

**MATLAB® Compiler SDK™**

.NET User's Guide



**MATLAB®**

R2023a



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Phone: 508-647-7000



The MathWorks, Inc.  
1 Apple Hill Drive  
Natick, MA 01760-2098

*MATLAB® Compiler SDK™ .NET User's Guide*

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# Getting Started

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## MATLAB Compiler SDK .NET Target Requirements

In this section...
“System and Product Requirements” on page 1-2
“Supported Microsoft .NET Versions” on page 1-2
“Data API” on page 1-3
“Development Environment” on page 1-3
“Cross-platform Support” on page 1-4
“MATLAB Compiler SDK .NET Limitations” on page 1-4

### System and Product Requirements

#### System Dependencies

Development of .NET assemblies using MATLAB Compiler SDK is supported on Windows® systems only.

#### Product Dependencies

The following products must be installed prior to installing and using MATLAB Compiler SDK:

- MATLAB
- MATLAB Compiler™

.NET assemblies developed using MATLAB Compiler SDK and integrated with .NET applications require MATLAB Runtime during execution. For details, see “Install and Configure MATLAB Runtime”.

### Supported Microsoft .NET Versions

- Microsoft® .NET Framework 4.x
- Microsoft .NET Core 2.0 or higher
- Microsoft .NET 5.0 or higher

For an up-to-date list of .NET versions supported by MATLAB Compiler SDK, see [https://www.mathworks.com/support/compilers/current\\_release/](https://www.mathworks.com/support/compilers/current_release/).

You can download and install .NET SDK from <https://dotnet.microsoft.com/download>.

#### Compatibility

- If you are loading a deployed application that references an assembly built with version 4.0 or above, you need to install .NET Framework version 4.0 or above (such as 4.7 or 4.8). The .NET Framework used for building the assembly may have a version higher than the one used to load the application.
- If you are loading a deployed application that references an assembly built with version 5.0, you do not need to install .NET to load the application.

- Cross-platform applications can be only be developed using .NET Core 2.0 or higher and .NET 5.0 or higher.

---

**Caution** According to Microsoft, .NET Framework 4.8 is the last version of .NET Framework. For new .NET development, Microsoft recommends using .NET 5.0 or higher.

---

## Data API

MathWorks® provides two data APIs for handling data exchange between a .NET application and deployed MATLAB code:

- MWArray API that works with .NET Framework 4.0 or higher.
- MATLAB Data API for .NET that works with .NET 5.0 or higher and select versions of .NET Framework and .NET Core. For details, see “Compatibility” on page 1-3.

These data APIs are installed on your system when you install MATLAB and MATLAB Compiler SDK or MATLAB Runtime. For assembly reference locations associated with these data APIs, see “.NET Development Environment” on page 10-10.

MATLAB Data API for .NET is shared between MATLAB Compiler SDK and MATLAB Engine. For details, see “Call MATLAB from .NET”.

## Compatibility

If you plan on using the MATLAB Data API for .NET with .NET Framework or .NET Core, you may want to consider the following limitations:

- Deployed applications developed using .NET Framework can run only on Windows systems and not across multiple platforms.
- Only the following .NET Framework versions are supported: 4.6.1, 4.6.2, 4.7, 4.7.1, 4.7.2, 4.8
- According to Microsoft, .NET Framework 4.8 is the last version of .NET Framework.
- .NET Framework does not have a command-line interface for development.
- As of R2022b, .NET Core versions 2.0 to 3.0 are already out of support from Microsoft and .NET Core 3.1 is in a maintenance phase. According to Microsoft, .NET 5.0 and higher represent the successor to .NET Core and are part of the company's plan of a unified .NET stack and ecosystem.

MathWorks recommends using the MATLAB Data API for .NET with .NET 5.0 or higher to deploy MATLAB functions across the broadest array of platforms.

## Development Environment

- Use the MATLAB desktop to author MATLAB code and MATLAB Compiler SDK to generate .NET assemblies or artifacts from MATLAB code.
- Use the .NET command-line interface (CLI) along with a code editor to integrate the assemblies or artifacts generated by MATLAB Compiler SDK with .NET applications. For details, see .NET CLI Overview.

You can also use an integrated development environment (IDE) such as Microsoft Visual Studio® for integrating assemblies or artifacts with applications.

- Test your application against the installed version of MATLAB that was used to generate the .NET artifacts or against MATLAB Runtime. However, during deployment you must use MATLAB Runtime.

## **Cross-platform Support**

- Starting in R2019b, you can build .NET applications on a Windows platform and run them on Linux<sup>®</sup> and macOS using .NET Core. To use this functionality, you must have .NET Core 2.0 or higher installed.
- Starting in R2022a, you can build .NET applications on a Windows platform and run them on Linux and macOS using .NET 5.0 or higher. To use this functionality, you must have .NET 5.0 or higher installed.

## **MATLAB Compiler SDK .NET Limitations**

- The .NET External Interface method `addAssembly` is unsupported.
- Serializing MATLAB objects from MATLAB into .NET code is unsupported.

## **See Also**

### **More About**

- “.NET Development Environment” on page 10-10
- “Install and Configure MATLAB Runtime”
- “Set MATLAB Runtime Path for Deployment”

# Component Integration

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- “Common Integration Tasks and Naming Conventions” on page 2-2
- “Data Marshaling with MWArray API” on page 2-4
- “Convert Data Between .NET and MATLAB” on page 2-6
- “Block Console Display When Creating Figures” on page 2-17
- “Error Handling and Resource Management” on page 2-19
- “Limitations on Multiple Assemblies in Single Application” on page 2-21

## Common Integration Tasks and Naming Conventions

### In this section...

“Component Access On Another Computer” on page 2-2

“Component and Class Naming Conventions” on page 2-2

In “Generate .NET Assembly and Build .NET Application”, steps are illustrated that cover the basics of customizing your code in preparation for integrating your deployed .NET component into a large-scale enterprise application. These steps include:

- Installing MATLAB Runtime on end user computers
- Creating a Microsoft Visual Studio project
- Creating references to the component and the MWArray API
- Specifying component assemblies and namespaces
- Initializing and instantiating your classes
- Invoking the component using some implicit data conversion techniques
- Handling errors using a basic try-catch block

### Component Access On Another Computer

To implement your .NET assembly on a computer other than the one on which it was built:

- 1 If the component is not already installed on the machine where you want to develop your application, run the self-extracting executable that you created in “Generate .NET Assembly and Build .NET Application”.
- 2 Reference the .NET assembly in your Microsoft Visual Studio project or from the command line of a CLS-compliant compiler.

You must also add a reference to the MWArray component in `matlabroot\toolbox\dotnetbuilder\bin\architecture\framework_version`. See “Supported Microsoft .NET Versions” on page 1-2 for a list of supported framework versions.

- 3 Instantiate the generated .NET classes and call the class methods as you would with any .NET class. To marshal data between the native .NET types and the MATLAB array type, you need to use either the MWArray data conversion classes or the MWArray native API.

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**Note** For information about these data conversion classes, see the *MWArray Class Library Reference*, which is also available in the `matlabroot\help\dotnetbuilder\MWArrayAPI` folder, where `matlabroot` represents your MATLAB installation folder.

---

To avoid using data conversion classes, see “Implement Type-Safe Interface and Integrate into .NET Application” on page 7-8.

### Component and Class Naming Conventions

Typically, you should specify names for assemblies and classes that will be clear to programmers who use the generated code. For example, if you are encapsulating many MATLAB functions, it helps to determine a scheme of function categories and to create a separate class for each category. Also, the name of each class should be descriptive of what the class does.

The .NET naming guidelines recommends the use of Pascal case for capitalizing the names of identifiers of three or more characters. That is, the first letter in the identifier and the first letter of each subsequent concatenated word are capitalized. For example:

```
MakeSquare
```

In contrast, MATLAB programmers typically use all lowercase for names of functions. For example:

```
makesquare
```

By convention, the MATLAB Compiler SDK .NET examples use Pascal case.

Valid characters are any alpha or numeric characters, as well as the underscore ( `_` ) character.

### **See Also**

“Supported Microsoft .NET Versions” on page 1-2

### **Related Examples**

- “Generate .NET Assembly and Build .NET Application”
- “Implement Type-Safe Interface and Integrate into .NET Application” on page 7-8

## Data Marshaling with MWArray API

To support data conversion between managed .NET types and MATLAB types, MATLAB Compiler SDK provides a set of data conversion classes derived from the abstract class `MWArray`. These classes allow you to pass most native .NET value types as parameters directly without using explicit data conversion. You reference the `MWArray` assembly in your managed application to convert native arrays to MATLAB arrays and vice versa. This process is called data marshaling.

When you invoke a method on a component, the input and output parameters are a derived type of `MWArray`. To pass parameters, you can either instantiate one of the `MWArray` subclasses explicitly, or, in many cases, pass the parameters as a managed data type and rely on the implicit data conversion feature of MATLAB Compiler SDK.

For examples that demonstrate guidelines for manual data conversion between various native data types and types compatible with MATLAB, see “Convert Data Between .NET and MATLAB” on page 2-6.

### MWArray Data Conversion Classes

The `MWArray` data conversion classes are built as a class hierarchy that represents the major MATLAB array types.

- `MWArray`
- `MWIndexArray`
- `MWCellArray`
- `MWCharacterArray`
- `MWLogicalArray`
- `MWNumericArray`
- `MWStructArray`

The root of the hierarchy is the `MWArray` abstract class. `MWIndexArray` is also an abstract class. The other subclasses represent the major MATLAB array types: `MWNumericArray`, `MWLogicalArray`, `MWCharArray`, `MWCellArray`, and `MWStructArray`.

`MWArray` and its derived classes provide the following functionality:

- Constructors and destructors to instantiate and dispose of MATLAB arrays
- Properties to get and set the underlying array data
- Indexers to support a subset of MATLAB array indexing
- Implicit and explicit data conversion operators
- General methods

For information about these data conversion classes, see the *MWArray Class Library Reference*, which is also available in the `matlabroot\help\dotnetbuilder\MWArrayAPI` folder, where `matlabroot` represents your MATLAB installation folder.

### Pass Data from .NET Code to MATLAB

In most instances, if you use a native .NET primitive or array as an input parameter in a C# program, MATLAB Compiler SDK automatically and transparently converts it to an instance of the appropriate



MArray class before passing it to the generated method. MATLAB Compiler SDK converts most CLS-compliant strings, numeric types, or multidimensional arrays of these types to an appropriate MArray type. For a list of the unsupported types, see “Unsupported MATLAB Array Types” on page 13-7. This conversion is transparent in C# applications, but might require an explicit casting operator in other languages, for example, `op_implicit` in Visual Basic®.

For example, consider the .NET statement:

```
result = theFourier.plotfft(3, data, interval);
```

In this statement, the argument `interval` is of the .NET native type `System.Double`. MATLAB Compiler SDK casts this argument to a MATLAB 1-by-1 double `MWNumericArray` type, which is a wrapper class containing a MATLAB double array.

## Pass Data from MATLAB to .NET Code

All data returned from a MATLAB function to a .NET method is represented as an instance of the appropriate MArray subclass. For example, a MATLAB cell array is returned as an `MWCellArray` object.

Returned data is *not* automatically converted to a native array. If you need to get the corresponding native array type, call the `ToArray` method, which converts a MATLAB array to the appropriate native data type, with some exceptions. Cell arrays, structure arrays, and arrays of complex numbers are not available as native .NET types. To represent these data types, you must create an instance of `MWCellArray`, `MWStructArray`, or `MWNumericArray`, respectively.

For a list of the .NET native data types and their equivalents in MATLAB, see “Rules for Data Conversion Between .NET and MATLAB” on page 13-2.

## See Also

### Related Examples

- “Convert Data Between .NET and MATLAB” on page 2-6
- “Rules for Data Conversion Between .NET and MATLAB” on page 13-2

## Convert Data Between .NET and MATLAB

The MATLAB Compiler SDK product provides the `MWArray` assembly to facilitate data conversion between native data and compiled MATLAB functions. For information on the data conversion classes, see “Data Marshaling with `MWArray` API” on page 2-4.

Refer to the following examples for guidelines on how to marshal data between native .NET and MATLAB data types.

---

**Note** Data objects that merely pass through either the target or MATLAB environments may not need to be marshaled, particularly if they do not cross a process boundary. Because marshaling is costly, only marshal on demand.

---

### Manually Cast to MATLAB Types

#### Native Data Conversion

You can explicitly create a numeric constant using the constructor for the `MWNumericArray` class with a `System.Int32` argument. You then pass this variable to one of the generated .NET methods.

```
int data = 24;
MWNumericArray array = new MWNumericArray(data);
Console.WriteLine("Array is of type " + array.NumericType);
```

When you run this example, the results are:

```
Array is of type double
```

The native integer (`int data`) is converted to an `MWNumericArray` containing a 1-by-1 MATLAB double array, which is the default MATLAB type.

To preserve the integer type, use the `MWNumericArray` constructor that provides the ability to control the automatic conversion.

```
MWNumericArray array = new MWNumericArray(data, false);
```

#### Multidimensional Array Processing

MATLAB and .NET implement different indexing strategies for multidimensional arrays. When you create a variable of type `MWNumericArray`, MATLAB automatically creates an equivalent array, using its own internal indexing. For example, MATLAB indexes using this schema:

```
(row column page1 page2 ...)
```

while .NET indexes as follows:

```
(... page2 page1 row column)
```

Given the multidimensional MATLAB `myarr`:

```
>> myarr(:,:,1) = [1, 2, 3; 4, 5, 6];
>> myarr(:,:,2) = [7, 8, 9; 10, 11, 12];
>> myarr
```

```
myarr(:,:,1) =
```

```
    1    2    3
    4    5    6
```

```
myarr(:,:,2) =
```

```
    7    8    9
   10   11   12
```

You would code this equivalent in .NET:

```
double[, ,] myarr = {{{1.000000, 2.000000, 3.000000},
{4.000000, 5.000000, 6.000000}}, {{7.000000, 8.000000,
9.000000}, {10.000000, 11.000000, 12.000000}}};
```

### MWNumericArray Example

Here is a code fragment that shows how to convert a double value (5.0) to a `MWNumericArray` type:

```
MWNumericArray arraySize = 5.0;
magicSquare = magic.MakeSqr(arraySize);
```

After converting and assigning the double value to the variable `arraySize`, you can use the `arraySize` argument with the MATLAB based method without further conversion. In this example, the MATLAB based method is `magic.MakeSqr(arraySize)`.

### Specify Array Type

If you want to create a MATLAB numeric array of a specific type, set the optional `makeDouble` argument to `False`. The native type then determines the type of the MATLAB array that is created.

Here, the code specifies that the array should be constructed as a MATLAB 1-by-1 16-bit integer array:

```
short data = 24;
MWNumericArray array = new MWNumericArray(data, false);
Console.WriteLine("Array is of type " + array.NumericType);
```

Running this example produces the following results:

```
Array is of type int16
```

### Specify Optional Arguments

In MATLAB, you can use `varargin` and `varargout` to specify arguments that are not required. Consider the following MATLAB function:

```
function y = mysum(varargin)
y = sum([varargin{:}]);
```

This function returns the sum of the inputs. The inputs are provided as a `varargin`, which means that the caller can specify any number of inputs to the function. The result is returned as a scalar double array.

For the `mysum` function, the MATLAB Compiler SDK product generates the following interfaces:

```
// Single output interfaces
public MArray mysum()
public MArray mysum(params MArray[] varargin)
// Standard interface
public MArray[] mysum(int numArgsOut)
public MArray[] mysum(int numArgsOut,
    params MArray[] varargin)
// feval interface
public void mysum(int numArgsOut, ref MArray ArgsOut,
    params MArray[] varargin)
```

You can pass the `varargin` arguments as either an `MArray[]`, or as a list of explicit input arguments. (In C#, the `params` modifier for a method argument specifies that a method accepts any number of parameters of the specific type.) Using `params` allows your code to add any number of optional inputs to the encapsulated MATLAB function.

Here is an example of how you might use the single output interface of the `mysum` method in a .NET application:

```
static void Main(string[] args)
{
    MArray sum= null;
    MySumClass mySumClass = null;
    try
    {
        mySumClass= new MySumClass();
        sum= mySumClass.mysum((double)2, 4);
        Console.WriteLine("Sum= {0}", sum);
        sum= mySumClass.mysum((double)2, 4, 6, 8);
        Console.WriteLine("Sum= {0}", sum);
    }
}
```

The number of input arguments can vary.

