ";
   retVal += (this.accType == AccountType.Checking) ?
➥"Checking" : "Deposit";
   retVal += "\tBalance: " + this.accBal;

   return retVal;
}

public override int GetHashCode( )
{
   return (int)this.accNo;
}
```

6. Save and compile the project. Correct any errors.

↙ To test the Equals and ToString methods

1. Open the TestHarness.sln project in the *install folder*\Labs\Lab12\Starter\TestHarness folder.
2. In the **Main** method of the **CreateAccount** class, replace the use of == and **!=** with **Equals**, as follows:

```
if (acc1.Equals(acc2)) {
  ...
}

if (!acc1.Equals(acc2)) {
  ...
}
```

3. After the **if** statements, add three **WriteLine** statements that print the contents of *acc1*, *acc2*, and *acc3*, as shown in the following code. The **WriteLine** method uses **ToString** to format its arguments as strings.

```
Console.WriteLine("acc1 – {0}", acc1);
Console.WriteLine("acc2 – {0}", acc2);
Console.WriteLine("acc3 – {0}", acc3);
```

4. Compile and run the test harness. Check the results.

Exercise 2
Handling Rational Numbers

In this exercise, you will create an entirely new class for handling rational numbers. This is a brief respite from the world of banking.

A rational number is a number that can be written as a ratio of two integers. (Examples of rational numbers include ½, ¾, and -17.) You will create a **Rational** class, which will consist of a pair of private integer instance variables (called *dividend* and *divisor*) and operators for performing calculations and comparisons on them. The following operators and methods will be defined:

- Rational(**int** dividend)

  This is a constructor that sets the dividend to the supplied value and the divisor to 1.

- Rational(**int** dividend, **int** divisor)

  This is a constructor that sets the dividend and the divisor.

- == and !=

  These will perform comparisons based upon the calculated numeric value of the two operands (for example, `Rational(6, 8) == Rational(3, 4)`). You must override the **Equals**( ) methods to perform the same comparison.

- <, >, <=, >=

  These will perform the appropriate relational comparisons between two rational numbers (for example, `Rational(6, 8) > Rational(1, 2)`).

- binary + and –

  These will add one rational number to or subtract one rational number from another.

- ++ and --

  These will increment and decrement the rational number.

↙ To create the constructors and the ToString method

1. Open the Rational.sln project in the *install folder*\Labs\Lab12\Starter\Rational folder.
2. The **Rational** class contains two private instance variables called *dividend* and *divisor*. They are initialized to 0 and 1, respectively. Add a constructor that takes a single integer and uses it to set *dividend*, leaving *divisor* with the value 1.
3. Add another constructor that takes two integers. The first is assigned to *dividend*, and the second is assigned to *divisor*. Check to ensure that *divisor* is not set to zero. Throw an exception if this occurs and raise **ArgumentOutOfRangeException**.
4. Create a third constructor that takes a *Rational* as a parameter and copies the values it contains.

Note C++ developers will recognize the third constructor as a copy constructor. You will use this constructor later in this lab.

The completed code for all three constructors is as follows:

```
public Rational(int dividend)
{
   this.dividend = dividend;
   this.divisor = 1;
}

public Rational(int dividend, int divisor)
{
   if (divisor == 0) {
       throw new ArgumentOutOfRangeException(
                              "Divisor cannot be zero");
   } else {
       this.dividend = dividend;
       this.divisor = divisor;
   }
}

public Rational(Rational r1)
{
   this.dividend = r1.dividend;
   this.divisor = r1.divisor;
}
```

5. Override the **ToString** method that returns a **string** version of the *Rational*, as follows:

```
public override string ToString( )
{
   return String.Format("{0}/{1}", dividend, divisor);
}
```

6. Compile the project and correct any errors.

↙ To define the relational operators

1. In the **Rational** class, create the == operator as follows:

```
public static bool operator == (Rational r1, Rational r2)
{
    ...
}
```

2. The == operator will:
   a. Establish the decimal value of *r1* by using the following formula.

```
decimalValue1 = r1.dividend / r1.divisor
```

   b. Establish the decimal value of *r2* by using a similar formula.
   c. Compare the two decimal values and return **true** or **false**, as appropriate. The completed code is as follows:

```
public static bool operator == (Rational r1, Rational
➥r2)
{
    decimal decimalValue1 =
                (decimal)r1.dividend / r1.divisor;
    decimal decimalValue2 =
                (decimal)r2.dividend / r2.divisor;
    return decimalValue1 == decimalValue2;
}
```

   Why are the decimal casts necessary when performing the division?
3. Create and define the != operator by using the == operator, as follows:

```
public static bool operator != (Rational r1, Rational r2)
{
   return !(r1 == r2);
}
```

4. Override the **Equals** method. Use the == operator, as follows:

```
public override bool Equals(Object r1)
{
   return (this == r1);
}
```

5. Define the < operator. Use a strategy similar to that used for the == operator, as follows:

```
public static bool operator < (Rational r1, Rational r2)
{
   return (r1.dividend * r2.divisor) < (r2.dividend *
➥r1.divisor);
}
```

6. Create the > operator, using == and <, as shown in the following code. Be sure that you understand the Boolean logic used by the expression in the return statement.

```
public static bool operator > (Rational r1, Rational r2)
{
   return !((r1 < r2) || (r1 == r2));
}
```

7. Define the <= and >= operators in terms of > and <, as shown in the following code:

```
public static bool operator <= (Rational r1, Rational r2)
{
   return !(r1 > r2);
}

public static bool operator >= (Rational r1, Rational r2)
{
   return !(r1 < r2);
}
```

8. Compile the project and correct any errors.

↙ To test the constructors, the ToString method, and the relational operators

1. In the **Main** method of the **TestRational** class of the Rational project, create two **Rational** variables, *r1* and *r2*, and instantiate them with the value pairs (1,2) and (1,3), respectively.
2. Print them by using **WriteLine** to test the **ToString** method.
3. Perform the following comparisons, and print a message indicating the results:
   a. Is *r1* > *r2*?
   b. Is *r1* <= *r2*?
   c. Is *r1* != *r2*?
4. Compile and run the program. Check the results.
5. Change *r2* and instantiate it with the value pair (2,4).
6. Compile and run the program again. Check the results.

↙ To create the binary additive operators

1. In the **Rational** class, create the binary **+** operator. Create two versions for:
   a. Adding two **Rationals** together.

Tip To add two rational numbers together, you need to establish a common divisor. Unless both divisors are the same (if they are you can skip this step and the next), do this by multiplying the divisors together. For example, assume you want to add 1/4 to 2/3. The common divisor is 12 (4 * 3). The next step is to multiply the dividend of each number by the divisor of the other. Hence, 1/4 would become (1 * 3)/12, or 3/12, and 2/3 would become (4 * 2)/12, or 8/12. Finally, you add the two dividends together and use the common divisor. So 3/12 + 8/12 = 11/12, and hence 1/4 + 2/3 = 11/12.
If you use this algorithm, you will need to make copies of the parameters passed in (using the copy constructor defined earlier) to the + operator. If you modify the formal parameters, you will find that the actual parameters will also be changed because of the way in which reference types are passed.

---

   b. Adding a rational number and an integer.

Tip To add an integer to a rational number, convert the integer to a rational number that has the same divisor. For example, to add 2 and 3/8, convert 2 into 16/8, and then perform the addition.

   Both versions should return a **Rational**. (Do not worry about producing a normalized result.)
2. Create the binary **–** operator. Create two versions, one each for:
   a. Subtracting one rational number from another.
   b. Subtracting an integer from a rational number.

Both versions should return a **Rational** (non-normalized). The completed code for the + and – operators is as follows:

```
public static Rational operator + (Rational r1, Rational
➥r2)
{
   // Make working copies of r1 and r2
   Rational tempR1 = new Rational(r1);
   Rational tempR2 = new Rational(r2);

   // Determine a common divisor.
   // That is, to add 1/4 and 2/3, convert to 3/12 and 8/12
   int commonDivisor;
   if (tempR1.divisor != tempR2.divisor) {
       commonDivisor = tempR1.divisor * tempR2.divisor;

       // Multiply out the dividends of each rational
       tempR1.dividend *= tempR2.divisor;
       tempR2.dividend *= tempR1.divisor;
   } else {
       commonDivisor = tempR1.divisor;
   }

   // Create a new Rational.
   // For example, 1/4 + 2/3 = 3/12 + 8/12 = 11/12.

   Rational result = new Rational(tempR1.dividend +
                         tempR2.dividend, commonDivisor);
   return result;
}

public static Rational operator + (Rational r1, int i1)
{
   // Convert i1 into a Rational
   Rational r2 = new Rational(i1 * r1.divisor,
                                     r1.divisor);

   return r1 + r2;
}
```

(Code continued on following page.)

```
   // Perform Rational addition
public static Rational operator - (Rational r1, Rational
➥r2)
{
   // Make working copies of r1 and r2
   Rational tempR1 = new Rational(r1);
   Rational tempR2 = new Rational(r2);

   // Determine a common divisor.
   // For example, to subtract 2/3 from 1/4,
   // convert to 8/12 and 3/12.
   int commonDivisor;
   if (tempR1.divisor != tempR2.divisor) {
       commonDivisor = tempR1.divisor * tempR2.divisor;

       // Multiply the dividends of each rational
       tempR1.dividend *= tempR2.divisor;
       tempR2.dividend *= tempR1.divisor;
   } else {
       commonDivisor = tempR1.divisor;
   }

   // Create a new Rational.
   // For example, 2/3 - 1/4 = 8/12 - 3/12 = 5/12.

   Rational result = new Rational(tempR1.dividend –
                        tempR2.dividend, commonDivisor);
   return result;
}

public static Rational operator - (Rational r1, int i1)
{
   // Convert i1 into a Rational
   Rational r2 = new Rational(i1 * r1.divisor, r1.divisor);

   // Perform Rational subtraction
   return r1 - r2;
}
```

↙ To define the increment and decrement operators

1. In the **Rational** class, create the unary ++ operator.

> **Tip** Use the + operator that you defined earlier. Use it to add 1 to the parameter passed to the ++ operator.

2. In the **Rational** class, create the unary -- operator. The completed code for both operators is as follows:

```
public static Rational operator ++ (Rational r1)
{
    return r1 + 1;
}

public static Rational operator -- (Rational r1)
{
    return r1 - 1;
}
```

↙ To test the additive operators

1. In the **Main** method of the **TestRational** class, add statements to:
   a. Add *r2* to *r1* and print the result.
   b. Add 5 to *r2* (use +=) and print the result.
   c. Subtract *r1* from *r2* (use -=) and print the result.
   d. Subtract 2 from *r2* and print the result.
   e. Increment *r1* and print the result.
   f. Decrement *r2* and print the result.
2. Compile and run the program. Check the results.

If Time Permits
Creating Additional Rational Number Operators

In this exercise, you will create the following additional operators for the **Rational** class:

- Explicit and implicit casts

  These casts are for conversion between **Rational**, **float**, and **int** types.

- *****, /, **%**

  These binary multiplicative operators are for multiplying, for dividing, and for extracting the remainder after integer division of two rational numbers.

↙ To define the cast operators

1. Define an explicit cast operator for converting a rational number to a floating-point number, as follows:

```
public static explicit operator float (Rational r1)
{
    ...
}
```

2. In the body of the of the **float** cast operator, return the result of dividing *dividend* by *divisor*. Ensure that floating-point division is performed.

3. Create an explicit cast operator for converting a rational number to an integer, as follows:

```
public static explicit operator int (Rational r1)
{
    ...
}
```

Note This operator is explicit because information loss is likely to occur.

4. In the body of the **int** cast operator, divide *dividend* by *divisor*. Ensure that floating-point division is performed. Truncate the result to an **int** and return it.

5. Create an implicit cast operator for converting an integer to a rational number, as follows:

```
public static implicit operator Rational (int i1)
{
    ...
}
```

Note It is safe to make this operator implicit.

6. In the body of the **Rational** cast operator, create a new **Rational** with *dividend* set to *i1* and *divisor* set to 1. Return this **Rational**. The complete code for all three cast operators is as follows:

```
public static implicit operator float (Rational r1)
{
   float temp = (float)r1.dividend / r1.divisor;
   return temp;
}

public static explicit operator int (Rational r1)
{
   float temp = (float)r1.dividend / r1.divisor;
   return (int) temp;
}

public static implicit operator Rational (int i1)
{
   Rational temp = new Rational(i1, 1);
   return temp;
}
```

7. Add statements to the test harness to test these operators.

↙ To define the multiplicative operators

1. Define the multiplication operator (*) to multiply two rational numbers, as follows:

```
public static Rational operator *(Rational r1, Rational r2)
{
   ...
}
```

Tip To multiply two rational numbers, you multiply the dividend and the divisor of both rational numbers together.

2. Define the division operator (/) to divide one rational number by another, as follows:

```
public static Rational operator / (Rational r1, Rational
➥r2)
{
   ...
}
```

Tip To divide **Rational** *r1* by **Rational** *r2*, multiply *r1* by the reciprocal of *r2*. In other words, exchange the *dividend* and *divisor* of *r2*, and then perform multiplication. (1/3 / 2/5 is the same as 1/3 * 5/2.)

3. Define the modulus operator (%). (The modulus is the remainder after division.) It returns the remainder after dividing by an integer:

```
public static Rational operator % (Rational r1, int i1)
{
   ...
}
```

Tip Convert *r1* to an **int** called *temp*, and determine the difference between *r1* and *temp*, storing the result in a **Rational** called *diff*. Perform *temp* % *i1*, and store the result in an **int** called *remainder*. Add *diff* and *remainder* together.

4. Add statements to the test harness to test these operators. The completed code for the operators is as follows:

```
public static Rational operator *(Rational r1, Rational r2)
{
   int dividend = r1.dividend * r2.dividend;
   int divisor = r1.divisor * r2.divisor;
   Rational temp = new Rational(dividend, divisor);
   return temp;
}

public static Rational operator / (Rational r1, Rational
➥r2)
{
   // Create the reciprocal of r2, and then multiply
   Rational temp = new Rational(r2.divisor, r2.dividend);
   return r1 * temp;
}

public static Rational operator % (Rational r1, int i1)
{
   // Convert r1 to an int
   int temp = (int)r1;

   // Compute the rounding difference between temp and r1
   Rational diff = r1 - temp;

   // Perform % on temp and i1
   int remainder = temp % i1;

   // Add remainder and diff together to get the
   // complete result
   diff += remainder;
   return diff;
}
```

◆ Creating and Using Delegates

- Scenario: Power Station
- Analyzing the Problem
- Creating Delegates
- Using Delegates

Delegates allow you to write code that can dynamically change the methods that it calls. This is a flexible feature that allows a method to vary independently of the code that invokes it.

In this section, you will analyze a power station scenario for which delegates prove useful, and learn how to define and use delegates.

Scenario: Power Station

- **The Problem**
  - How to respond to temperature events in a power station
  - Specifically, if the temperature of the reactor core rises above a certain temperature, coolant pumps need to be alerted and switched on
- **Possible Solutions**
  - Should all coolant pumps monitor the core temperature?
  - Should a component that monitors the core turn on the appropriate pumps when the temperature changes?

To understand how to use delegates, consider a power station example for which using a delegate is a good solution.

The Problem

In a power station, the temperature of the nuclear reactor must be kept below a critical temperature. Probes inside the core constantly monitor the temperature. If the temperature rises significantly, various pumps need to be started to increase the flow of coolant throughout the core. The software controlling the working of the nuclear reactor must start the appropriate pumps at the appropriate time.

Possible Solutions

The controlling software could be designed in many ways that would meet these criteria, two of which are listed below:

- The software driving the coolant pumps could constantly measure the temperature of the nuclear core and increase the flow of coolant as the temperature requires.
- The component monitoring the core temperature could start the appropriate coolant pumps every time the temperature changes.

Both of these techniques have drawbacks. In the first technique, the frequency with which the temperature must be measured needs to be determined. Measuring too frequently could affect the operation of the pumps because the software has to drive the pumps as well as monitor the core temperature. Measuring infrequently could mean that a very rapid rise in temperature could be missed until it is too late.

In the second technique, there may be many dozens of pumps and controllers that need to be alerted about each temperature change. The programming required to achieve this could be complex and difficult to maintain, especially if there are different types of pumps in the system that need to be alerted in different ways.

Analyzing the Problem

- **Existing Concerns**
  - There may be several types of pumps, supplied by different manufacturers
  - Each pump could have its own method for activation
- **Future Concerns**
  - To add a new pump, the entire code will need to change
  - A high overhead cost will result with every such addition
- **A Solution**
  - Use delegates in your code

To start solving the problem, consider the dynamics involved in implementing a solution in the power station scenario.

Existing Concerns

The major issue is that there could be several different types of pumps supplied by different manufacturers, each with its own controlling software. The component monitoring the core temperature will have to recognize, for each type of pump, which method to call to turn the pump on.

For this example, suppose that there are two types of pumps: electric and pneumatic. Each type of pump has its own software driver that contains a method to switch the pump on, as follows:

```
public class ElectricPumpDriver
{
  ...
  public void StartElectricPumpRunning( )
  {
  ...
  }
}

public class PneumaticPumpDriver
{
  ...
  public void SwitchOn( )
  {
    ...
  }
}
```

The component monitoring the core temperature will switch the pumps on. The following code shows the main part of this component, the **CoreTempMonitor** class. It creates a number of pumps and stores them in an **ArrayList**, a collection class that implements a variable-length array. The **SwitchOnAllPumps** method iterates through the **ArrayList**, determines the type of pump, and calls the appropriate method to turn the pump on:

```
public class CoreTempMonitor
{
  public void Add(object pump)
  {
     pumps.Add(pump);
  }

  public void SwitchOnAllPumps()
  {
     foreach (object pump in pumps) {
     if (pump is ElectricPumpDriver) {
        ((ElectricPumpDriver)pump).StartElectricPumpRunning();
     }
     if (pump is PneumaticPumpDriver) {
        ((PneumaticPumpDriver)pump).SwitchOn();
     }
       ...
    }
    ...
    private ArrayList pumps = new ArrayList();
}

public class ExampleOfUse
{
    public static void Main( )
    {
      CoreTempMonitor ctm = new CoreTempMonitor();

      ElectricPumpDriver ed1 = new ElectricPumpDriver();
      ctm.Add(ed1);