---

**Note** For this particular signature, you must explicitly cast the first argument to `MArray` or a type other than integer. Doing this distinguishes the signature from the method signature, which takes an integer as the first argument. If the first argument is not explicitly cast to `MArray` or as a type other than integer, the argument can be mistaken as representing the number of output arguments.

---

### Pass a Variable Number of Outputs

When present, `varargout` arguments are handled in the same way that `varargin` arguments are handled. Consider the following MATLAB function:

```
function varargout = randvectors()
for i=1:nargout
    varargout{i} = rand(1, i);
end
```

This function returns a list of random `double` vectors such that the length of the `i`th vector is equal to `i`. The MATLAB Compiler SDK product generates the following .NET interface to this function:

```
public void randvectors()
public MWArray[] randvectors(int numArgsOut)
public void randvectors(int numArgsOut, ref MWArray[] varargout)
```

In this example, you use the standard interface and request two output arguments.

```
MyVarargoutClass myClass = new MyVarargoutClass();
MWArray[] results = myClass.randvectors(2);
Console.WriteLine("First output= {0}", results[0]);
Console.WriteLine("Second output= {0}", results[1]);
```

## Pass Input Arguments

The following examples show generated code for the `myprimes` MATLAB function, which has the following definition:

```
function p = myprimes(n)
p = primes(n);
```

### Construct a Single Input Argument

The following sample code constructs data as a `MWNumericArray` to be passed as input argument:

```
MWNumericArray data = 5;
MyPrimesClass myClass = new MyPrimesClass();
MWArray primes = myClass.myprimes(data);
```

### Pass a Native .NET Type

This example passes a native double type to the function.

```
MyPrimesClass myClass = new MyPrimesClass();
MWArray primes = myClass.myprimes((double)13);
```

The input argument is converted to a MATLAB 1-by-1 double array, as required by the MATLAB function. This is the default conversion rule for a native double type. For a discussion of the default data conversion for all supported .NET types, see “Rules for Data Conversion Between .NET and MATLAB” on page 13-2.

### Use the `feval` Interface

The `feval` interface passes both input and output arguments on the right-hand side of the function call. The output argument `primes` must be preceded by a `ref` attribute.

```
MyPrimesClass myClass = new MyPrimesClass();
MWArray[] maxPrimes = new MWArray[1];
maxPrimes[0] = new MWNumericArray(13);
MWArray[] primes = new MWArray[1];
myClass.myprimes(1, ref primes, maxPrimes);
```

## Query Type of Return Value

The previous examples show guidelines to use if you know the type and dimensionality of the output argument. Sometimes in MATLAB programming this information is unknown, or can vary. In this case, the code that calls the method might need to query the type and dimensionality of the output arguments.

There are two ways to make the query:

- Use .NET reflection to query any object for its type.
- Use any of several methods provided by the `MWArray` class to query information about the underlying MATLAB array.

### **.NET Reflection**

You can use reflection to dynamically create an instance of a type, bind the type to an existing object, or get the type from an existing object. You can then invoke the type's methods or access its fields and properties. For more information on reflection, see the MSDN Library.

The following code sample calls the `myprimes` method and then determines the type using reflection. The example assumes that the output is returned as a numeric vector array, but the exact numeric type is unknown.

### **GetPrimes Using .NET Reflection**

```
public void GetPrimes(int n)
{
    MWArray primes= null;
    MyPrimesClass myPrimesClass= null;
    try
    {
        myPrimesClass= new MyPrimesClass();
        primes= myPrimesClass.myprimes((double)n);
        Array primesArray= ((MWNumericArray)primes).
            ToVector(MWArrayComponent.Real);
        if (primesArray is double[])
        {
            double[] doubleArray= (double[])primesArray;
            /* Do something with doubleArray . . . */
        }
        else if (primesArray is float[])
        {
            float[] floatArray= (float[])primesArray;
            /* Do something with floatArray . . . */
        }
        else if (primesArray is int[])
        {
            int[] intArray= (int[])primesArray;
            /*Do something with intArray . . . */
        }
        else if (primesArray is long[])
        {
            long[] longArray= (long[])primesArray;
            /*Do something with longArray . . . */
        }
        else if (primesArray is short[])
        {
            short[] shortArray= (short[])primesArray;
            /*Do something with shortArray . . . */
        }
        else if (primesArray is byte[])
        {
            byte[] byteArray= (byte[])primesArray;
            /*Do something with byteArray . . . */
        }
    }
}
```

```

    }
    else
    {
        throw new ApplicationException("
            Bad type returned from myprimes");
    }
}
}

```

The example uses the `toVector` method to return a .NET primitive array (`primesArray`), which represents the underlying MATLAB array. See the following code fragment from the example:

```

primes= myPrimesClass.myprimes((double)n);
    Array primesArray= ((MWNumericArray)primes).
        ToVector(MWArrayComponent.Real);

```

The `toVector` is a method of the `MWNumericArray` class. It returns a copy of the array component in column major order. The type of the array elements is determined by the data type of the numeric array.

### MWArray Query

This example uses the `MWNumericArray.NumericType` method, along with `MWNumericType` enumeration to determine the type of the underlying MATLAB array. See the `switch (numericType)` statement.

### GetPrimes Using MWArray Query

```

public void GetPrimes(int n)
{
    MWArray primes= null;
    MyPrimesClass myPrimesClass= null;
    try
    {
        myPrimesClass= new MyPrimesClass();
        primes= myPrimesClass.myprimes((double)n);
        if ((!primes.IsNumericArray) || (2 !=
            primes.NumberofDimensions))
        {
            throw new ApplicationException("Bad type returned
                by mwprimes");
        }
        MWNumericArray _primes= (MWNumericArray)primes;
        MWNumericType numericType= _primes.NumericType;
        Array primesArray= _primes.ToVector(
            MWArrayComponent.Real);
        switch (numericType)
        {
            case MWNumericType.Double:
            {
                double[] doubleArray= (double[])primesArray;
                /* (Do something with doubleArray . . .) */
                break;
            }
            case MWNumericType.Single:
            {
                float[] floatArray= (float[])primesArray;
                /* (Do something with floatArray . . .) */
            }
        }
    }
}

```

```
        break;
    }
    case MWNumericType.Int32:
    {
        int[] intArray= (int[])primesArray;
        /* (Do something with intArray . . .) */
        break;
    }
    case MWNumericType.Int64:
    {
        long[] longArray= (long[])primesArray;
        /* (Do something with longArray . . .) */
        break;
    }
    case MWNumericType.Int16:
    {
        short[] shortArray= (short[])primesArray;
        /* (Do something with shortArray . . .) */
        break;
    }
    case MWNumericType.UInt8:
    {
        byte[] byteArray= (byte[])primesArray;
        /* (Do something with byteArray . . .) */
        break;
    }
    default:
    {
        throw new ApplicationException("Bad type returned
            by myprimes");
    }
    }
}
}
```

The code in the example also checks the dimensionality by calling `NumberOfDimensions`; see the following code fragment:

```
if ((!primes.IsNumericArray) || (2 !=
    primes.NumberofDimensions))
    {
        throw new ApplicationException("Bad type returned
            by mwprimes");
    }
```

This call throws an exception if the array is not numeric and of the proper dimension.

## Pass Objects by Reference

`MWObjectArray`, a special subclass of `MWArray`, lets you create a MATLAB array that references .NET objects.

You can create a MATLAB code wrapper around .NET objects using `MWObjectArray`. Use this technique to pass objects by reference to MATLAB functions and return .NET objects. The examples in this section present some common use cases.



## Pass .NET Object into .NET Assembly

To pass an object into a MATLAB Compiler SDK assembly:

- 1 Write the MATLAB function that references a .NET type.

```
function addItem(hDictionary, key, value)

    if ~isa(hDictionary, 'System.Collections.Generic.IDictionary')
        error('foo:IncorrectType',
            ... 'expecting a System.Collections.Generic.Dictionary');
    end

    hDictionary.Add(key, value);

end
```

- 2 Create a .NET object to pass to the MATLAB function.

```
Dictionary char2Ascii= new Dictionary();
char2Ascii.Add("A", 65);
char2Ascii.Add("B", 66);
```

- 3 Create an instance of `MWObjectArray` to wrap the .NET object.

```
MWObjectArray MWchar2Ascii=
    new MWObjectArray(char2Ascii);
```

- 4 Pass the wrapped object to the MATLAB function.

```
myComp.addItem(MWchar2Ascii, 'C', 67);
```

## Return Custom .NET Object in MATLAB Function Using Deployed .NET Assembly

You can use `MWObjectArray` to clone an object inside a MATLAB Compiler SDK .NET assembly. Continuing with the previous example, perform the following steps:

- 1 Write the MATLAB function that references a .NET type.

```
function result= add(hMyDouble, value)

    if ~isa(hMyDouble, 'MyDoubleComp.MyDouble')
        error('foo:IncorrectType', 'expecting a MyDoubleComp.MyDouble');
    end
    hMyDoubleClone= hMyDouble.Clone();
    result= hMyDoubleClone.Add(value);

end
```

- 2 Create the object.

```
MyDouble myDouble= new MyDouble(75);
```

- 3 Create an instance of `MWObjectArray` to wrap the .NET object.

```
MWObjectArray MWdouble= new MWObjectArray(myDouble);
origRef = new MWObjectArray(hash);
```

- 4 Pass the wrapped object to the MATLAB function and retrieve the returned cloned object.

```
MWObjectArray result=
    (MWObjectArray)myComp.add(MWdouble, 25);
```

- 5 Unwrap the .NET object and print the result.

```
MyDouble doubleClone= (MyDouble)result.Object;

Console.WriteLine(myDouble.ToDouble());
Console.WriteLine(doubleClone.ToDouble());
```

### **Clone MWObjectArray**

When calling the `Clone` method on `MWObjectArray`, the following rules apply for the wrapped object:

- If the wrapped object is a `ValueType`, it is deep-copied.
- If an object is not a `ValueType` and implements `ICloneable`, the `Clone` method for the object is called.
- The `MemberwiseClone` method is called on the wrapped object.

```
MWObjectArray aDate = new MWObjectArray(new  
    DateTime(1, 1, 2010));  
MWObjectArray clonedDate = aDate.Clone();
```

### **Optimization Using MWObjectArray**

For a full example of how to use `MWObjectArray` to create a reference to a .NET object and pass it to a component, see “Integrate MATLAB Optimization Routines with Objective Functions” on page 3-35.

### **MWObjectArray and Application Domains**

Every ASP .NET web application deployed to IIS is started in a separate `AppDomain`.

The MATLAB .NET interface must support the .NET type wrapped by `MWObjectArray`. If the `MWObjectArray` is created in the default `AppDomain`, the wrapped type has no other restrictions.

If the `MWObjectArray` is not created in the default `AppDomain`, the wrapped .NET type must be serializable. This limitation is imposed by the fact that the object needs to be marshaled from the non-default `AppDomain` to the default `AppDomain` in order for MATLAB to access it.

### **MWObjectArray Limitation**

If you have any global objects in your C# code, then you will get a Windows exception on exiting the application. To overcome this limitation, use one of these solutions:

- Explicitly clear global objects before exiting the application.  

```
globalObj.Destroy();
```
- Call `TerminateApplicationEx` method before exiting the application.  

```
MWMCR.TerminateApplicationEx();
```

For more information on `TerminateApplicationEx`, see the `MWArray` Class Library Reference.

## **Access Real or Imaginary Components Within Complex Arrays**

### **Component Extraction**

When you access a complex array (an array made up of both real and imaginary data), you extract both real and imaginary parts (called components) by default. This method call extracts both real and imaginary components:

```
MWNumericArray complexResult= complexDouble[1, 2];
```

It is also possible to extract only the real or imaginary component of a complex matrix by calling the appropriate component indexing method.

### Component Indexing on Complex Numeric Arrays

To return the real or imaginary component from a full complex numeric array, call the `.real` or `.imaginary` method on `MWArrayComponent`.

```
complexResult= complexDouble[MWArrayComponent.Real, 1, 2];
complexResult= complexDouble[MWArrayComponent.Imaginary, 1, 2];
```

To assign the real or imaginary component to a full complex numeric array, call the `.real` or `.imaginary` method on `MWArrayComponent`.

```
matrix[MWArrayComponent.Real, 2, 2]= 5;
matrix[MWArrayComponent.Imaginary, 2, 2]= 7;
```

You can return the real or imaginary component from a sparse complex numeric array in Microsoft Visual Studio 8 and later.

```
complexResult= sparseComplexDouble[MWArrayComponent.Real, 4, 3];
complexResult = sparseComplexDouble[MWArrayComponent.Imaginary, 4, 3];
```

### Convert MATLAB Arrays to .NET Arrays

To convert MATLAB arrays to .NET arrays call the `toArray` method with either the `.real` or `.imaginary` method on `MWArrayComponent`.

```
Array nativeArray_real= matrix.ToArray(MWArrayComponent.Real);
Array nativeArray_imag= matrix.ToArray(MWArrayComponent.Imaginary);
```

### Convert MATLAB Arrays to .NET Vectors

To convert MATLAB vectors to .NET vectors (single dimension arrays) call the `.real` or `.imaginary` method on `MWArrayComponent`.

```
Array nativeArray= sparseMatrix.ToVector(MWArrayComponent.Real);
Array nativeArray= sparseMatrix.ToVector(MWArrayComponent.Imaginary);
```

## Jagged Array Processing

A jagged array is an array whose elements are arrays. The elements of a jagged array can be of different dimensions and sizes, as opposed to the elements of a non-jagged array whose elements are of the same dimensions and size.

Web services, in particular, process data almost exclusively in jagged arrays.

`MWNumericArrays` can only process jagged arrays with a rectangular shape.

In the following code snippet, a rectangular jagged array of type `int` is initialized and populated.

```
int[][] jagged = new int[5][];
for (int i = 0; i < 5; i++)
    jagged[i] = new int[10];
MWNumericArray jaggedMWArray = new MWNumericArray(jagged);
Console.WriteLine(jaggedMWArray);
```

### **See Also**

### **Related Examples**

- “Data Marshaling with MWArray API” on page 2-4
- “Rules for Data Conversion Between .NET and MATLAB” on page 13-2

## Block Console Display When Creating Figures

### In this section...

“WaitForFiguresToDie Method” on page 2-17

“Using WaitForFiguresToDie to Block Execution” on page 2-17

### WaitForFiguresToDie Method

The MATLAB Compiler SDK product adds a `WaitForFiguresToDie` method to each .NET class that it creates.

The purpose of `WaitForFiguresToDie` is to block execution of a calling program as long as figures created in encapsulated MATLAB code are displayed. Typically you use `WaitForFiguresToDie` when:

- There are one or more figures open that were created by a .NET assembly created by the MATLAB Compiler SDK product.
- The method that displays the graphics requires user input before continuing.
- The method that calls the figures was called from `main()` in a console program.

When `WaitForFiguresToDie` is called, execution of the calling program is blocked if any figures created by the calling object remain open.

`WaitForFiguresToDie` takes no arguments. Your application can call `WaitForFiguresToDie` any time during execution.

---

**Tip** Consider using the `console.readline` method when possible, as it accomplishes much of this functionality in a standardized manner.

---



---

**Caution** Calling `WaitForFiguresToDie` from an interactive program can make the application stop responding. This method should be called *only* from console-based programs.

---

### Using WaitForFiguresToDie to Block Execution

The following example illustrates using `WaitForFiguresToDie` from a .NET application. The example uses a .NET assembly created by the MATLAB Compiler SDK product. The component encapsulates MATLAB code that draws a simple plot.

- 1 Create a work folder for your source code. In this example, the folder is `D:\work\plotdemo`.
- 2 In this folder, create the following MATLAB file named `drawplot.m`:

```
function drawplot()
plot(1:10);
```

- 3 Build the .NET component with the **Library Compiler** app or `compiler.build.dotNETAssembly` using the following information:

Field	Value
Library Name	Figure

Field	Value
Class Name	Plotter
File to Compile	drawplot.m

For example, if you are using `compiler.build.dotNETAssembly`, type:

```
buildResults = compiler.build.dotNETAssembly('drawplot.m', ...  
'AssemblyName','Figure', ...  
'ClassName','Plotter');
```

For more details, see the instructions in “Generate .NET Assembly and Build .NET Application”.