      PneumaticPumpDriver pd1 = new PneumaticPumpDriver();
      ctm.Add(pd1);

      ctm.SwitchOnAllPumps();
    }
}
```

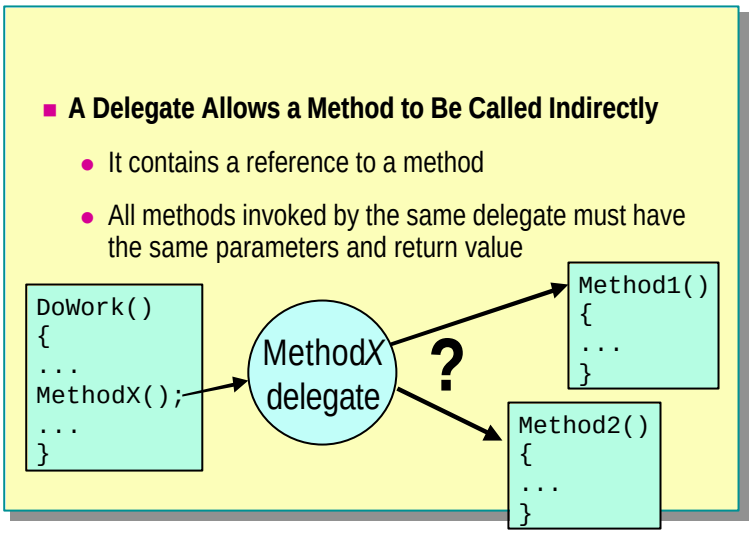
Future Concerns

Using the structure as described has a serious drawback. If a new type of pump is installed later, you will need to change the **SwitchOnAllPumps** method to incorporate the new pump. This would also mean that the entire code would need to be thoroughly retested, with all the associated downtime and costs, since this is a crucial piece of software.

A Solution

To solve this problem, you can use a mechanism referred to as a *delegate*. The **SwitchOnAllPumps** method can use the delegate to call the appropriate method to turn on a pump without needing to determine the type of pump.

Creating Delegates



A delegate contains a reference to a method rather than the method name. By using delegates, you can invoke a method without knowing its name. Calling the delegate will actually execute the method referenced by the delegate.

In the power station example, rather than use an **ArrayList** to hold pump objects, you can use it to hold delegates that refer to the methods required to start each pump.

A delegate is a similar to an interface. It specifies a contract between a caller and an implementer. A delegate associates a name with the specification of a method. An implementation of the method can be attached to this name, and a component can call the method by using this name. The primary requirement of the implementing methods is that they must all have the same signature and return the same type of parameters. In the case of the power station scenario, the **StartElectricPumpRunning** and **SwitchOn** methods are both **void**, and neither takes any parameters.

To use a delegate, you must first define it and then instantiate it.

Defining Delegates

A delegate specifies the return type and parameters that each method must provide. You use the following syntax to define a delegate:

```
public delegate void StartPumpCallback( );
```

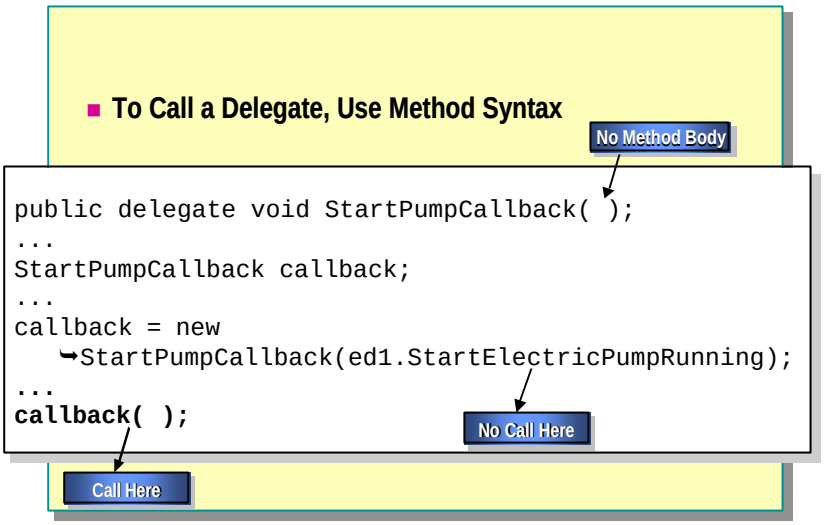
Note that the syntax for defining a delegate is similar to the syntax for defining a method. In this example, you define the delegate **StartPumpCallback** as being for a method that returns no value (**void**) and takes no parameters. This matches the specifications of the methods **StartElectricPumpRunning** and **SwitchOn** in the two pump driver classes.

Instantiating Delegates

After you define a delegate, you must instantiate it and make it refer to a method. To instantiate a delegate, use the delegate constructor and supply the object method it should invoke when it is called. In the following example, an **ElectricPumpDriver**, **ed1**, is created, and then a delegate, **callback**, is instantiated, referencing the **StartElectricPumpRunning** method of **ed1**:

```
public delegate void StartPumpCallback( );

void Example()
{
    ElectricPumpDriver ed1 = new ElectricPumpDriver( );

    StartPumpCallback callback;
    callback =
      ➥new StartPumpCallback(ed1.StartElectricPumpRunning);
    ...
}
```

Using Delegates



A delegate is a variable that invokes a method. You call it in the same way you would call a method, except that the delegate replaces the method name.

Example

The following code shows how to define, create, and call delegates for use by the power station. It populates an **ArrayList** named *callbacks* with instances of delegates that refer to the methods used to start each pump. The **SwitchOnAllPumps** method iterates through this **ArrayList** and calls each delegate in turn. With delegates, the method need not perform type checking and is much simpler than the previous solution.