- 4 In Visual Studio, create a C# **Console App (.NET Framework)**. Replace the generated source code with the following code:

```
using Figure.Plotter;  
  
public class Main  
{  
    public static void main(String[] args)  
    {  
        try  
        {  
            plotter p = new Plotter();  
            try  
            {  
                p.drawplot();  
                p.WaitForFiguresToDie();  
            }  
            catch (Exception e)  
            {  
                console.WriteLine(e);  
            }  
        }  
    }  
}
```

- 5 Add a reference to your generated assembly file `Figure.dll`.
- 6 Compile and run the application.

The program displays a plot from 1 to 10 in a MATLAB figure window. The application ends when you close the figure.

---

**Note** To see what happens without the call to `WaitForFiguresToDie`, comment out the call, rebuild the application, and run it. In this case, the figure is drawn and is immediately destroyed as the application exits.

---

## See Also

**Library Compiler** | `compiler.build.dotNETAssembly` | `deploytool`

## Related Examples

- “Generate .NET Assembly and Build .NET Application”
- “Integrate Simple MATLAB Function into .NET Application” on page 3-2

## Error Handling and Resource Management

When creating the .NET application, it is a good practice to properly handle run-time errors and manage resources.

### Error Handling

As with managed code, any errors that occur during execution of a MATLAB function or during data conversion are signaled by a standard .NET exception.

Like any other .NET application, an application that calls a method generated by MATLAB Compiler SDK can handle errors by either catching and handling the exception locally or allowing the calling method to catch it.

Here are examples for each way of error handling.

In the `GetPrimes` example, the method itself handles the exception.

```
public double[] GetPrimes(int n)
{
    MWArray primes= null;
    MyPrimesClass myPrimesClass= null;
    try
    {
        myPrimesClass= new MyPrimesClass();
        primes= myPrimesClass.myprimes((double)n);
        return ((double[])(MWNumericArray)primes).
            ToVector(MWArrayComponent.Real);
    }
    catch (Exception ex)
    {
        Console.WriteLine("Exception: {0}", ex);
        return new double[0];
    }
}
```

In the next example, the method that calls `myprimes` does not catch the exception. Instead, its calling method (that is, the method that calls the method that calls `myprimes`) handles the exception.

```
public double[] GetPrimes(int n)
{
    MWArray primes= null;
    MyPrimesClass myPrimesClass= null;
    try
    {
        myPrimesClass= new MyPrimesClass();
        primes= myPrimesClass.myprimes((double)n);
        return ((double[])(MWNumericArray)primes).
            ToVector(MWArrayComponent.Real);
    }
    catch (Exception e)
    {
        throw;
    }
}
```

```
    }  
}
```

## Freeing Resources Explicitly

Typically, the `Dispose` method is called from a `finally` section in a `try-finally` block.

```
try  
{  
    /* Allocate a huge array */  
    MWNumericArray array = new MWNumericArray(1000,1000);  
    .  
    . (use the array)  
    .  
}  
finally  
{  
    /* Explicitly dispose of the managed array and its */  
    /* native resources */  
    if (null != array)  
    {  
        array.Dispose();  
    }  
}
```

The statement `array.Dispose()` frees the memory allocated by both the managed wrapper and the native MATLAB array.

The `MWArray` class provides two disposal methods: `Dispose` and the static method `DisposeArray`. The `DisposeArray` method is more general in that it disposes of either a single `MWArray` or an array of arrays of type `MWArray`.



## Limitations on Multiple Assemblies in Single Application

### In this section...

“Work with MATLAB Function Handles” on page 2-21

“Work with Objects” on page 2-22

When developing applications that use multiple MATLAB .NET assemblies, consider that the following cannot be shared between assemblies:

- MATLAB function handles
- MATLAB figure handles
- MATLAB objects
- C, Java®, and .NET objects
- Executable data stored in cell arrays and structures

### Work with MATLAB Function Handles

MATLAB function handles can be passed between an application and the MATLAB Runtime instance from which it originated. However, a MATLAB function handle cannot be passed into a MATLAB Runtime instance other than the one in which it originated. For example, suppose you had two MATLAB functions, `get_plot_handle` and `plot_xy`, and `plot_xy` used the function handle created by `get_plot_handle`.

#### `get_plot_handle.m`

```
function h = get_plot_handle(lnSpec, lnWidth, mkEdge, mkFace, mkSize)
h = @draw_plot;
    function draw_plot(x, y)
        plot(x, y, lnSpec, ...
            'LineWidth', lnWidth, ...
            'MarkerEdgeColor', mkEdge, ...
            'MarkerFaceColor', mkFace, ...
            'MarkerSize', mkSize)
    end
end
```

#### `plot_xy.m`

```
function plot_xy(x, y, h)
h(x, y);
end
```

If you compiled them into two shared libraries, the call to `plot_xy` would throw an exception.

```
using System;

using MathWorks.MATLAB.NET.Utility;
using MathWorks.MATLAB.NET.Arrays;

using get_plot_handle;
using plot_xy;

namespace MathWorks.Examples.PlotApp
{
    class PlotCSApp
    {
        static void Main(string[] args)
```

```
{
  try
  {
    // Create objects for the generated functions
    get_plot_handle.Class1 plotter=
      new get_plot_handle.Class1();
    plot_xy.Class1 plot = new plot_xy.Class1();

    MWArray h = plotter.get_plot_handle('--rs', (double)2,
      'k','g', (double)10);

    double[] x_data = {1,2,3,4,5,6,7,8,9};
    double[] y_data = {2,6,12,20,30,42,56,72,90};
    MWArray x = new MWArray(x_data);
    MWArray y = new MWArray(y_data);
    plot.plot_xy(x, y, h);
  }

  catch(Exception exception)
  {
    Console.WriteLine("Error: {0}", exception);
  }
}
}
```

The correct way to handle the situation is to compile both functions into a single assembly.

```
using System;

using MathWorks.MATLAB.NET.Utility;
using MathWorks.MATLAB.NET.Arrays;

using plot_functions;

namespace MathWorks.Examples.PlotApp
{
  class PlotCSApp
  {
    static void Main(string[] args)
    {
      try
      {
        // Create object for the generated functions
        Class1 plot= new Class1();

        MWArray h = plot.get_plot_handle('--rs', (double)2,
          'k','g', (double)10);

        double[] x_data = {1,2,3,4,5,6,7,8,9};
        double[] y_data = {2,6,12,20,30,42,56,72,90};
        MWArray x = new MWArray(x_data);
        MWArray y = new MWArray(y_data);
        plot.plot_xy(x, y, h);
      }

      catch(Exception exception)
      {
        Console.WriteLine("Error: {0}", exception);
      }
    }
  }
}
```

## Work with Objects

MATLAB Compiler SDK enables you to return the following types of objects from the MATLAB Runtime to your application code:

- MATLAB
- C++
- .NET

- Java

However, you cannot pass an object created in one MATLAB Runtime instance into a different MATLAB Runtime instance. This conflict can happen when a function that returns an object and a function that manipulates that object are compiled into different assemblies.

For example, you develop a bank account class and two functions. The first creates a bank account for a customer based on some set of conditions. The second transfers funds between two accounts.

### **account.m**

```
% Saved as account.m
classdef account < handle

    properties
        name
    end

    properties (SetAccess = protected)
        balance = 0
        number
    end

    methods
        function obj = account(name)
            obj.name = name;
            obj.number = round(rand * 1000);
        end

        function deposit(obj, deposit)
            new_bal = obj.balance + deposit;
            obj.balance = new_bal;
        end

        function withdraw(obj, withdrawl)
            new_bal = obj.balance - withdrawl;
            obj.balance = new_bal;
        end
    end
end
```

### **open\_acct .m**

```
% Saved as open_acct .m
function acct = open_acct(name, open_bal )

    acct = account(name);

    if open_bal > 0
        acct.deposit(open_bal);
    end

end
```

### **transfer.m**

```
% Saved as transfer.m
function transfer(source, dest, amount)
```

```
if (source.balance > amount)
    dest.deposit(amount);
    source.withdraw(amount);
end
```

```
end
```

If you compiled `open_acct.m` and `transfer.m` into separate assemblies, you could not transfer funds using accounts created with `open_acct`. The call to `transfer` throws an exception.

One way of resolving this is to compile both functions into a single assembly. You could also refactor the application such that you are not passing MATLAB objects to the functions.

# C# Integration Examples

---

- “Integrate Simple MATLAB Function into .NET Application” on page 3-2
- “Integrate Function with Variable Number of Arguments” on page 3-13
- “Use Multiple Classes in .NET Assembly” on page 3-19
- “Assign Multiple MATLAB Functions in Component Class” on page 3-27
- “Integrate MATLAB Optimization Routines with Objective Functions” on page 3-35
- “Build .NET Core Application That Runs on Linux and macOS” on page 3-40
- “Build .NET 5.0 Application That Runs on Linux and macOS” on page 3-45

## Integrate Simple MATLAB Function into .NET Application

### In this section...

“Prerequisites” on page 3-2

“Create Simple Plot” on page 3-2

“Create Phone Book” on page 3-7

**Note** The examples for the MATLAB Compiler SDK product are in `matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET`, where *VSVersion* specifies the version of Microsoft Visual Studio .NET you are using. You can load projects for all the examples by opening the following solution in Visual Studio:

```
matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\DotNetExamples.sln
```

The Simple Plot on page 3-2 example shows you how to create a .NET assembly that calls a MATLAB function to display a plot. For an example that uses a MATLAB function to modify a structure array, see Phone Book on page 3-7.

In the following examples, you perform these steps to integrate a MATLAB function into a .NET application:

- Use the MATLAB Compiler SDK product to convert a MATLAB function to a method of a .NET class and wrap the class in a .NET assembly.
- Access the component in either a C# application or a Visual Basic application by instantiating your .NET class and using the `MWArray` class library to handle data conversion.
- Build and run the generated application using the Visual Studio .NET development environment.

### Prerequisites

- Verify that you have met all of the MATLAB Compiler SDK .NET target requirements. For details, see “MATLAB Compiler SDK .NET Target Requirements” on page 1-2.
- Verify that you have Microsoft Visual Studio installed.
- End users must have an installation of MATLAB Runtime to run the application. For details, see “Install and Configure MATLAB Runtime”.

For testing purposes, you can use an installation of MATLAB instead of MATLAB Runtime.

### Create Simple Plot

#### Files

MATLAB Function Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\PlotExample\PlotComp\drawgraph.m</code>
C# Code Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\PlotExample\PlotCSApp\PlotApp.cs</code>

Visual Basic Code Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\PlotExample\PlotVBAApp\PlotApp.vb</code>
----------------------------	--

## Procedure

- 1 Copy the following folder that ships with the MATLAB product to your work folder:

```
matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\PlotExample
```

At the MATLAB command prompt, navigate to the `PlotExample\PlotComp` subfolder in your work folder.

- 2 Examine the `drawgraph` function located in `PlotExample\PlotComp`.

```
function drawgraph(coords)
plot(coords(1,:), coords(2,:));
pause(5)
```

Test the function at the MATLAB command prompt.

```
x = 0:0.01:10;
y = sin(x);
z = [x;y];
drawgraph(z)
```

The function outputs a figure that displays a sine wave.

- 3 Build the .NET component with the **Library Compiler** app or compiler.`build.dotNETAssembly` using the following information:

Field	Value
Library Name	PlotComp
Class Name	Plotter
File to Compile	drawgraph.m

For example, if you are using `compiler.build.dotNETAssembly`, type:

```
buildResults = compiler.build.dotNETAssembly('drawgraph.m', ...
'AssemblyName','PlotComp', ...
'ClassName','Plotter');
```

For more details, see the instructions in “Generate .NET Assembly and Build .NET Application”.

- 4 Decide whether you are using C# or Visual Basic to access the component.

- **C#**

If you are using C#, write source code for a C# application that accesses the component.

The sample application for this example is in `PlotExample\PlotCSApp\PlotApp.cs`.

### PlotApp.cs

```
using System;

using MathWorks.MATLAB.NET.Utility;
using MathWorks.MATLAB.NET.Arrays;

using PlotComp;

namespace MathWorks.Examples.PlotApp
{
    /// <summary>
    /// This application demonstrates plotting x-y data by graphing a simple
    /// parabola into a MATLAB figure window.

```

```
/// </summary>
class PlotCSApp
{
    #region MAIN

    /// <summary>
    /// The main entry point for the application.
    /// </summary>
    [STAThread]
    static void Main(string[] args)
    {
        try
        {
            const int numPoints= 10; // Number of points to plot

            // Allocate native array for plot values
            double [,] plotValues= new double[2, numPoints];

            // Plot 5x vs x^2
            for (int x= 1; x <= numPoints; x++)
            {
                plotValues[0, x-1]= x*5;
                plotValues[1, x-1]= x*x;
            }

            // Create a new plotter object
            Plotter plotter= new Plotter();

            // Plot the two sets of values - Note the ability to cast
            // the native array to a MATLAB numeric array
            plotter.drawgraph((MWNumericArray)plotValues);

            Console.ReadLine(); // Wait for user to exit application
        }

        catch(Exception exception)
        {
            Console.WriteLine("Error: {0}", exception);
        }
    }

    #endregion
}
}
```

This statement creates an instance of the `Plotter` class:

```
Plotter plotter= new Plotter();
```

This statement explicitly casts the native `plotValues` to `MWNumericArray` and then calls the method `drawgraph`:

```
plotter.drawgraph((MWNumericArray)plotValues);
```

- **Visual Basic**

If you are using Visual Basic, write source code for a Visual Basic application that accesses the component.

The sample application for this example is in `PlotExample\PlotVBApp\PlotApp.vb`.

#### **PlotApp.vb**

```
Imports System

Imports MathWorks.MATLAB.NET.Utility
Imports MathWorks.MATLAB.NET.Arrays

Imports PlotComp
```



```

Namespace MathWorks.Examples.PlotApp
    ' <summary>
    ' This application demonstrates plotting x-y data by graphing a simple
    ' parabola into a MATLAB figure window.
    ' </summary>
    Class PlotDemoApp
#Region " MAIN "
        ' <summary>
        ' The main entry point for the application.
        ' </summary>
        Shared Sub Main(ByVal args() As String)
            Try
                Const numPoints As Integer = 10 ' Number of points to plot
                Dim idx As Integer
                Dim plotValues(,) As Double = New Double(1, numPoints - 1) {}
                Dim coords As MWNumericArray

                'Plot 5x vs x^2
                For idx = 0 To numPoints - 1
                    Dim x As Double = idx + 1
                    plotValues(0, idx) = x * 5
                    plotValues(1, idx) = x * x
                Next idx

                coords = New MWNumericArray(plotValues)

                ' Create a new plotter object
                Dim plotter As Plotter = New Plotter

                ' Plot the values
                plotter.drawgraph(coords)

                Console.ReadLine() ' Wait for user to exit application

            Catch exception As Exception
                Console.WriteLine("Error: {0}", exception)
            End Try
        End Sub
#End Region
    End Class
End Namespace

```

This statement creates an instance of the `Plotter` class:

```
Dim plotter As Plotter = New Plotter
```

This statement calls the method `drawgraph`:

```
plotter.drawgraph(coords)
```

In either case, the `PlotApp` program does the following:

- Creates two arrays of double values.
- Creates a `Plotter` object.
- Calls the `drawgraph` method to plot the equation using the MATLAB `plot` function.
- Uses `MWNumericArray` to represent the data needed by the `drawgraph` method to plot the equation.
- Uses a `try-catch` block to catch and handle any exceptions.

5 Open the .NET project file that corresponds to your application language using Visual Studio.

- **C#**

If you are using C#, the `PlotCSApp` folder contains a Visual Studio .NET project file for this example. Open the project in Visual Studio .NET by double-clicking `PlotCSApp.csproj` in Windows Explorer. You can also open it from the desktop by right-clicking **PlotCSApp.csproj** and selecting **Open Outside MATLAB**.

- **Visual Basic**

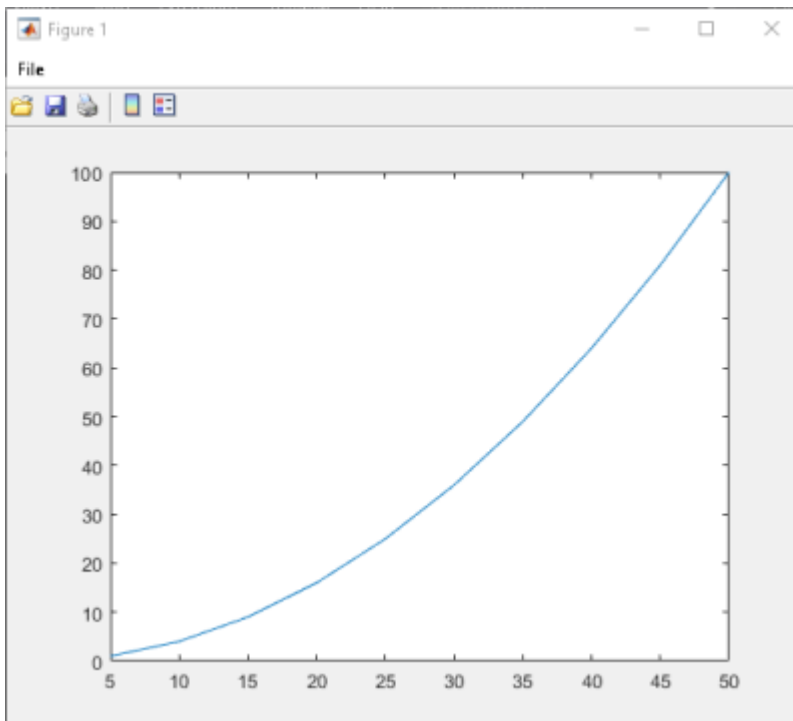
If you are using Visual Basic, the `PlotVBApp` folder contains a Visual Studio .NET project file for this example. Open the project in Visual Studio .NET by double-clicking `PlotVBApp.vbproj` in Windows Explorer. You can also open it from the desktop by right-clicking **PlotVBApp.vbproj** and selecting **Open Outside MATLAB**.

- 6 Add a reference to your assembly file `PlotComp.dll` located in the folder where you generated or installed the assembly.
- 7 Add a reference to the `MWArray` API.

If MATLAB is installed on your system	<code>matlabroot\toolbox\dotnetbuilder\bin\win64\&lt;version&gt;\MWArray.dll</code>
If MATLAB Runtime is installed on your system	<code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\toolbox\dotnetbuilder\bin\win64\&lt;version&gt;\MWArray.dll</code>

- 8 Build and run the `PlotApp` application in Visual Studio .NET.

The application displays the following plot:



- 9 To follow up on this example:
  - Try running the generated application on a different computer.
  - Try building an installer for the package using `compiler.package.installer`.
  - Try integrating an assembly that consists of multiple functions.

## Create Phone Book

In this example, you create a .NET assembly that calls a MATLAB function to modify a structure array that contains phone numbers.

### Files

MATLAB Function Location	<i>matlabroot</i> \toolbox\dotnetbuilder\Examples\VSVersion\NET\PhoneBookExample\PhoneBookComp\makephone.m
C# Code Location	<i>matlabroot</i> \toolbox\dotnetbuilder\Examples\VSVersion\NET\PhoneBookExample\PhoneBookCSApp\PhoneBookApp.cs
Visual Basic Code Location	<i>matlabroot</i> \toolbox\dotnetbuilder\Examples\VSVersion\NET\PhoneBookExample\PhoneBookVBApp\PhoneBookApp.vb

### Procedure

- 1 Copy the following folder that ships with MATLAB to your work folder:

*matlabroot*\toolbox\dotnetbuilder\Examples\VSVersion\NET\PhoneBookExample

At the MATLAB command prompt, navigate to the PhoneBookExample\PhoneBookComp subfolder in your work folder.

- 2 Examine the makephone function located in PhoneBookExample\PhoneBookComp.

```
function book = makephone(friends)
book = friends;
for i = 1:numel(friends)
    numberStr = num2str(book(i).phone);
    book(i).external = ['(508) 555-' numberStr];
end
```

Test the function at the MATLAB command prompt.

```
friends(1).name = "Jordan Robert";
friends(1).phone = 3386;
friends(2).name = "Mary Smith";
friends(2).phone = 3912;
struct2table(makephone(friends))
```

ans =

2x3 table

name	phone	external
"Jordan Robert"	3386	{ '(508) 555-3386' }
"Mary Smith"	3912	{ '(508) 555-3912' }

- 3 Build the .NET component with the **Library Compiler** app or `compiler.build.dotNETAssembly` using the following information:

Field	Value
Library Name	PhoneBookComp

Field	Value
Class Name	PhoneBook
File to Compile	makephone

For example, if you are using `compiler.build.dotNETAssembly`, type:

```
buildResults = compiler.build.dotNETAssembly('makephone.m', ...
'AssemblyName', 'PhoneBookComp', ...
'ClassName', 'PhoneBook');
```

For more details, see the instructions in “Generate .NET Assembly and Build .NET Application”.

#### 4 Decide whether you are using C# or Visual Basic to access the component.

- **C#**

If you are using C#, write source code for a C# application that accesses the component.

The sample application for this example is in  
PhoneBookExample\PhoneBookCSApp\PhoneBookApp.cs.

#### PhoneBookApp.cs

```
/* Necessary package imports */
using System;
using System.Collections.Generic;
using System.Text;
using MathWorks.MATLAB.NET.Arrays;
using PhoneBookComp;

namespace MathWorks.Examples.PhoneBookApp
{
    //
    // This class demonstrates the use of the MWStructArray class
    //
    class PhoneBookApp
    {
        static void Main(string[] args)
        {
            PhoneBook thePhonebook = null; /* Stores deployment class instance */
            MWStructArray friends= null; /* Sample input data */
            MWArray[] result= null; /* Stores the result */
            MWStructArray book= null; /* Output data extracted from result */

            /* Create the new deployment object */
            thePhonebook= new PhoneBook();

            /* Create an MWStructArray with two fields */
            String[] myFieldNames= { "name", "phone" };
            friends= new MWStructArray(2, 2, myFieldNames);

            /* Populate struct with some sample data --- friends and phone */
            /* number extensions */
            friends["name", 1]= new MWCharArray("Jordan Robert");
            friends["phone", 1]= 3386;
            friends["name", 2]= new MWCharArray("Mary Smith");
            friends["phone", 2]= 3912;
            friends["name", 3]= new MWCharArray("Stacy Flora");
            friends["phone", 3]= 3238;
            friends["name", 4]= new MWCharArray("Harry Alpert");
            friends["phone", 4]= 3077;

            /* Show some of the sample data */
            Console.WriteLine("Friends: ");
            Console.WriteLine(friends.ToString());

            /* Pass it to a MATLAB function that determines external phone number */
            result= thePhonebook.makephone(1, friends);
            book= (MWStructArray)result[0];

            Console.WriteLine("Result: ");
            Console.WriteLine(book.ToString());
        }
    }
}
```



## PhoneBookApp.vb

```

' Necessary package imports

Imports MathWorks.MATLAB.NET.Arrays
Imports PhoneBookComp

'
' getphone class demonstrates the use of the MWStructArray class
Public Module PhoneBookVBAApp
    Public Sub Main()
        Dim thePhonebook As phonebook 'Stores deployment class instance
        Dim friends As MWStructArray 'Sample input data
        Dim result As Object() 'Stores the result
        Dim book As MWStructArray 'Output data extracted from result

        ' Create the new deployment object
        thePhonebook = New phonebook()

        ' Create an MWStructArray with two fields
        Dim myFieldNames As String() = {"name", "phone"}
        friends = New MWStructArray(2, 2, myFieldNames)

        ' Populate struct with some sample data --- friends and phone numbers
        friends("name", 1) = New MWCharArray("Jordan Robert")
        friends("phone", 1) = 3386
        friends("name", 2) = New MWCharArray("Mary Smith")
        friends("phone", 2) = 3912
        friends("name", 3) = New MWCharArray("Stacy Flora")
        friends("phone", 3) = 3238
        friends("name", 4) = New MWCharArray("Harry Alpert")
        friends("phone", 4) = 3077

        ' Show some of the sample data
        Console.WriteLine("Friends: ")
        Console.WriteLine(friends.ToString())

        ' Pass it to a MATLAB function that determines external phone number
        result = thePhonebook.makephone(1, friends)
        book = CType(result(0), MWStructArray)
        Console.WriteLine("Result: ")
        Console.WriteLine(book.ToString())

        ' Extract some data from the returned structure '
        Console.WriteLine("Result record 2:")

        Console.WriteLine(book("name", 2))
        Console.WriteLine(book("phone", 2))
        Console.WriteLine(book("external", 2))

        ' Print the entire result structure using the helper function below
        Console.WriteLine("")
        Console.WriteLine("Entire structure:")
        dispStruct(book)
    End Sub

    Sub dispStruct(ByVal arr As MWStructArray)
        Console.WriteLine("Number of Elements: " + arr.NumberOfElements.ToString())
        'int numDims = arr.NumberofDimensions
        Dim dims As Integer() = arr.Dimensions
        Console.WriteLine("Dimensions: " + dims(0).ToString())

        Dim i As Integer
        For i = 1 To dims.Length
            Console.WriteLine("-by-" + dims(i - 1).ToString())
        Next i
        Console.WriteLine("")
        Console.WriteLine("Number of Fields: " + arr.NumberOfFields.ToString())
        Console.WriteLine("Standard MATLAB view:")
        Console.WriteLine(arr.ToString())
        Console.WriteLine("Walking structure:")

        Dim fieldNames As String() = arr.FieldNames

        Dim element As Integer
        For element = 1 To arr.NumberOfElements
            Console.WriteLine("Element " + element.ToString())
            Dim field As Integer
            For field = 0 To arr.NumberOfFields - 1

```

```

Dim fieldVal As MArray = arr(arr.FieldName(field), element)
' Recursively print substructures, give string display of other classes
If (TypeOf fieldVal Is MStructArray) Then
    Console.WriteLine(" " + fieldNames(field) + ": nested structure:")
    Console.WriteLine("+++ Begin of \" + fieldNames[field] +
        " \" nested structure")

    dispStruct(CType(fieldVal, MStructArray))
    Console.WriteLine("+++ End of \" + fieldNames[field] +
        " \" nested structure")
Else
    Console.WriteLine(" " + fieldNames(field) + ": ")
    Console.WriteLine(fieldVal.ToString())
End If
Next field
Next element
End Sub
End Module

```

In either case, the PhoneBookApp program does the following:

- Creates a structure array using MStructArray to represent the example phonebook data containing names and phone numbers.
  - Instantiates the Phonebook class as thePhonebook object, as shown:  
`thePhonebook = new phonebook();`
  - Calls the MATLAB function makephone to create a modified copy of the structure by adding an additional field, as shown:  
`result = thePhonebook.makephone(1, friends);`
  - Displays the resulting structure array.
- 5 Open the .NET project file that corresponds to your application language using Visual Studio.

- **C#**

If you are using C#, the PhoneBookCSApp folder contains a Visual Studio .NET project file for this example. Open the project in Visual Studio .NET by double-clicking PhoneBookCSApp.csproj in Windows Explorer. You can also open it from the desktop by right-clicking **PhoneBookCSApp.csproj** and selecting **Open Outside MATLAB**.

- **Visual Basic**

If you are using Visual Basic, the PhoneBookVBApp folder contains a Visual Studio .NET project file for this example. Open the project in Visual Studio .NET by double-clicking PhoneBookVBApp.vbproj in Windows Explorer. You can also open it from the desktop by right-clicking **PhoneBookVBApp.vbproj** and selecting **Open Outside MATLAB**.

- 6 Create a reference to your assembly file PhoneBookComp.dll located in the folder where you generated the assembly.
- 7 Create a reference to the MArray API, which is located in:

MATLAB	<code>matlabroot\toolbox\dotnetbuilder\bin\win64\&lt;version&gt;\MArray.dll</code>
MATLAB Runtime	<code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\toolbox\dotnetbuilder\bin\win64\&lt;version&gt;\MArray.dll</code>

- 8 Build and run the PhoneBookComp application in Visual Studio .NET.

The application displays the following output:

```

Friends:
2x2 struct array with fields:
    name
    phone

```

```
Result:
2x2 struct array with fields:
    name
    phone
    external
Result record 2:
Mary Smith
3912
(508) 555-3912
```

```
Entire structure:
Number of Elements: 4
Dimensions: 2-by-2
Number of Fields: 3
Standard MATLAB view:
2x2 struct array with fields:
    name
    phone
    external
```

```
Walking structure:
Element 1
    name: Jordan Robert
    phone: 3386
    external: (508) 555-3386
Element 2
    name: Mary Smith
    phone: 3912
    external: (508) 555-3912
Element 3
    name: Stacy Flora
    phone: 3238
    external: (508) 555-3238
Element 4
    name: Harry Alpert
    phone: 3077
    external: (508) 555-3077
```

## See Also

**Library Compiler** | [compiler.build.dotNETAssembly](#) | [deploytool](#)

## Related Examples

- “Generate .NET Assembly and Build .NET Application”
- “Integrate Function with Variable Number of Arguments” on page 3-13



## Integrate Function with Variable Number of Arguments

This example shows you how to create a .NET application using a MATLAB function that takes a variable number of arguments instead of just one.

In this example, you perform the following steps:

- Use the MATLAB Compiler SDK product to convert the MATLAB function `drawgraph` to a method of a .NET class (`Plotter`) and wrap the class in a .NET assembly (`VarArgComp`). The `drawgraph` function displays a plot of the input parameters and is called as a method of the `Plotter` class.
- Access the component in a C# application (`VarArgApp.cs`) or a Visual Basic application (`VarArgApp.vb`) by instantiating the `Plotter` class and using `MWArray` to represent data.
- Build and run the `VarArgDemoApp` application using the Visual Studio .NET development environment.

### Files

MATLAB Functions	<code>drawgraph.m</code> <code>extractcoords.m</code>
MATLAB Function Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\VarArgExample\VarArgComp\</code>
C# Code Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\VarArgExample\VarArgCSApp\VarArgApp.cs</code>
Visual Basic Code Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\VarArgExample\VarArgVBApp\VarArgApp.vb</code>

### Procedure

- 1 Copy the following folder that ships with the MATLAB product to your work folder:

```
matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\VarArgExample
```

At the MATLAB command prompt, navigate to the new `VarArgExample\VarArgComp` subfolder in your work folder.

- 2 Examine the `drawgraph` and `extractcoords` functions.

```
function [xyCoords] = DrawGraph(colorSpec, varargin)
    numVarArgIn= length(varargin);
    xyCoords= zeros(numVarArgIn, 2);

    for idx = 1:numVarArgIn
        xCoord = varargin{idx}(1);
        yCoord = varargin{idx}(2);

        x(idx) = xCoord;
        y(idx) = yCoord;

        xyCoords(idx,1) = xCoord;
        xyCoords(idx,2) = yCoord;
    end

    xmin = min(0, min(x));
    ymin = min(0, min(y));

    axis([xmin fix(max(x))+3 ymin fix(max(y))+3])

    plot(x, y, 'color', colorSpec);
```

```
function [varargout] = ExtractCoords(coords)
    for idx = 1:nargout
        varargout{idx}= coords(idx,:);
    end
end
```

- 3 Build the .NET component with the **Library Compiler** app or `compiler.build.dotNETAssembly` using the following information:

Field	Value
Library Name	VarArgComp
Class Name	Plotter
Files to Compile	extractcoords.m drawgraph.m

For example, if you are using `compiler.build.dotNETAssembly`, type:

```
buildResults = compiler.build.dotNETAssembly(["extractcoords.m","drawgraph.m"], ...
    'AssemblyName','VarArgComp', ...
    'ClassName','Plotter');
```

For more details, see the instructions in “Generate .NET Assembly and Build .NET Application”.

- 4 Decide whether you are using C# or Visual Basic to access the component.

- **C#**

If you are using C#, write source code for a C# application that accesses the component.

The sample application for this example is in `VarArgExample\VarArgCSApp\VarArgApp.cs`.

#### **VarArgApp.cs**

```
using System;

using MathWorks.MATLAB.NET.Utility;
using MathWorks.MATLAB.NET.Arrays;

using VarArgComp;

namespace MathWorks.Examples.VarArgApp
{
    /// <summary>
    /// This application demonstrates how to call components
    /// having methods with varargin/varargout arguments.
    /// </summary>
    class VarArgApp
    {
        #region MAIN

        /// <summary>
        /// The main entry point for the application.
        /// </summary>
        [STAThread]
        static void Main(string[] args)
        {
            // Initialize the input data
            MWNumericArray colorSpec= new double[]
                {0.9, 0.0, 0.0};

            MWNumericArray data=
                new MWNumericArray(new int[]{{1,2},{2,4},
                    {3,6},{4,8},{5,10}});

            MWArray[] coords= null;

            try
            {
                // Create a new plotter object
                Plotter plotter= new Plotter();
```

```

//Extract a variable number of two element x and y coordinate
// vectors from the data array
coords= plotter.extractcoords(5, data);

// Draw a graph using the specified color to connect the
// variable number of input coordinates.
// Return a two column data array containing the input coordinates.
data= (MWNumericArray)plotter.drawgraph(colorSpec,
    coords[0], coords[1], coords[2],coords[3], coords[4]);

Console.WriteLine("result=\n{0}", data);

Console.ReadLine(); // Wait for user to exit application

// Note: You can also pass in the coordinate array directly.
data= (MWNumericArray)plotter.drawgraph(colorSpec, coords);

Console.WriteLine("result=\n{0}", data);

Console.ReadLine(); // Wait for user to exit application
}

catch(Exception exception)
{
    Console.WriteLine("Error: {0}", exception);
}
}

#endregion
}
}

```

The following statements are alternative ways to call the `drawgraph` method:

```

data= (MWNumericArray)plotter.drawgraph(colorSpec,
    coords[0], coords[1], coords[2],coords[3], coords[4]);
...
data= (MWNumericArray)plotter.drawgraph((MWArray)colorSpec, coords);

```

- **Visual Basic**

If you are using Visual Basic, write source code for a Visual Basic application that accesses the component.