```
public delegate void StartPumpCallback( );

public class CoreTempMonitor2
{
   public void Add(StartPumpCallback callback)
   {
      callbacks.Add(callback);
   }

   public void SwitchOnAllPumps( )
   {
       foreach(StartPumpCallback callback in callbacks)
       {
           callback( );
       }
   }

   private ArrayList callbacks = new ArrayList( );
}

class ExampleOfUse
{
    public static void Main( )
    {
        CoreTempMonitor2 ctm = new CoreTempMonitor2( );

        ElectricPumpDriver ed1 = new ElectricPumpDriver( );
        ctm.Add(
          new StartPumpCallback(ed1.StartElectricPumpRunning)
        );

        PneumaticPumpDriver pd1 = new PneumaticPumpDriver( );
        ctm.Add(
          new StartPumpCallback(ed2.StartElectricPumpRunning)
        );

        ctm.SwitchOnAllPumps( );
    }
}
```

◆ Defining and Using Events

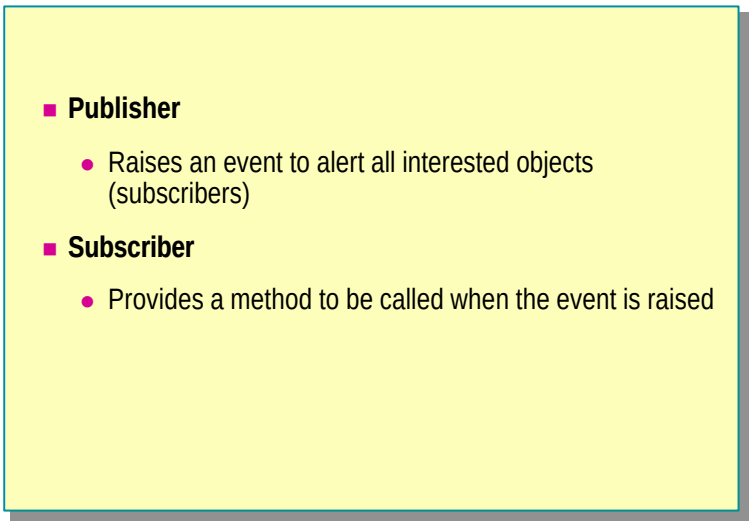
- How Events Work
- Defining Events
- Passing Event Parameters
- Demonstration: Handling Events

In the power station example, you learned how to use a delegate to solve the problem of how to start different types of pumps in a generic manner. However, the component that monitors the temperature of the reactor core is still responsible for notifying each of the pumps in turn that they need to start. You can address the issue of notification by using events.

Events allow an object to notify other objects that a change has occurred. The other objects can register an interest in an event, and they will be notified when the event occurs.

Events are very closely related to delegates. In this section, you will learn how to define and handle events to address the remaining problems with the power station.

How Events Work



Events allow objects to *register an interest* in changes to other objects. In other words, events allow objects to register that they need to be notified about changes to other objects. Events use the publisher and subscriber model.

Publisher

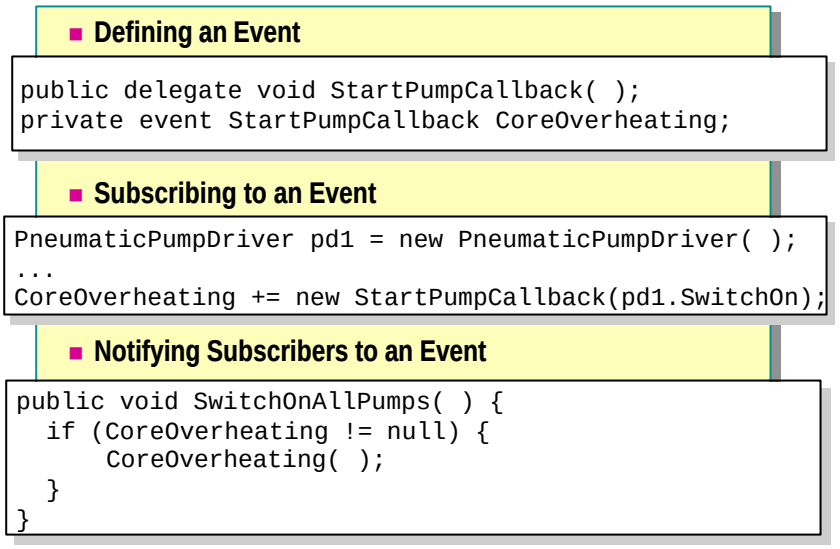
A publisher is an object that maintains its internal state. However, when its state changes, it can raise an event to alert other interested objects about the change.

Subscriber

A subscriber is an object that registers an interest in an event. It is alerted when a publisher raises the event. An event can have zero or more subscribers.

Events can be quite complex. To make them easier to understand and maintain, there are guidelines that you should follow when using them.

Defining Events



Events in C# use delegates to call methods in subscribing objects. They are multicast. This means that when a publisher raises an event, it may result in many delegates being called. However, you cannot rely on the order in which the delegates are invoked. If one of the delegates throws an exception, it could halt the event processing altogether, resulting in the other delegates not being called at all.

Defining an Event

To define an event, a publisher first defines a delegate and bases the event on it. The following code defines a delegate named **StartPumpCallback** and an event named **CoreOverheating** that invokes the **StartPumpCallback** delegate when it is raised:

```
public delegate void StartPumpCallback( );
private event StartPumpCallback CoreOverheating;
```

Subscribing to an Event

Subscribing objects specify a method to be called when the event is raised. If the event has not yet been instantiated, subscribing objects specify a delegate that refers to the method when creating the event. If the event exists, then subscribing objects add a delegate that calls a method when the event is raised.

For example, in the power station scenario, you could create two pump drivers and have them both subscribe to the **CoreOverheating** event:

```
ElectricPumpDriver ed1 = new ElectricPumpDriver( );
PneumaticPumpDriver pd1 = new PneumaticPumpDriver( );
...
CoreOverheating = new
StartPumpCallback( ➥ed1.StartElectricPumpRunning);
CoreOverheating += new StartPumpCallback(pd1.SwitchOn);
```

Note You must declare delegates (and methods) that are used to subscribe to an event as **void**. This restriction does not apply when a delegate is used without an event.

Notifying Subscribers to an Event

To notify the subscribers, you must *raise* the event. The syntax you use is the same as that for calling a method or a delegate. In the power station example, the **SwitchOnAllPumps** method of the core-temperature monitoring component no longer needs to iterate through a list of delegates:

```
public void SwitchOnAllPumps( )
{
  if (CoreOverheating= null) {
      CoreOverheating( );
  }
}
```

Executing the event in this way will cause all of the delegates to be invoked, and, in this example, all of the pumps that subscribe to the event will be activated. Notice that the code first checks that the event has at least one subscribing delegate. Without this check, the code would throw an exception if there were no subscribers.

For information about guidelines and best practices to follow when using events, search for “event guidelines” in the .NET Framework SDK Help documents.

Passing Event Parameters

- **Parameters for Events Should Be Passed As EventArgs**
  - This is because of marshalling
  - Define a class descended from EventArgs to act as a container for event parameters
- **The Same Subscribing Method May Be Called by Several Events**
  - Always pass the event publisher (sender) as the first parameter to the method

Because of the marshalling process that is used to call subscribing methods when an event is raised, there are some guidelines to follow when defining the methods, especially if they require parameters.

Event Parameter Guidelines

To pass parameters to a subscribing method, enclose the parameters in a single class that supplies accessor methods to retrieve them. Derive this class from **System.EventArgs**.

For example, in the power station scenario, assume that the methods that start the pumps, **StartElectricPumpRunning** and **SwitchOn**, need the current core temperature to determine the speed at which the pumps should run. To address this issue, you create the following class to pass the core temperature from the core-monitoring component to the pump objects:

```
public class CoreOverheatingEventArgs: EventArgs
{
    private readonly int temperature;

    public CoreOverheatingEventArgs(int temperature)
    {
        this.temperature = temperature;
    }

    public int GetTemperature( )
    {
        return temperature;
    }
}
```

The **CoreOverheatingEventArgs** class contains an integer parameter. The constructor stores the temperature internally, and you use the method **GetTemperature** to retrieve it.

The sender Object

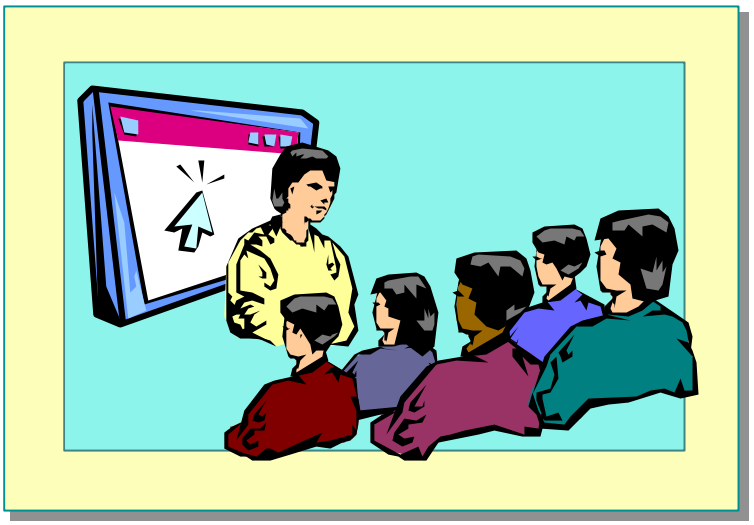
An object may subscribe to more than one event from different publishers and could use the same method in each case. Therefore, it is customary for an event to pass information about the publisher that raised it to the subscribers. By convention, this is the first parameter passed to the subscribing method, and it is usually called *sender*. The following code shows the new versions of the **StartElectricPumpRunning** and **SwitchOn** methods, modified to expect *sender* as the first parameter and the temperature as the second parameter:

```
public class ElectricPumpDriver
{
  ...

  public void StartElectricPumpRunning(object sender,
➥CoreOverheatingEventArgs args)
  {
      // Examine the temperature
      int currentTemperature = args.GetTemperature( );

      // Start the pump at the required speed for
      // this temperature
      ...
  }
  ...
}



public class PneumaticPumpDriver
{
  ...

  public void SwitchOn(object sender,
➥CoreOverheatingEventArgs args)
  {
      // Examine the temperature
      int currentTemperature = args.GetTemperature( );

      // Start the pump at the required speed for
      // this temperature
      ...
  }
  ...
}
```

Note You will also need to modify the delegate in the core-temperature monitoring component. In the power station example, the delegate will become:

```
public delegate void StartPumpCallback(object sender,
➥CoreOverheatingEventArgs args);
```

Demonstration: Handling Events



In this demonstration, you will see an example of how you can use events to communicate information between objects.

Lab 12.2: Defining and Using Events

Objectives

After completing this lab, you will be able to:

- Publish events.
- Subscribe to events.
- Pass parameters to events.

Prerequisites

Before working on this lab, you must be familiar with the following:

- Creating classes in C#
- Defining constructors and destructors
- Compiling and using assemblies

Estimated time to complete this lab: 30 minutes

Exercise 1
Auditing Bank Transactions

This exercise extends the bank example used in Lab 12.1 and other earlier labs. In this exercise, you will create a class called **Audit**. The purpose of this class is to record the changes made to account balances in a text file. The account will be notified of changes by an event published by the **BankAccount** class.

You will use the **Deposit** and **Withdraw** methods of the **BankAccount** class to raise the event, called **Auditing**, which is subscribed to by an **Audit** object.

The **Auditing** event will take a parameter containing a **BankTransaction** object. If you completed the earlier labs, you will recall that the **BankTransaction** class contains the details of a transaction, such as the amount of the transaction, the date it was created, and so on. A **BankTransaction** object is created whenever a deposit or withdrawal is made by using a **BankAccount**.

You will make full use of the event-handling guidelines discussed in the module.

↙ To define the event parameter class

In this exercise, the event that will be raised will be passed a **BankTransaction** object as a parameter. Event parameters should be derived from **System.EventArgs**, so a new class will be created that contains a **BankTransaction**.

1. Open the Audit.sln project in the *install folder*\Labs\Lab12\Starter\Audit folder.
2. Create a new class by using **Add New Item** on the **Project** menu. Make sure that you create a **New C# Class**, and name it **AuditEventArgs.cs**.
3. When the class has been created, add a comment that summarizes the purpose of the **AuditEventArgs** class. Use the exercise description to help you.
4. Change the namespace to **Banking**.
5. Change the definition of **AuditEventArgs** so that it is derived from **System.EventArgs**, as follows:

```
public class AuditEventArgs : System.EventArgs
{
   ...
}
```

6. Create a private readonly **BankTransaction** variable called *transData*, and initialize it to **null**, as follows:

```
private readonly BankTransaction transData = null;
```

7. Create a constructor that takes a single **BankTransaction** parameter called *transaction* and sets **this.transData** to this parameter. The code for the constructor is as follows:

```
public AuditEventArgs(BankTransaction transaction)
{
   this.transData = transaction;
}
```

8. Provide a public accessor method called **getTransaction** that returns the value of **this.transData**, as follows:

```
public BankTransaction getTransaction( )
{
   return this.transData;
}
```

9. Compile the project and correct any errors.

↙ To define the Audit class

1. In the **Audit** project, create a new class by using **Add New Item** from the **Project** menu. Make sure that you create a **New C# Class**, and name it **Audit.cs**. This is the class that will subscribe to the **Auditing** event and write details of transactions to a file on disk.
2. When the class has been created, add a comment that summarizes the purpose of the **Audit** class. Use the exercise description to help you.
3. Change the namespace to **Banking**.
4. Add a **using** directive that refers to **System.IO**.
5. Add a private **string** variable called *filename* to the **Audit** class.
6. Add a private **StreamWriter** variable called *auditFile* to the **Audit** class.

Note A **StreamWriter** allows you to write data to a file. You used **StreamReader** for reading from a file in Lab 6. In this exercise, you will use the **AppendText** method of the **StreamWriter** class.

The **AppendText** method opens a named file to append text to that file. It writes data to the end of the file. You use the **WriteLine** method to actually write data to the file once it is open (just like the **Console** class).

7. Create a constructor in the **Audit** class that takes a single string parameter called *fileToUse*. In the constructor:
   - Set **this.filename** to *fileToUse*.
   - Open this named file in AppendText mode and store the file descriptor in *auditFile*.

The completed code for the constructor is as follows:

```
private string filename;
private StreamWriter auditFile;

public Audit(string fileToUse)
{
  this.filename = fileToUse;
  this.auditFile = File.AppendText(fileToUse);
}
```

8. In the **Audit** class, add the method that will be used to subscribe to the **Auditing** event of the **BankTransaction** class. It will be executed when a **BankTransaction** object raises the event. This method should be public **void** and called **RecordTransaction**. It will take two parameters: an **object** called *sender*, and an **AuditEventArgs** parameter called *eventData*.
9. In the **RecordTransaction** method, add code to:
   - Create a **BankTransaction** variable called *tempTrans*.
   - Execute **eventData.getTransaction( )** and assign the result to *tempTrans*.
   - If *tempTrans* is not **null**, use the **WriteLine** method of **this.auditFile** to append the amount of *tempTrans* (use the **Amount( )** method) and the date created (use the **When( )** method) to the end of the audit file. Do not close the file.

Note The *sender* parameter is not used by this method, but by convention all event-handling methods expect the sender of the event as the first parameter.

The completed code for this method is as follows:

```
public void RecordTransaction(Object sender,
                              AuditEventArgs eventData)
{
   BankTransaction tempTrans = eventData.getTransaction( );
   if (tempTrans == null) {
       return;
   }

   this.auditFile.WriteLine("Amount: {0}\tDate: {1}",
             tempTrans.Amount( ), tempTrans.When( ));
}
```

10. Add a destructor to the **Audit** class that closes **this.auditFile**.

11. In the **Audit** class, create a public **void Dispose** method that invokes the destructor and suppresses any further garbage collection for this object. The complete code for the destructor and the **Finalize** method is as follows:

```
~Audit( )
{
   this.auditFile.Close( );
}

public void Dispose( )
{
   this.Finalize( );
   GC.SuppressFinalize(this);
}
```

12. Compile the project and correct any errors.

↙ To test the Audit class

1. Open the AuditTestHarness.sln project in the *install folder*\Labs\Lab12\Starter\AuditTestHarness folder.
2. Perform the following steps to add a reference to the library containing your compiled **Audit** class. It will be in a dynamic-link library (DLL) called Bank.dll in *install folder*\Labs\Lab12\Starter\Audit\Bin\Debug.
   a. In Solution Explorer, expand the **AuditTestHarness** project tree.
   b. Right-click **References**.
   c. Click **Add Reference**.
   d. Click **Browse**.
   e. Navigate to *install folder*\Labs\Lab12\Starter\Audit\Bin\Debug.
   f. Click **Bank.dll**.
   g. Click **Open**, and then click **OK**.
3. In the **Test** class, review the **Main** method. This class:
   a. Creates an instance of the **Audit** class, using the name AuditTrail.dat for the file name in which it stores the audit information.
   b. Creates a new **BankTransaction** object for an amount of 500 Dollars.
   c. Creates an **AuditEventArgs** object that uses the **BankTransaction** object.
   d. Invokes the **RecordTransaction** method of the **Audit** object.

   The test is repeated with a second transaction for –200 Martian Wombats.

   After the second test, the **Dispose** method is called to ensure that audit records are stored on the disk.
4. Compile the project.
5. Open a Command window and navigate to the folder *install folder*\Labs\Lab12\Starter\AuditTestHarness\Bin\Debug. This folder will contain the AuditTestHarness.exe and Bank.dll files. It will also contain the AuditTestHarness.pdb file, which you can ignore.

6. Execute **AuditTestHarness**.
7. Using a text editor of your choice (Wordpad, for example), examine the contents of the file AuditTrail.dat. It should contain the data for the two transactions.

↙ To define the Auditing event

1. Open the Audit.sln project in the *install folder*\Labs\Lab12\Starter\Audit folder.
2. In the BankAccount.cs file, above the **BankAccount** class, declare a public delegate of type **void** that is called **AuditEventHandler** and takes two parameters—an **Object** called *sender* and an **AuditEventArgs** called *data*—as shown:

```
public delegate void AuditEventHandler(Object sender,
➥AuditEventArgs data);

public class BankAccount
{
  ...
}
```

3. In the **BankAccount** class, declare a private event of type **AuditEventHandler** called **AuditingTransaction**, and initialize it to **null**, as follows:

```
public class BankAccount
{
  private event AuditEventHandler AuditingTransaction =
➥null;
  ...
}
```

4. Add a public **void** method called **AddOnAuditingTransaction**. This method will take a single **AuditEventHandler** parameter called *handler*. The purpose of the method is to add *handler* to the list of delegates that subscribe to the **AuditingTransaction** event. The method will look as follows:

```
public void AddOnAuditingTransaction(AuditEventHandler
➥handler)
{
   this.AuditingTransaction += handler;
}
```

5. Add another public **void** method called **RemoveOnAuditingTransaction**. This method will also take a single **AuditEventHandler** parameter called *handler*. The purpose of this method is to remove *handler* from the list of delegates that subscribe to the **AuditingTransaction** event. The method will look as follows:

```
public void RemoveOnAuditingTransaction(AuditEventHandler
➥handler)
{
   this.AuditingTransaction -= handler;
}
```

6. Add a third method that the **BankAccount** object will use to raise the event and alert all subscribers. The method should be protected virtual **void** and should be called **OnAuditingTransaction**. This method will take a **BankTransaction** parameter called *bankTrans*. The method will examine the event **this.AuditingTransaction**. If it contains any delegates, it will create an **AuditEventArgs** object called *auditTrans*, which will be constructed by using *bankTrans*. It will then cause the delegates to be executed, passing itself in as the sender of the event along with the *auditTrans* parameter as the data. The code for this method will look as follows:

```
protected virtual void
➥OnAuditingTransaction(BankTransaction bankTrans)
{
   if (this.AuditingTransaction != null) {
       AuditEventArgs auditTrans = new
                           AuditEventArgs(bankTrans);
       this.AuditingTransaction(this, auditTrans);
   }
}
```

7. In the **Withdraw** method of **BankAccount,** add a statement that will call **OnAuditingTransaction**. Pass in the transaction object created by the **Withdraw** method. This statement should be placed just prior to the return statement at the end of the method. The completed code for **Withdraw** is as follows:

```
public bool Withdraw(decimal amount)
{
   bool sufficientFunds = accBal >= amount;
   if (sufficientFunds) {
       accBal -= amount;
       BankTransaction theTran = new BankTransaction(-
   ➥amount);
       tranQueue.Enqueue(theTran);
       this.OnAuditingTransaction(theTran);
   }
   return sufficientFunds;
}
```

8. Add a similar statement to the **Deposit** method. The completed code for **Deposit** is as follows:

```
public decimal Deposit(decimal amount)
{
   accBal += amount;
   BankTransaction theTran = new BankTransaction(amount);
   tranQueue.Enqueue(theTran);
   this.OnAuditingTransaction(theTran);
   return accBal;
}
```

9. Compile the project and correct any errors.

↙ To subscribe to the Auditing event

1. The final stage is to create the **Audit** object that will subscribe to the **Auditing** event. This **Audit** object will be part of the **BankAccount** class, and will be created when the **BankAccount** is instantiated, so that each account will get its own audit trail.

   Define a private **Audit** variable called *accountAudit* in the **BankAccount** class, as follows:

   ```
   private Audit accountAudit;
   ```

2. Add a public **void** method to **BankAccount** called **AuditTrail**. This method will create an **Audit** object and subscribe to the **Auditing** event. It will take a **string** parameter, which will be the name of a file to use for the audit trail. The method will:

   - Instantiate *accountAudit* by using this **string**.
   - Create an **AuditEventHandler** variable called *doAuditing* and instantiate it by using the **RecordTransaction** method of *accountAudit*.
   - Add *doAuditing* to the list of subscribers to the **Auditing** event. Use the **AddOnAuditingTransaction** method, passing *doAuditing* as the parameter.

   The completed code for this method is as follows:

   ```
   public void AuditTrail(string auditFileName)
   {
      this.accountAudit = new Audit(auditFileName);
      AuditEventHandler doAuditing = new
   ➥AuditEventHandler(this.accountAudit.RecordTransaction);
      this.AddOnAuditingTransaction(doAuditing);
   }
   ```

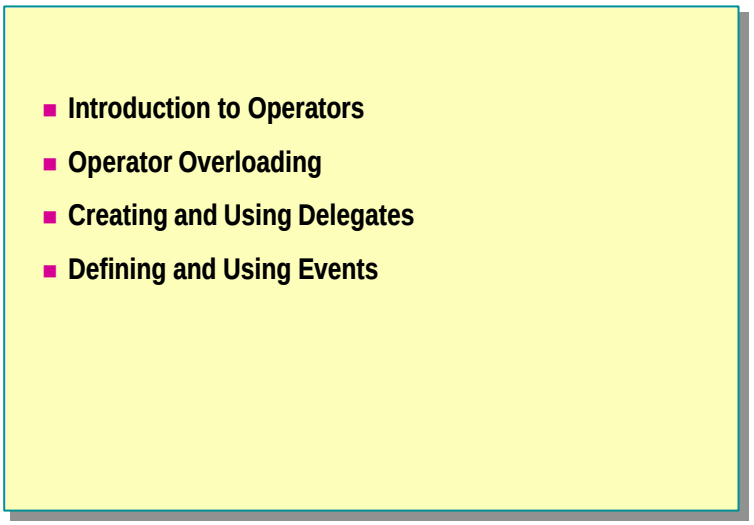
3. In the destructor for the **BankAccount** class, add a statement that invokes the **Dispose** method of the *accountAudit* object. (This is to ensure that all audit records are correctly written to disk.)
4. Compile the project and correct any errors.

↙ To test the Auditing event

1. Open the EventTestHarness.sln project in the *install folder*\Labs\Lab12\Starter\EventTestHarness folder.
2. Perform the following steps to add a reference to the DLL (Bank.dll) containing your compiled **Audit** and **BankAccount** classes. The Bank.dll is located in *install folder*\Labs\Lab12\Starter\Audit\Bin\Debug.
   a. In Solution Explorer, expand the **EventTestHarness** project tree.
   b. Right-click **References**.
   c. Click **Add Reference**.
   d. Click **Browse**.
   e. Navigate to *install folder*\Labs\Lab12\Starter\Audit\Bin\Debug.
   f. Click **Bank.dll**.
   g. Click **Open**, and then click **OK**.

3. In the **Test** class, review the **Main** method. This class:
   a. Creates two bank accounts.
   b. Uses the **AuditTrail** method to cause the embedded **Audit** objects in each account to be created and to subscribe to the **Auditing** event.
   c. Performs a number of deposits and withdrawals on each account.
   d. Closes both accounts.
4. Compile the project and correct any errors.
5. Open a Command window and navigate to the *install folder*\Labs\Lab12\Starter\EventTestHarness\Bin\Debug folder. This folder will contain the EventTestHarness.exe and Bank.dll files. It will also contain the EventTestHarness.pdb file, which you can ignore.
6. Execute EventTestHarness.
7. Using a text editor of your choice, examine the contents of the Account1.dat and Account2.dat files. They should contain the data for the transactions performed on the two accounts.

Review



1. Can the arithmetic compound assignment operators (+=, -=, *=, /=, and %=) be overloaded?

2. Under what circumstances should a conversion operator be explicit?

3. How are explicit conversion operators invoked?

4. What is a delegate?

5. How do you subscribe to an event?

6. In what order are the methods that subscribe to an event called? Will all methods that subscribe to an event always be executed?