The sample application for this example is in `VarArgExample\VarArgVbApp\VarArgApp.vb`.

### **VarArgApp.vb**

```

Imports System

Imports MathWorks.MATLAB.NET.Utility
Imports MathWorks.MATLAB.NET.Arrays

Imports VarArgComp

Namespace MathWorks.Demo.VarArgDemoApp

    ' <summary>
    ' This application demonstrates how to call components having methods with
    ' varargin/varargout arguments.
    ' </summary>
    Class VarArgDemoApp

        #Region " MAIN "

            ' <summary>
            ' The main entry point for the application.
            ' </summary>
            Shared Sub Main(ByVal args() As String)

                ' Initialize the input data
                Dim colorSpec As MWNumericArray =
                    New MWNumericArray(New Double() {0.9, 0.0, 0.0})
            
```

```

Dim data As MWNumericArray =
    New MWNumericArray(New Integer(.) {{1, 2}, {2, 4}, {3, 6}, {4, 8}, {5, 10}})
Dim coords() As MArray = Nothing

Try

    ' Create a new plotter object
    Dim plotter As Plotter = New Plotter

    'Extract a variable number of two element x and y coordinate
    ' vectors from the data array
    coords = plotter.extractcoords(5, data)

    ' Draw a graph using the specified color to connect the variable number of
    ' input coordinates.
    ' Return a two column data array containing the input coordinates.
    data = CType(plotter.drawgraph(colorSpec, coords(0), coords(1), coords(2),
        coords(3), coords(4)), _
        MWNumericArray)

    Console.WriteLine("result={0}{1}", Chr(10), data)

    Console.ReadLine() ' Wait for user to exit application

    ' Note: You can also pass in the coordinate array directly.
    data = CType(plotter.drawgraph(colorSpec, coords), MWNumericArray)

    Console.WriteLine("result=\{0}{1}", Chr(10), data)

    Console.ReadLine() ' Wait for user to exit application

Catch exception As Exception
    Console.WriteLine("Error: {0}", exception)
End Try
End Sub
#End Region

End Class
End Namespace

```

The following statements are alternative ways to call the `drawgraph` method:

```

data = CType(plotter.drawgraph(colorSpec, coords(0), coords(1), coords(2),
    coords(3), coords(4)), MWNumericArray)
...
data = CType(plotter.drawgraph(colorSpec, coords), MWNumericArray)

```

In either case, the `VarArgApp` program does the following:

- Initializes three arrays (`colorSpec`, `data`, and `coords`) using the `MArray` class library
  - Creates a `Plotter` object
  - Calls the `extracoords` and `drawgraph` methods
  - Uses `MWNumericArray` to represent the data needed by the methods
  - Uses a `try-catch` block to catch and handle any exceptions
- 5 Open the `.NET` project file that corresponds to your application language using Visual Studio.
- **C#**

If you are using `C#`, the `VarArgCSApp` folder contains a Visual Studio `.NET` project file for this example. Open the project in Visual Studio `.NET` by double-clicking `VarArgCSApp.csproj` in Windows Explorer. You can also open it from the desktop by right-clicking `VarArgCSApp.csproj` and selecting **Open Outside MATLAB**.

- **Visual Basic**

If you are using Visual Basic, the `VarArgVBApp` folder contains a Visual Studio `.NET` project file for this example. Open the project in Visual Studio `.NET` by double-clicking `VarArgVBApp.vbproj` in Windows Explorer. You can also open it from the desktop by right-clicking `VarArgVBApp.vbproj` and selecting **Open Outside MATLAB**.

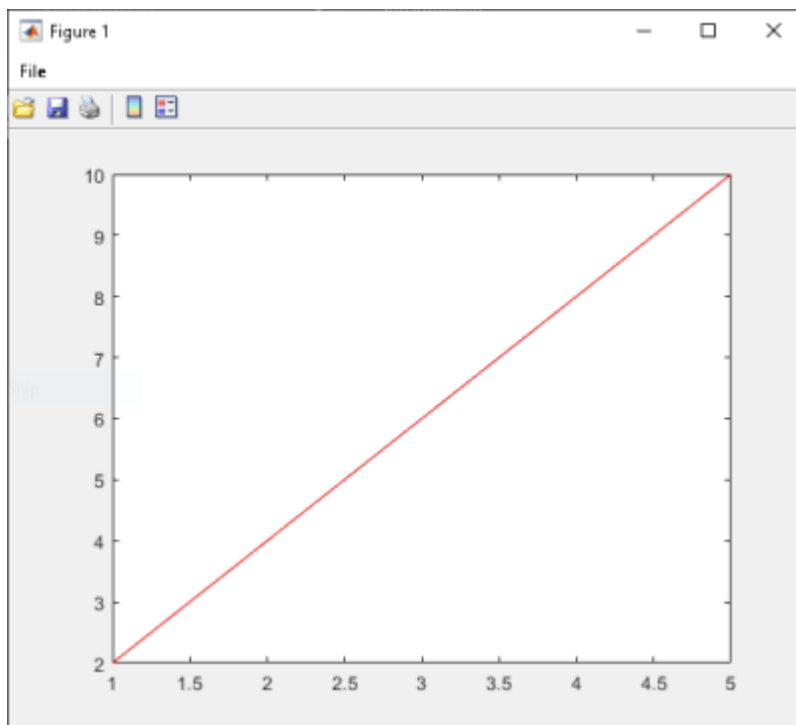
- 6 Create a reference to your assembly file `VarArgComp.dll` located in the folder where you generated or installed the assembly.
- 7 Create a reference to the `MWArray` API.

If MATLAB is installed on your system	<code>matlabroot\toolbox\dotnetbuilder\bin\win64\&lt;framework_version&gt;\MWArray.dll</code>
If MATLAB Runtime is installed on your system	<code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\toolbox\dotnetbuilder\bin\win64\&lt;framework_version&gt;\MWArray.dll</code>

- 8 Build and run the `VarArgApp` application in Visual Studio .NET.

The program displays the following output:

```
result=
     1     2
     2     4
     3     6
     4     8
     5    10
```



## See Also

[Library Compiler](#) | [compiler.build.dotNETAssembly](#) | [deploytool](#)

## Related Examples

- “Generate .NET Assembly and Build .NET Application”

- “Assign Multiple MATLAB Functions in Component Class” on page 3-27

## Use Multiple Classes in .NET Assembly

### In this section...

“SpectraComp Application” on page 3-19

“Files” on page 3-19

“Procedure” on page 3-19

This example shows you how to create a .NET assembly that uses multiple classes to analyze a signal and graph the result.

In this example, you perform the following steps:

- Use the MATLAB Compiler SDK product to create an assembly (`SpectraComp`) containing more than one class.
- Access the component in a C# application (`SpectraApp.cs`) or a Microsoft Visual Basic application (`SpectraApp.vb`), including use of the `MWArray` class hierarchy to represent data.
- Build and run the application using the Visual Studio .NET development environment.

### SpectraComp Application

The class `SignalAnalyzer` performs a fast Fourier transform (FFT) on an input data array. A method of this class, `computefft`, returns the results of that FFT as two output arrays—an array of frequency points and the power spectral density.

The second class, `Plotter`, graphs the returned data using the `plotfft` method. The two methods `computefft` and `plotfft` encapsulate MATLAB functions. `computefft` computes the FFT and power spectral density of the input data and computes a vector of frequency points based on the length of the data entered and the sampling interval. `plotfft` plots the FFT data and the power spectral density in a MATLAB figure window.

### Files

MATLAB Functions	<code>computefft.m</code> <code>plotfft.m</code>
MATLAB Function Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\SpectraExample\SpectraComp\</code>
C# Code Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\SpectraExample\SpectraCSApp\SpectraApp.cs</code>
Visual Basic Code Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\SpectraExample\SpectraVBApp\SpectraApp.vb</code>

### Procedure

- 1 Copy the following folder that ships with the MATLAB product to your work folder:

```
matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\SpectraExample
```

At the MATLAB command prompt, navigate to the new `SpectraExample\SpectraComp` subfolder in your work folder.

- Examine the MATLAB functions `computefft.m` and `plotfft.m`.

#### **computefft.m**

```
function [fftData, freq, powerSpect] =
    ComputeFFT(data, interval)
if (isempty(data))
    fftdata = [];
    freq = [];
    powerspect = [];
    return;
end
if (interval <= 0)
    error('Sampling interval must be greater than zero');
    return;
end
fftData = fft(data);
freq = (0:length(fftData)-1)/(length(fftData)*interval);
powerSpect = abs(fftData)/(sqrt(length(fftData)));
```

#### **plotfft.m**

```
function PlotFFT(fftData, freq, powerSpect)

len = length(fftData);
if (len <= 0)
    return;
end
plot(freq(1:floor(len/2)), powerSpect(1:floor(len/2)))
xlabel('Frequency (Hz)'), grid on
title('Power spectral density')
```

- Build the .NET component with the **Library Compiler** app or `compiler.build.dotNETAssembly`.

Name the library `SpectraComp`. Map a class named `SignalAnalyzer` to the function `computefft.m`, and map a second class named `Plotter` to the function `plotfft.m`.

For example, if you are using `compiler.build.dotNETAssembly`, type:

```
cmap = containers.Map;
cmap('SignalAnalyzer') = 'computefft.m';
cmap('Plotter') = 'plotfft.m';
buildResults = compiler.build.dotNETAssembly(cmap, ...
    'AssemblyName', 'SpectraComp');
```

For more details, see the instructions in “Generate .NET Assembly and Build .NET Application”.

- Decide whether you are using C# or Visual Basic to access the component.

- **C#**

If you are using C#, write source code for a C# application that accesses the component.

The sample application for this example is in `SpectraExample\SpectraCSApp\SpectraApp.cs`.

#### **SpectraApp.cs**

```
using System;

using MathWorks.MATLAB.NET.Utility;
using MathWorks.MATLAB.NET.Arrays;
```



```

using SpectraComp;

namespace MathWorks.Examples.SpectraApp
{
    /// <summary>
    /// This application computes and plots the power spectral density of an input signal.
    /// </summary>
    class SpectraCSApp
    {
        #region MAIN

        /// <summary>
        /// The main entry point for the application.
        /// </summary>
        [STAThread]
        static void Main(string[] args)
        {
            try
            {
                const double interval= 0.01; // The sampling interval
                const int numSamples= 1001; // The number of samples

                // Construct input data as sin(2*PI*15*t) + (sin(2*PI*40*t)) plus a
                // random signal. Duration= 10; Sampling interval= 0.01
                MWNumericArray data= new MWNumericArray(MWArrayComplexity.Real,
                    MWNumericType.Double, numSamples);

                Random random= new Random();

                // Initialize data
                for (int idx= 1; idx <= numSamples; idx++)
                {
                    double t= (idx-1)* interval;

                    data[idx]= Math.Sin(2.0*Math.PI*15.0*t) + Math.Sin(2.0*Math.PI*40.0*t) +
                        random.NextDouble();
                }

                // Create a new signal analyzer object
                SignalAnalyzer signalAnalyzer= new SignalAnalyzer();

                // Compute the fft and power spectral density for the data array
                MWArray[] argsOut= signalAnalyzer.computefft(3, data, interval);

                // Print the first twenty elements of each result array
                int numElements= 20;

                MWNumericArray resultArray= new MWNumericArray(MWArrayComplexity.Complex,
                    MWNumericType.Double, numElements);

                for (int idx= 1; idx <= numElements; idx++)
                {
                    resultArray[idx]= ((MWNumericArray)argsOut[0])[idx];
                }

                Console.WriteLine("FFT:\n{0}\n", resultArray);

                for (int idx= 1; idx <= numElements; idx++)
                {
                    resultArray[idx]= ((MWNumericArray)argsOut[1])[idx];
                }

                Console.WriteLine("Frequency:\n{0}\n", resultArray);

                for (int idx= 1; idx <= numElements; idx++)
                {
                    resultArray[idx]= ((MWNumericArray)argsOut[2])[idx];
                }

                Console.WriteLine("Power Spectral Density:\n{0}", resultArray);

                // Create a new plotter object
                Plotter plotter= new Plotter();

                // Plot the fft and power spectral density for the data array
                plotter.plotfft(argsOut[0], argsOut[1], argsOut[2]);

                Console.ReadLine(); // Wait for user to exit application
            }
        }
    }
}

```

```

        catch(Exception exception)
        {
            Console.WriteLine("Error: {0}", exception);
        }
    }
}
#endregion
}
}

```

The following statement shows how to use the `MWArray` class library to construct a `MWNumericArray` that is used as method input to the `computefft` function.

```
MWNumericArray data= new MWNumericArray(MWArrayComplexity.Real,
MWNumericType.Double, numSamples);
```

The following statements create an instance of the class `SignalAnalyzer` and call the method `computefft`, requesting 3 outputs.

```
SignalAnalyzer signalAnalyzer = new SignalAnalyzer();
...
MWArray[] argsOut= signalAnalyzer.computefft(3, data, interval);
```

- **Visual Basic**

If you are using Visual Basic, write source code for a Visual Basic application that accesses the component.

The sample application for this example is in `SpectraExample\SpectraVBApp\SpectraApp.vb`.

#### **SpectraApp.vb**

```
Imports System

Imports MathWorks.MATLAB.NET.Utility
Imports MathWorks.MATLAB.NET.Arrays

Imports SpectraComp

Namespace MathWorks.Examples.SpectraApp
    ' <summary>
    ' This application computes and plots the power spectral density of an input signal.
    ' </summary>
    Class SpectraDemoApp
#Region " MAIN "
        ' <summary>
        ' The main entry point for the application.
        ' </summary>
        Shared Sub Main(ByVal args() As String)
            Try
                Const interval As Double = 0.01 ' The sampling interval
                Const numSamples As Integer = 1001 ' The number of samples

                ' Construct input data as sin(2*PI*15*t) + (sin(2*PI*40*t)) plus a
                ' random signal. Duration= 10; Sampling interval= 0.01
                Dim data As MWNumericArray = New MWNumericArray(MWArrayComplexity.Real,
                    MWNumericType.Double, numSamples)

                Dim random As Random = New Random

                ' Initialize data
                Dim t As Double
                Dim idx As Integer
                For idx = 1 To numSamples
                    t = (idx - 1) * interval
                    data(idx) = New MWNumericArray(Math.Sin(2.0 * Math.PI * 15.0 * t) +
                        Math.Sin(2.0 * Math.PI * 40.0 * t) +

```

```

        random.NextDouble())
    Next idx

    ' Create a new signal analyzer object
    Dim signalAnalyzer As SignalAnalyzer = New SignalAnalyzer

    ' Compute the fft and power spectral density for the data array
    Dim argsOut() As MWArray = signalAnalyzer.computefft(3, data,
        MWArray.op_implicit(interval))

    ' Print the first twenty elements of each result array
    Dim numElements As Integer = 20
    Dim resultArray As MWNumericArray =
        New MWNumericArray(MWArrayComplexity.Complex,
            MWNumericType.Double, numElements)

    For idx = 1 To numElements
        resultArray(idx) = (CType(argsOut(0), MWNumericArray))(idx)
    Next idx

    Console.WriteLine("FFT:{0}{1}{2}", Chr(10), resultArray, Chr(10))

    For idx = 1 To numElements
        resultArray(idx) = (CType(argsOut(1), MWNumericArray))(idx)
    Next idx

    Console.WriteLine("Frequency:{0}{1}{2}", Chr(10), resultArray, Chr(10))

    For idx = 1 To numElements
        resultArray(idx) = (CType(argsOut(2), MWNumericArray))(idx)
    Next idx

    Console.WriteLine("Power Spectral Density:{0}{1}{2}",
        Chr(10), resultArray, Chr(10))

    ' Create a new plotter object
    Dim plotter As Plotter = New Plotter

    ' Plot the fft and power spectral density for the data array
    plotter.plotfft(argsOut(0), argsOut(1), argsOut(2))

    Console.ReadLine() ' Wait for user to exit application

Catch exception As Exception
    Console.WriteLine("Error: {0}", exception)

End Try
End Sub
#End Region

End Class
End Namespace

```

The following statements show how to use the `MWArray` class library to construct the necessary data types:

```

Dim data As MWNumericArray = New MWNumericArray_
    (MWArrayComplexity.Real, MWNumericType.Double, numSamples)
...
Dim resultArray As MWNumericArray = New MWNumericArray_
    (MWArrayComplexity.Complex,
        MWNumericType.Double, numElements)

```

The following statements create an instance of the class `SignalAnalyzer` and call the method `computefft`, requesting three outputs:

```

Dim signalAnalyzer As SignalAnalyzer = New SignalAnalyzer
...
Dim argsOut() As MWArray =
    signalAnalyzer.computefft(3, data,
        MWArray.op_implicit(interval))

```

In either case, the `SpectraApp` program does the following:

- Constructs an input array with values representing a random signal with two sinusoids at 15 and 40 Hz embedded inside of it
  - Creates an `MWNumericArray` array that contains the data
  - Instantiates a `SignalAnalyzer` object
  - Calls the `computefft` method, which computes the FFT, frequency, and the spectral density
  - Instantiates a `Plotter` object
  - Calls the `plotfft` method, which plots the data
  - Uses a `try/catch` block to handle exceptions
- 5 Open the .NET project file that corresponds to your application language using Visual Studio.

- **C#**

If you are using C#, the `SpectraCSApp` folder contains a Visual Studio .NET project file for this example. Open the project in Visual Studio .NET by double-clicking `SpectraCSApp.csproj` in Windows Explorer. You can also open it from the desktop by right-clicking **SpectraCSApp.csproj** and selecting **Open Outside MATLAB**.

- **Visual Basic**

If you are using Visual Basic, the `SpectraVBApp` folder contains a Visual Studio .NET project file for this example. Open the project in Visual Studio .NET by double-clicking `SpectraVBApp.vbproj` in Windows Explorer. You can also open it from the desktop by right-clicking **SpectraVBApp.vbproj** and selecting **Open Outside MATLAB**.

- 6 Add a reference to your assembly file `SpectraComp.dll`.

- 7 Add a reference to the `MWArray` API.

If MATLAB is installed on your system	<code>matlabroot\toolbox\dotnetbuilder\bin\win64\&lt;framework_version&gt;\MWArray.dll</code>
If MATLAB Runtime is installed on your system	<code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\toolbox\dotnetbuilder\bin\win64\&lt;framework_version&gt;\MWArray.dll</code>

- 8 Build and run the `SpectraApp` application in Visual Studio .NET.

The program displays the following output:

```
FFT:
  1.0e+02 *

  4.8646 + 0.0000i
 -0.0289 + 0.1080i
 -0.0326 + 0.0237i
 -0.0141 - 0.0148i
  0.0674 - 0.0487i
  0.0753 + 0.0669i
  0.0275 - 0.0101i
 -0.0429 + 0.0472i
  0.0803 - 0.1163i
 -0.0619 - 0.1072i
  0.0565 - 0.0502i
 -0.0223 + 0.0587i
 -0.0853 - 0.0812i
```

```
-0.0662 - 0.0143i
0.0543 - 0.0972i
0.0814 - 0.0463i
-0.0981 - 0.0190i
0.0042 + 0.0083i
-0.0339 + 0.0290i
0.0291 + 0.0036i
```

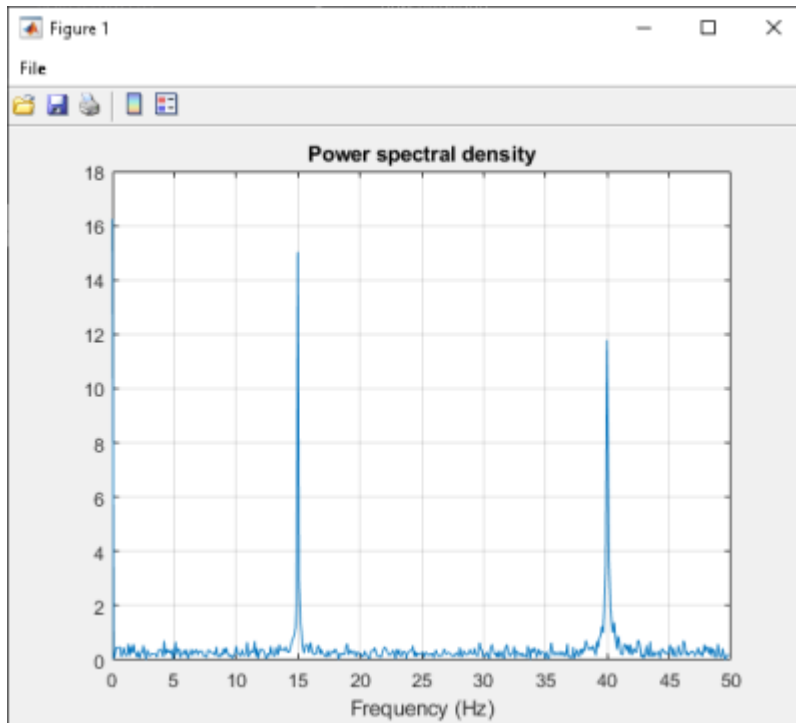
Frequency:

```
0.0000 + 0.0000i
0.0999 + 0.0000i
0.1998 + 0.0000i
0.2997 + 0.0000i
0.3996 + 0.0000i
0.4995 + 0.0000i
0.5994 + 0.0000i
0.6993 + 0.0000i
0.7992 + 0.0000i
0.8991 + 0.0000i
0.9990 + 0.0000i
1.0989 + 0.0000i
1.1988 + 0.0000i
1.2987 + 0.0000i
1.3986 + 0.0000i
1.4985 + 0.0000i
1.5984 + 0.0000i
1.6983 + 0.0000i
1.7982 + 0.0000i
1.8981 + 0.0000i
```

Power Spectral Density:

```
15.3755 + 0.0000i
0.3534 + 0.0000i
0.1274 + 0.0000i
0.0646 + 0.0000i
0.2628 + 0.0000i
0.3183 + 0.0000i
0.0925 + 0.0000i
0.2016 + 0.0000i
0.4465 + 0.0000i
0.3912 + 0.0000i
0.2387 + 0.0000i
0.1985 + 0.0000i
0.3723 + 0.0000i
0.2140 + 0.0000i
0.3520 + 0.0000i
0.2960 + 0.0000i
0.3158 + 0.0000i
0.0294 + 0.0000i
0.1411 + 0.0000i
0.0927 + 0.0000i
```

Plotting Power spectral density, please wait...



### See Also

**Library Compiler** | `compiler.build.dotNETAssembly` | `deploytool`

### Related Examples

- “Generate .NET Assembly and Build .NET Application”

### More About

- “Convert Data Between .NET and MATLAB” on page 2-6

## Assign Multiple MATLAB Functions in Component Class

### In this section...

"MatrixMathApp Application" on page 3-27

"Files" on page 3-27

"Procedure" on page 3-28

"Understanding the MatrixMath Program" on page 3-34

This example shows you how to create a .NET matrix math program using multiple MATLAB functions.

In this example, you perform the following steps:

- Assign more than one MATLAB function to a component class.
- Access the component in a C# application (`MatrixMathApp.cs`) or a Visual Basic application (`MatrixMathApp.vb`) by instantiating `Factor` and using the `MWArray` class library to handle data conversion.
- Build and run the `MatrixMathApp` application using the Visual Studio .NET development environment.

### MatrixMathApp Application

The `MatrixMathApp` application performs Cholesky, LU, and QR factorizations on a simple tridiagonal matrix (finite difference matrix) with the following form:

$$A = \begin{bmatrix} 2 & -1 & 0 & 0 & 0 \\ -1 & 2 & -1 & 0 & 0 \\ 0 & -1 & 2 & -1 & 0 \\ 0 & 0 & -1 & 2 & -1 \\ 0 & 0 & 0 & -1 & 2 \end{bmatrix}$$

You supply the size of the matrix on the command line, and the program constructs the matrix and performs the three factorizations. The original matrix and the results are printed to standard output. You may optionally perform the calculations using a sparse matrix by specifying the string "sparse" as the second parameter on the command line.

### Files

MATLAB Functions	<code>cholesky.m</code> <code>ludecomp.m</code> <code>qrdecomp.m</code>
MATLAB Function Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\MatrixMathExample\MatrixMathComp\</code>
C# Code Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\MatrixMathExample\MatrixMathCSApp\MatrixMathApp.cs</code>
Visual Basic Code Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\MatrixMathExample\MatrixMathVBApp\MatrixMathApp.vb</code>

## Procedure

- 1 Copy the following folder that ships with the MATLAB product to your work folder:

```
matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\MatrixMathExample
```

At the MATLAB command prompt, navigate to the new `MatrixMathExample\MatrixMathComp` subfolder in your work folder.

- 2 Examine the MATLAB functions `cholesky.m`, `ludecomp.m`, and `qrdecomp.m`.

```
function [L] = Cholesky(A)
    L = chol(A);

function [L,U] = LUDecomp(A)
    [L,U] = lu(A);

function [Q,R] = QRDecomp(A)

    [Q,R] = qr(A);
```

- 3 Build the .NET component with the **Library Compiler** app or `compiler.build.dotNETAssembly` using the following information:

Field	Value
Library Name	MatrixMathComp
Class Name	Factor
Files to compile	cholesky ludecomp qrdecomp

For example, if you are using `compiler.build.dotNETAssembly`, type:

```
buildResults = compiler.build.dotNETAssembly(["cholesky.m", "ludecomp.m", "qrdecomp.m"], ...
    'AssemblyName', 'MatrixMathComp', ...
    'ClassName', 'Factor');
```

For more details, see the instructions in “Generate .NET Assembly and Build .NET Application”.

- 4 Decide whether you are using C# or Visual Basic to access the component.

- **C#**

If you are using C#, write source code for a C# application that accesses the component.

The sample application for this example is in `MatrixMathExample\MatrixMathCSApp\MatrixMathApp.cs`.

### MatrixMathApp.cs

```
using System;

using MathWorks.MATLAB.NET.Utility;
using MathWorks.MATLAB.NET.Arrays;

using MatrixMathComp;

namespace MathWorks.Examples.MatrixMath
{
    /// <summary>
    /// This application computes cholesky, LU, and QR factorizations of a finite
    /// difference matrix of order N.
    /// The order is passed into the application on the command line.
    /// </summary>
    /// <remarks>
    /// Command Line Arguments:
    /// <newpara></newpara>
    /// args[0] - Matrix order(N)
    /// <newpara></newpara>
    /// args[1] - (optional) sparse; Use a sparse matrix
    /// </remarks>
}
```



```

class MatrixMathApp
{
    #region MAIN

    /// <summary>
    /// The main entry point for the application.
    /// </summary>
    [STAThread]
    static void Main(string[] args)
    {
        bool makeSparse= true;
        int matrixOrder= 4;

        MWNumericArray matrix= null; // The matrix to factor

        MWArray argOut= null; // Stores single factorization result
        MWArray[] argsOut= null; // Stores multiple factorization results

        try
        {
            // If no argument specified, use defaults
            if (0 != args.Length)
            {
                // Convert matrix order
                matrixOrder= Int32.Parse(args[0]);

                if (0 >= matrixOrder)
                {
                    throw new ArgumentOutOfRangeException("matrixOrder", matrixOrder,
                        "Must enter a positive integer for the matrix order(N)");
                }

                makeSparse= ((1 < args.Length) && (args[1].Equals("sparse")));
            }

            // Create the test matrix. If the second argument is "sparse",
            // create a sparse matrix.
            matrix= (makeSparse)
                ? MWNumericArray.MakeSparse(matrixOrder, matrixOrder,
                    MWArrayComplexity.Real, (matrixOrder+(2*(matrixOrder-1))))
                : new MWNumericArray(MWArrayComplexity.Real,
                    MWNumericType.Double, matrixOrder, matrixOrder);

            // Initialize the test matrix
            for (int rowIdx= 1; rowIdx <= matrixOrder; rowIdx++)
                for (int colIdx= 1; colIdx <= matrixOrder; colIdx++)
                    if (rowIdx == colIdx)
                        matrix[rowIdx, colIdx]= 2.0;
                    else if ((colIdx == rowIdx+1) || (colIdx == rowIdx-1))
                        matrix[rowIdx, colIdx]= -1.0;

            // Create a new factor object
            Factor factor= new Factor();

            // Print the test matrix
            Console.WriteLine("Test Matrix:\n{0}\n", matrix);

            // Compute and print the cholesky factorization using the
            // single output syntax
            argOut= factor.cholesky((MWArray)matrix);

            Console.WriteLine("Cholesky
                Factorization:\n{0}\n", argOut);

            // Compute and print the LU factorization using the multiple output syntax
            argsOut= factor.ludecomp(2, matrix);

            Console.WriteLine("LU Factorization:\nL
                Matrix:\n{0}\nU Matrix:\n{1}\n", argsOut[0],
                argsOut[1]);

            MWNumericArray.DisposeArray(argsOut);

            // Compute and print the QR factorization
            argsOut= factor.qrdecomp(2, matrix);

            Console.WriteLine("QR Factorization:\nQ Matrix:\n{0}\nR Matrix:\n{1}\n",
                argsOut[0], argsOut[1]);

            Console.ReadLine();
        }
    }
}

```

```

        catch(Exception exception)
        {
            Console.WriteLine("Error: {0}", exception);
        }

        finally
        {
            // Free native resources
            if (null != (object)matrix) matrix.Dispose();
            if (null != (object)argOut) argOut.Dispose();

            MWNumericArray.DisposeArray(argsOut);
        }
    }
}
#endregion
}
}

```

This statement creates an instance of the class `Factor`:

```
Factor factor= new Factor();
```

The following statements call the methods that encapsulate the MATLAB functions:

```

argOut= factor.cholesky((MArray)matrix);
...
argsOut= factor.ludecomp(2, matrix);
...
argsOut= factor.qrdecomp(2, matrix);
...

```

- **Visual Basic**

If you are using Visual Basic, write source code for a Visual Basic application that accesses the component.

The sample application for this example is in `MatrixMathExample\MatrixMathVBApp\MatrixMathApp.vb`.

#### **MatrixMathApp.vb**

```

Imports System

Imports MathWorks.MATLAB.NET.Utility
Imports MathWorks.MATLAB.NET.Arrays

Imports MatrixMathComp

Namespace MathWorks.Demo.MatrixMathApp

    ' <summary>
    ' This application computes cholesky, LU, and QR factorizations of a
    ' finite difference matrix of order N.
    ' The order is passed into the application on the command line.
    ' </summary>
    ' <remarks>
    ' Command Line Arguments:
    ' <newpara></newpara>
    ' args[0] - Matrix order(N)
    ' <newpara></newpara>
    ' args[1] - (optional) sparse; Use a sparse matrix
    ' </remarks>
    Class MatrixMathDemoApp

        #Region " MAIN "

            ' <summary>
            ' The main entry point for the application.
            ' </summary>
            Shared Sub Main(ByVal args() As String)

```

```

Dim makeSparse As Boolean = True
Dim matrixOrder As Integer = 4

Dim matrix As MWNumericArray = Nothing ' The matrix to factor

Dim argOut As MWArray = Nothing ' Stores single factorization result
Dim argsOut() As MWArray = Nothing ' Stores multiple factorization results

Try
    ' If no argument specified, use defaults
    If (0 <> args.Length) Then
        'Convert matrix order
        matrixOrder = Int32.Parse(args(0))

        If (0 > matrixOrder) Then
            Throw New ArgumentOutOfRangeException("matrixOrder", matrixOrder, _
                "Must enter a positive integer for the matrix order(N)")
        End If

        makeSparse = ((1 < args.Length) AndAlso (args(1).Equals("sparse")))
    End If

    ' Create the test matrix. If the second argument
    ' is "sparse", create a sparse matrix.
    matrix = IIf(makeSparse, _
        MWNumericArray.MakeSparse(matrixOrder, matrixOrder,
            MWArrayComplexity.Real,
            (matrixOrder + (2 * (matrixOrder - 1)))), _
        New MWNumericArray(MWArrayComplexity.Real, MWNumericType.Double,
            matrixOrder, matrixOrder))

    ' Initialize the test matrix
    For rowIdx As Integer = 1 To matrixOrder
        For colIdx As Integer = 1 To matrixOrder
            If rowIdx = colIdx Then
                matrix(rowIdx, colIdx) = New MWNumericArray(2.0)
            ElseIf colIdx = rowIdx + 1 Or colIdx = rowIdx - 1 Then
                matrix(rowIdx, colIdx) = New MWNumericArray(-1.0)
            End If
        Next colIdx
    Next rowIdx

    ' Create a new factor object
    Dim factor As Factor = New Factor

    ' Print the test matrix
    Console.WriteLine("Test Matrix:{0}{1}{2}", Chr(10), matrix, Chr(10))

    ' Compute and print the cholesky factorization using
    ' the single output syntax
    argOut = factor.cholesky(matrix)

    Console.WriteLine("Cholesky Factorization:{0}{1}{2}",
        Chr(10), argOut, Chr(10))

    ' Compute and print the LU factorization using the multiple output syntax
    argsOut = factor.ludecomp(2, matrix)

    Console.WriteLine("LU Factorization:
        {0}L Matrix:{1}{2}{3}U Matrix:{4}{5}{6}", Chr(10), Chr(10),
        argsOut(0), Chr(10), Chr(10), argsOut(1), Chr(10))

    MWNumericArray.DisposeArray(argsOut)

    ' Compute and print the QR factorization
    argsOut = factor.qrdecomp(2, matrix)

    Console.WriteLine("QR Factorization:
        {0}Q Matrix:{1}{2}{3}R Matrix:{4}{5}{6}", Chr(10), Chr(10),
        argsOut(0), Chr(10), Chr(10), argsOut(1), Chr(10))

    Console.ReadLine()

Catch exception As Exception
    Console.WriteLine("Error: {0}", exception)

Finally
    ' Free native resources

```

```

        If Not (matrix Is Nothing) Then
            matrix.Dispose()
        End If
        If Not (argOut Is Nothing) Then
            argOut.Dispose()
        End If

        MWNumericArray.DisposeArray(argsOut)
    End Try
End Sub
#End Region
End Class
End Namespace

```

This statement creates an instance of the class `Factor`:

```
Dim factor As Factor = New Factor
```

The following statements call the methods that encapsulate the MATLAB functions:

```
argOut = factor.cholesky(matrix)
```

```
argsOut = factor.ludecomp(2, matrix)
```

```
argsOut = factor.qrdecomp(2, matrix)
```

- 5 Open the .NET project file that corresponds to your application language using Visual Studio.

- **C#**

If you are using C#, the `MatrixMathCSApp` folder contains a Visual Studio .NET project file for this example. Open the project in Visual Studio .NET by double-clicking `MatrixMathCSApp.csproj` in Windows Explorer. You can also open it from the desktop by right-clicking **MatrixMathCSApp.csproj** and selecting **Open Outside MATLAB**.

- **Visual Basic**

If you are using Visual Basic, the `MatrixMathVBApp` folder contains a Visual Studio .NET project file for this example. Open the project in Visual Studio .NET by double-clicking `MatrixMathVBApp.vbproj` in Windows Explorer. You can also open it from the desktop by right-clicking **MatrixMathVBApp.vbproj** and selecting **Open Outside MATLAB**.

- 6 Add a reference to your assembly file `MatrixMathComp.dll` located in the folder where you generated the assembly.
- 7 Add a reference to the `MWArray` API.

If MATLAB is installed on your system	<code>matlabroot\toolbox\dotnetbuilder\bin\win64\&lt;framework_version&gt;\MWArray.dll</code>
If MATLAB Runtime is installed on your system	<code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\toolbox\dotnetbuilder\bin\win64\&lt;framework_version&gt;\MWArray.dll</code>

- 8 Build and run the `MatrixMathApp` application in Visual Studio.

The program displays the following output:

Test Matrix:

```

(1,1)      2
(2,1)     -1
(1,2)     -1
(2,2)      2

```

```
(3,2)    -1
(2,3)    -1
(3,3)     2
(4,3)    -1
(3,4)    -1
(4,4)     2
```

Cholesky Factorization:

```
(1,1)    1.4142
(1,2)   -0.7071
(2,2)    1.2247
(2,3)   -0.8165
(3,3)    1.1547
(3,4)   -0.8660
(4,4)    1.1180
```

LU Factorization:

L Matrix:

```
(1,1)    1.0000
(2,1)   -0.5000
(2,2)    1.0000
(3,2)   -0.6667
(3,3)    1.0000
(4,3)   -0.7500
(4,4)    1.0000
```

U Matrix:

```
(1,1)    2.0000
(1,2)   -1.0000
(2,2)    1.5000
(2,3)   -1.0000
(3,3)    1.3333
(3,4)   -1.0000
(4,4)    1.2500
```

QR Factorization:

Q Matrix:

```
(1,1)   -0.8944
(2,1)    0.4472
(1,2)   -0.3586
(2,2)   -0.7171
(3,2)    0.5976
(1,3)   -0.1952
(2,3)   -0.3904
(3,3)   -0.5855
(4,3)    0.6831
(1,4)    0.1826
(2,4)    0.3651
(3,4)    0.5477
(4,4)    0.7303
```

R Matrix:

```
(1,1)   -2.2361
(1,2)    1.7889
(2,2)   -1.6733
(1,3)   -0.4472
(2,3)    1.9124
(3,3)   -1.4639
(2,4)   -0.5976
```

```
(3,4)      1.9518  
(4,4)      0.9129
```

## Understanding the MatrixMath Program

The `MatrixMath` program takes one or two arguments from the command line. The first argument is converted to the integer order of the test matrix. If the string `sparse` is passed as the second argument, a sparse matrix is created to contain the test array. The Cholesky, LU, and QR factorizations are then computed and the results are displayed.

The main method has three parts:

- The first part sets up the input matrix, creates a new factor object, and calls the `cholesky`, `ludcomp`, and `qrdecomp` methods. This part is executed inside of a `try` block. This is done so that if an exception occurs during execution, the corresponding `catch` block will be executed.
- The second part is the `catch` block. The code prints a message to standard output to let the user know about the error that has occurred.
- The third part is a `finally` block to manually clean up native resources before exiting. This is optional, as the garbage collector will automatically clean up resources for you.

## See Also

**Library Compiler** | `compiler.build.dotNETAssembly` | `deploytool`

## Related Examples

- “Generate .NET Assembly and Build .NET Application”
- “Use Multiple Classes in .NET Assembly” on page 3-19

## More About

- “Convert Data Between .NET and MATLAB” on page 2-6

# Integrate MATLAB Optimization Routines with Objective Functions

## In this section...

“Overview” on page 3-35

“OptimizeComp Application” on page 3-35

“Files” on page 3-35

“Procedure” on page 3-36

## Overview

This example shows you how to create a .NET application that finds a local minimum of an objective function using the MATLAB optimization function `fminsearch` and the `MWObjectArray` class.

In this example, you perform the following steps:

- Use the MATLAB Compiler SDK product to create an assembly (`OptimizeComp`). This assembly applies MATLAB optimization routines to objective functions implemented as .NET objects.
- Access the component in either a C# application (`OptimizeApp.cs`) or a Visual Basic application (`OptimizeApp.vb`).
- Use the `MWObjectArray` class to create a reference to a .NET object using C# (`BananaFunction.cs`) or Visual Basic (`BananaFunction.vb`), and pass that object to the component.
- Build and run the application using the Visual Studio .NET development environment.

## OptimizeComp Application

The `OptimizeComp` application finds a local minimum of an objective function and returns the minimal location and value. The component uses the MATLAB optimization function `fminsearch`. This example optimizes the Rosenbrock banana function used in the `fminsearch` documentation.

The class `OptimizeComp.OptimizeClass` performs an unconstrained nonlinear optimization on an objective function implemented as a .NET object. A method of this class, `doOptim`, accepts an initial value (NET object) that implements the objective function, and returns the location and value of a local minimum.

The second method, `displayObj`, is a debugging tool that lists the characteristics of a .NET object. The two methods `doOptim` and `displayObj` encapsulate MATLAB functions.

## Files

MATLAB Functions	<code>doOptim.m</code> <code>displayObj.m</code>
MATLAB Function Location	<code>matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\OptimizeExample\OptimizeComp</code>

C# Code Location	<i>matlabroot</i> \toolbox\dotnetbuilder\Examples\VSVersion\NET\OptimizeExample\OptimizeCSApp\BananaFunction.cs
Visual Basic Code Location	<i>matlabroot</i> \toolbox\dotnetbuilder\Examples\VSVersion\NET\OptimizeExample\OptimizeVBAApp\BananaFunction.vb
MWArray API Reference Location	<i>matlabroot</i> \help\dotnetbuilder\MWArrayAPI

## Procedure

- 1 Copy the following folder that ships with MATLAB to your work folder:  
*matlabroot*\toolbox\dotnetbuilder\Examples\VSVersion\NET\OptimizeExample

At the MATLAB command prompt, navigate to the new `OptimizeExample\OptimizeComp` subfolder in your work folder.

- 2 Examine the MATLAB code that you want to access. This example uses `doOptim.m` and `displayObj.m`.

```
function [x,fval] = doOptim(h, x0)
mWrapper = @(x) h.evaluateFunction(x);
```

```
directEval = h.evaluateFunction(x0)
wrapperEval = mWrapper(x0)
```

```
[x,fval] = fminsearch(mWrapper,x0)
```

```
function className = displayObj(h)
```

```
h
className = class(h)
whos('h')
methods(h)
```

- 3 Build the .NET component with the **Library Compiler** app or `compiler.build.dotNETAssembly` using the following information:

Field	Value
Library Name	OptimizeComp
Class Name	OptimizeComp.OptimizeClass
Files to Compile	doOptim.m displayObj.m

For example, if you are using `compiler.build.dotNETAssembly`, type:

```
buildResults = compiler.build.dotNETAssembly(["doOptim.m","displayObj.m"], ...
'AssemblyName','OptimizeComp', ...
'ClassName','OptimizeComp.OptimizeClass');
```

For more details, see the instructions in “Generate .NET Assembly and Build .NET Application”.

- 4 Decide whether you are using C# or Visual Basic to access the component.

- **C#**

If you are using C#, write source code for a class that implements an object function to optimize.



The sample application for this example is in `OptimizeExample\OptimizeCSApp\BananaFunction.cs`

### BananaFunction.cs

```
using System;

namespace MathWorks.Examples.Optimize
{
    public class BananaFunction
    {
        public BananaFunction() {}

        public double evaluateFunction(double[] x)
        {
            double term1= 100*Math.Pow((x[1]-Math.Pow(x[0],2.0)),2.0);
            double term2= Math.Pow((1-x[0]),2.0);
            return term1+term2;
        }
    }
}
```

- **Visual Basic**

If you are using Visual Basic, write source code for a class that implements an object function to optimize.

The sample application for this example is in `OptimizeExample\OptimizeVBApp\BananaFunction.vb`.

### BananaFunction.vb

```
Imports System

Namespace MathWorks.Examples.Optimize

    Class BananaFunction

        #Region "Methods"
        Public Sub BananaFunction()
            End Sub

        Public Function evaluateFunction(ByVal x As Double()) As Double

            Dim term1 As Double = 100 * Math.Pow((x(1) - Math.Pow(x(0),
                2.0)), 2.0)

            Dim term2 As Double = Math.Pow((1 - x(0)), 2.0)
            Return term1 + term2
        End Function
        #End Region

    End Class
End Namespace
```

The `BananaFunction` class implements the Rosenbrock banana function described in the `fminsearch` documentation.

**5** Open the .NET project file that corresponds to your application language using Visual Studio.

- **C#**

If you are using C#, the `OptimizeCSApp` folder contains a Visual Studio .NET project file for this example. Open the project in Visual Studio .NET by double-clicking `OptimizeCSApp.csproj` in Windows Explorer. You can also open it from the desktop by right-clicking **OptimizeCSApp.csproj** and selecting **Open Outside MATLAB**.

- **Visual Basic**

If you are using Visual Basic, the `OptimizeVBApp` folder contains a Visual Studio .NET project file for this example. Open the project in Visual Studio .NET by double-clicking `OptimizeVBApp.vbproj` in Windows Explorer. You can also open it from the desktop by right-clicking **OptimizeVBApp.vbproj** and selecting **Open Outside MATLAB**.

- 6 Add a reference to your assembly file `OptimizeComp.dll`.
- 7 Add a reference to the `MWArray` API.

If MATLAB is installed on your system	<code>matlabroot\toolbox\dotnetbuilder\bin\win64\&lt;framework_version&gt;\MWArray.dll</code>
If MATLAB Runtime is installed on your system	<code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\toolbox\dotnetbuilder\bin\win64\&lt;framework_version&gt;\MWArray.dll</code>

- 8 Build and run the `OptimizeApp` application in Visual Studio .NET.

The program displays the following output:

Using initial points= -1.2000 1

```
*****
**                Properties of .NET Object                **
*****
```

h =

```
MathWorks.Examples.Optimize.BananaFunction handle
with no properties.
Package: MathWorks.Examples.Optimize
```

className =

MathWorks.Examples.Optimize.BananaFunction

```
Name  Size  Bytes  Class  Attributes
h      1x1   60    MathWorks.Examples.Optimize.BananaFunction
```

Methods for class `MathWorks.Examples.Optimize.BananaFunction`:

```
BananaFunction  addlistener  findprop  lt
Equals          delete      ge        ne
GetHashCode     eq         gt        notify
GetType         evaluateFunction  isvalid
ToString       findobj    le
```

```
***** Finished displayObj *****

*****
** Performing unconstrained nonlinear optimization **
*****

directEval =

    24.2000

wrapperEval =

    24.2000

x =

    1.0000    1.0000

fval =

    8.1777e-010

***** Finished doOptim *****

Location of minimum: 1.0000    1.0000
Function value at minimum: 8.1777e-010
```

## See Also

**Library Compiler** | `compiler.build.dotNETAssembly` | `deploytool`

## Related Examples

- “Generate .NET Assembly and Build .NET Application”

## More About

- “Use Multiple Classes in .NET Assembly” on page 3-19

## Build .NET Core Application That Runs on Linux and macOS

**Supported Platform:** Windows (Authoring), Linux (Execution), and macOS (Execution).

This example shows how to create a .NET assembly using the **Library Compiler** and integrate it into a .NET Core application that can run on Linux or macOS.

### Prerequisites

- 1 Create a new work folder that is visible to the MATLAB search path. This example uses `C:\Work` as the new work folder.
- 2 Install MATLAB Runtime on Windows and on additional platforms where you plan on running your .NET Core application. For details, see “Install and Configure MATLAB Runtime”.
- 3 For Linux and macOS platforms, after installing MATLAB Runtime, you need to set the `LD_LIBRARY_PATH` and `DYLD_LIBRARY_PATH` environment variables respectively. For more information, see “Set MATLAB Runtime Path for Deployment”.
- 4 Verify that you have Visual Studio and .NET Core 2.0 or higher installed. If you have version 15.8.2 of Visual Studio 2017 installed, then you do not need to install .NET Core 2.0 or higher separately.

### Create .NET Assembly

Package the function into a .NET assembly using the **Library Compiler** app. Alternatively, if you want to create a .NET assembly from the MATLAB command window using a programmatic approach, see `compiler.build.dotNETAssembly`.

- 1 Create a new MATLAB file named `mymagic.m` with the following code in the work folder:

```
function out = mymagic(in)
out = magic(in);
```

- 2 Type `libraryCompiler` at the MATLAB command line to launch the Library Compiler app.
- 3 In the **TYPE** section of the toolstrip, select **.NET Assembly**, and in the **EXPORTED FUNCTIONS** section, click the **Add** button to add the file `mymagic.m` to the project.
- 4 In the **Library information** section, name the library `MyMatrixFunctions`.
- 5 Double-click the class `Class1` and rename it to `MyMagic`.
- 6 Save the deployment project with the project name `MyMatrixFunctions`.
- 7 Select **Package** to create a .NET assembly. For information about the created files, see “Files Generated After Packaging MATLAB Functions”.

### Create .NET Core Application

- 1 Open the command prompt in Windows and navigate to the folder `C:\Work`.
- 2 At the command line, type:

```
dotnet new console --name MyDotNetCoreApplication
```

This creates a folder named `MyDotNetCoreApplication` that has the following contents:

- obj folder
- MyDotNetCoreApp.csproj project file
- Program.cs C# source file

3 Open the project file in a text editor.

```
<Project Sdk="Microsoft.NET.Sdk">
  <PropertyGroup>
    <OutputType>Exe</OutputType>
    <TargetFramework>netcoreapp2.0</TargetFramework>
  </PropertyGroup>
</Project>
```

Add the following references to the project using the <ItemGroup> tag:

- .NET assembly file MyMatrixFunctions.dll created by the Library Compiler app
- MWArray.dll, which is located in <MATLAB\_RUNTIME\_INSTALL\_DIR>\toolbox\dotnetbuilder\bin\win64\<framework\_version>

Once you add the references, your project file should resemble the following:

```
<Project Sdk="Microsoft.NET.Sdk">
  <PropertyGroup>
    <OutputType>Exe</OutputType>
    <TargetFramework>netcoreapp2.2</TargetFramework>
  </PropertyGroup>
  <ItemGroup>
    <Reference Include="MyMatrixFunctions">
      <HintPath>C:\work\MyMatrixFunctions\for_redistribution_files_only\MyMatrixFunctions.dll</HintPath>
      <!--Path to .NET Assembly created by Library Compiler app-->
    </Reference>
    <Reference Include="MWArray">
      <HintPath>C:\Program Files\MATLAB\MATLAB Runtime\R2023a\toolbox\dotnetbuilder\bin\win64\v4.0\MWArray.dll</HintPath>
      <!--Path to MWArray.dll in the MATLAB Runtime-->
    </Reference>
  </ItemGroup>
</Project>
```

4 Open the C# source file Program.cs and replace the existing code with the following code:

### Program.cs

```
// *****
//
// Program.cs
//
// This example demonstrates how to use MATLAB .NET Assembly to build a simple
// component returning a magic square and how to convert MWNumericArray types
// to native .NET types.
//
// Copyright 2001-2019 The MathWorks, Inc.
//
// *****
```

```
using System;
```

```
using MathWorks.MATLAB.NET.Utility;
using MathWorks.MATLAB.NET.Arrays;
```

```

using MyMatrixFunctions;

namespace MathWorks.Examples.MagicSquare
{
    /// <summary>
    /// The MagicSquareApp class computes a magic square of the user specified size.
    /// </summary>
    /// <remarks>
    /// args[0] - a positive integer representing the size of the magic square.
    /// </remarks>
    class Program
    {
        #region MAIN

        /// <summary>
        /// The main entry point for the application.
        /// </summary>
        [STAThread]
        static void Main(string[] args)
        {
            MWNumericArray? arraySize= null;
            MWNumericArray? magicSquare= null;

            try
            {
                // Get user specified command line arguments or set default
                arraySize= (0 != args.Length) ? Double.Parse(args[0]) : 4;

                // Create the magic square object
                MyMagic magic= new MyMagic();

                // Compute the magic square and print the result
                magicSquare= (MWNumericArray)magic.mymagic(arraySize);

                Console.WriteLine("Magic square of order {0}\n\n{1}", arraySize, magicSquare);

                // Convert the magic square array to a two dimensional native double array
                double[,] nativeArray= (double[,])magicSquare.ToArray(MWArrayComponent.Real);

                Console.WriteLine("\nMagic square as native array:\n");

                // Display the array elements:
                for (int i= 0; i < (int)arraySize; i++)
                    for (int j= 0; j < (int)arraySize; j++)
                        Console.WriteLine("Element({0},{1})= {2}", i, j, nativeArray[i,j]);

                Console.ReadLine(); // Wait for user to exit application
            }

            catch(Exception exception)
            {
                Console.WriteLine("Error: {0}", exception);
            }
        }

        #endregion
    }
}

```

- 5 At the command line, build your .NET Core project by typing:

```
dotnet build MyDotNetCoreApp.csproj
```

- 6 At the command line, run your application by typing:

```
dotnet run -- 3
```

The application displays a 3-by-3 magic square.

- 7 Publish the project as a self-contained deployment to execute the application on either Linux or macOS.

- To publish to Linux, type the following command on a single line:

```
dotnet publish --configuration Release --framework netcoreapp2.2
--runtime linux-x64 --self-contained true MyDotNetCoreApp.csproj
```

- To publish to macOS, type the following command on a single line:

```
dotnet publish --configuration Release --framework netcoreapp2.2
--runtime osx.10.11-x64 --self-contained true MyDotNetCoreApp.csproj
```

## Run .NET Core Application on Linux

- 1 Copy the Release folder from C:\Work\MyDotNetCoreApp\bin on Windows to ~/Work on a Linux or macOS machine.
- 2 On the Linux machine, verify that you have installed MATLAB Runtime and set up your library path environment variable. For more information, see “Prerequisites” on page 3-40.
- 3 Open a command shell and navigate to:

```
~/Work/Release/netcoreapp2.2/<os-architecture>/publish
```

- 4 Run the .NET Core application by typing:

```
./MyDotNetCoreApp 3
```

Magic square of order 3

8	1	6
3	5	7
4	9	2

Magic square as native array:

```
Element(0,0)= 8
Element(0,1)= 1
Element(0,2)= 6
Element(1,0)= 3
Element(1,1)= 5
Element(1,2)= 7
Element(2,0)= 4
Element(2,1)= 9
Element(2,2)= 2
```

## **See Also**

### **Related Examples**

- [“Install and Configure MATLAB Runtime”](#)
- [“Set MATLAB Runtime Path for Deployment”](#)



## Build .NET 5.0 Application That Runs on Linux and macOS

**Supported Platform:** Windows (Authoring), Linux (Execution), and macOS (Execution).

This example shows how to create a .NET assembly using the **Library Compiler** and integrate it into a .NET 5.0 application that can run on Linux or macOS.

### Prerequisites

- 1 Create a new work folder that is visible to the MATLAB search path. This example uses C:\Work as the new work folder.
- 2 Install MATLAB Runtime on Windows and on additional platforms where you plan on running your .NET 5.0 application. For details, see “Install and Configure MATLAB Runtime”.
- 3 For Linux and macOS platforms, after installing MATLAB Runtime, you need to set the LD\_LIBRARY\_PATH and DYLD\_LIBRARY\_PATH environment variables respectively. For more information, see “Set MATLAB Runtime Path for Deployment”.
- 4 Verify that you have Visual Studio and .NET 5.0 or higher installed. If you have version 16.8.0 of Visual Studio 2019 installed, then you do not need to install .NET 5.0 or higher separately.

### Create .NET Assembly

Package a function into a .NET assembly using the **Library Compiler** app. Alternatively, if you want to create a .NET assembly from the MATLAB command window using a programmatic approach, see `compiler.build.dotNETAssembly`.

- 1 Create a new MATLAB file named `mymagic.m` with the following code in the work folder:

```
function out = mymagic(in)
out = magic(in);
```

- 2 Type `libraryCompiler` at the MATLAB command line to launch the Library Compiler app.
- 3 In the **TYPE** section of the toolstrip, select **.NET Assembly**, and in the **EXPORTED FUNCTIONS** section, click the **Add** button to add the file `mymagic.m` to the project.
- 4 In the **Library information** section, name the library `MyMatrixFunctions`.
- 5 Double-click the class `Class1` and rename it to `MyMagic`.
- 6 Expand the **Additional runtime settings** section and select `5.0` as the .NET version.

---

**Note** .NET 5.0 does not support type-safe API.

---

- 7 Save the deployment project with the project name `MyMatrixFunctions`.
- 8 Select **Package** to create a .NET assembly. For information about the created files, see “Files Generated After Packaging MATLAB Functions”.

### Create .NET 5.0 Application

If you are using Visual Studio, see “Create .NET 5.0 App Using Visual Studio” on page 3-48.

- 1 Open the command prompt in Windows and navigate to the folder C:\Work.
- 2 At the command line, type:

```
dotnet new console --framework net5.0 --name MyDotNet5App
```

This creates a folder named `MyDotNet5App` that has the following contents:

- `obj` folder
- `MyDotNet5App.csproj` project file
- `Program.cs` C# source file

3 Open the project file in a text editor.

```
<Project Sdk="Microsoft.NET.Sdk">

  <PropertyGroup>
    <OutputType>Exe</OutputType>
    <TargetFramework>net5.0</TargetFramework>
  </PropertyGroup>

</Project>
```

Add the following references to the project using the `<ItemGroup>` tag:

- .NET assembly file `MyMatrixFunctions.dll` created by the Library Compiler app
- `MWArray.dll`, which is located in `<MATLAB_RUNTIME_INSTALL_DIR>\toolbox\dotnetbuilder\bin\win64\<framework_version>`

Once you add the references, your project file should resemble the following:

```
<Project Sdk="Microsoft.NET.Sdk">

  <PropertyGroup>
    <OutputType>Exe</OutputType>
    <TargetFramework>net5.0</TargetFramework>
  </PropertyGroup>

  <ItemGroup>
    <Reference Include="MyMatrixFunctions">
      <HintPath>C:\work\MyMatrixFunctions\for_redistribution_files_only\MyMatrixFunctions.dll</HintPath>
      <!--Path to .NET Assembly created by Library Compiler app-->
    </Reference>
    <Reference Include="MWArray">
      <HintPath>C:\Program Files\MATLAB\MATLAB Runtime\R2023a\toolbox\dotnetbuilder\bin\win64\v5.0\MWArray.dll</HintPath>
      <!--Path to MWArray.dll in the MATLAB Runtime-->
    </Reference>
  </ItemGroup>
</Project>
```

4 Open the C# source file `Program.cs` and replace the existing code with the following code:

### Program.cs

```
// *****
//
// Program.cs
//
// This example demonstrates how to use MATLAB .NET Assembly to build a simple
// component returning a magic square and how to convert MWNumericArray types
// to native .NET types.
//
// Copyright 2001-2022 The MathWorks, Inc.
//
// *****

using System;
```

```

using MathWorks.MATLAB.NET.Utility;
using MathWorks.MATLAB.NET.Arrays;

using MyMatrixFunctions;

namespace MathWorks.Examples.MagicSquare
{
    /// <summary>
    /// The MagicSquareApp class computes a magic square of the user specified size.
    /// </summary>
    /// <remarks>
    /// args[0] - a positive integer representing the size of the magic square.
    /// </remarks>
    class Program
    {
        #region MAIN

        /// <summary>
        /// The main entry point for the application.
        /// </summary>
        [STAThread]
        static void Main(string[] args)
        {
            MWNumericArray arraySize= null;
            MWNumericArray magicSquare= null;

            try
            {
                // Get user specified command line arguments or set default
                arraySize= (0 != args.Length) ? Double.Parse(args[0]) : 4;

                // Create the magic square object
                MyMagic magic= new MyMagic();

                // Compute the magic square and print the result
                magicSquare= (MWNumericArray)magic.mymagic(arraySize);

                Console.WriteLine("Magic square of order {0}\n\n{1}", arraySize, magicSquare);

                // Convert the magic square array to a two dimensional native double array
                double[,] nativeArray= (double[,])magicSquare.ToArray(MWArrayComponent.Real);

                Console.WriteLine("\nMagic square as native array:\n");

                // Display the array elements:
                for (int i= 0; i < (int)arraySize; i++)
                    for (int j= 0; j < (int)arraySize; j++)
                        Console.WriteLine("Element({0},{1})= {2}", i, j, nativeArray[i,j]);

                Console.ReadLine(); // Wait for user to exit application
            }

            catch(Exception exception)
            {
                Console.WriteLine("Error: {0}", exception);
            }
        }
    }
}

```

```
        #endregion  
    }  
}
```

- 5 At the command line, build your .NET 5.0 project by typing:

```
dotnet build MyDotNet5App.csproj
```

- 6 At the command line, run your application by typing:

```
dotnet run -- 3
```

The application displays a 3-by-3 magic square.

- 7 Publish the project as a self-contained deployment to execute the application on either Linux or macOS.

- To publish to Linux, type the following command on a single line:

```
dotnet publish --configuration Release --framework net5.0  
--runtime linux-x64 --self-contained true MyDotNet5App.csproj
```

- To publish to macOS, type the following command on a single line:

```
dotnet publish --configuration Release --framework net5.0  
--runtime osx.10.11-x64 --self-contained true MyDotNet5App.csproj
```

### Create .NET 5.0 App Using Visual Studio

As an alternative to the interactive command line approach to creating a .NET 5.0 application, you can create a .NET 5.0 application using Microsoft Visual Studio. If you have already created a .NET 5.0 application using the above instructions, you can skip this section.

- 1 In Visual Studio create a .NET 5.0 C# project named `MyDotNet5App`. For details, see **Create the app** section in *Create a .NET console application using Visual Studio*.
- 2 In the **Solution Explorer** in Visual Studio, right-click the project name and select **Add > Project Reference**. In the **Reference Manager** window, click **Browse** and add the following references:
  - `C:\work\MyMatrixFunctions\for_redistribution_files_only\MyMatrixFunctions.dll`
  - `C:\Program Files\MATLAB\MATLAB Runtime\R2023a\toolbox\dotnetbuilder\bin\win64\v5.0\MWArray.dll`
- 3 Open the C# source file `Program.cs` and replace the existing code with the code provided in step 4 in the above section.
- 4 Build and run the application.

### Run .NET Core Application on Linux

- 1 Copy the `Release` folder from `C:\Work\MyDotNet5App\bin` on Windows to `~/Work` on a Linux or macOS machine.
- 2 On the Linux machine, verify that you have installed MATLAB Runtime and set up your library path environment variable. For more information, see “Prerequisites” on page 3-40.
- 3 Open a command shell and navigate to:

```
~/Work/Release/net5.0/<os-architecture>/publish
```

- 4 Run the .NET 5.0 application by typing:

```
./MyDotNet5App 3
```

Magic square of order 3

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

Magic square as native array:

```
Element(0,0)= 8
Element(0,1)= 1
Element(0,2)= 6
Element(1,0)= 3
Element(1,1)= 5
Element(1,2)= 7
Element(2,0)= 4
Element(2,1)= 9
Element(2,2)= 2
```

## See Also

### Related Examples

- [“Install and Configure MATLAB Runtime”](#)
- [“Set MATLAB Runtime Path for Deployment”](#)



# Microsoft Visual Basic Integration Examples

---

**Note** The examples for the MATLAB Compiler SDK product are in `matlabroot\toolbox\dotnetbuilder\Examples\VSVersion`, where `matlabroot` is the folder where the MATLAB product is installed and `VSVersion` specifies the version of Microsoft Visual Studio .NET you are using. If you have Microsoft Visual Studio .NET installed, you can load projects for all the examples by opening the following solution:

`matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\DotNetExamples.sln`

---





# Distribute Integrated .NET Applications

---

- “Package .NET Applications” on page 5-2
- “About the MATLAB Runtime” on page 5-3

## **Package .NET Applications**

- 1** Gather and package the following files for installation on end user computers:
  - MATLAB Runtime installer  
See “Install and Configure MATLAB Runtime”.
  - MATLAB generated .NET assembly
  - Executable for the application
- 2** Include directions for installing MATLAB Runtime.  
See “Install and Configure MATLAB Runtime”.

## About the MATLAB Runtime

### In this section...

“How is MATLAB Runtime Different from MATLAB?” on page 5-3

“Performance Considerations for MATLAB Runtime” on page 5-3

The MATLAB Runtime is a standalone set of shared libraries, MATLAB code, and other files that enables the execution of MATLAB files on computers without an installed version of MATLAB. Applications that use artifacts built with MATLAB Compiler SDK require access to an appropriate version of the MATLAB Runtime to run.

End-users of compiled artifacts without access to MATLAB must install the MATLAB Runtime on their computers or know the location of a network-installed MATLAB Runtime. The installers generated by the compiler apps may include the MATLAB Runtime installer. If you compiled your artifact using `mcc`, you should direct your end-users to download the MATLAB Runtime installer from the website <https://www.mathworks.com/products/compiler/mcr>.

For more information, see “Install and Configure MATLAB Runtime”.

### How is MATLAB Runtime Different from MATLAB?

The MATLAB Runtime differs from MATLAB in several important ways:

- In MATLAB Runtime, MATLAB files are encrypted and immutable.
- MATLAB has a desktop graphical interface. MATLAB Runtime has all the MATLAB functionality without the graphical interface.
- MATLAB Runtime is version-specific. You must run your applications with the version of MATLAB Runtime associated with the version of MATLAB Compiler SDK with which it was created. For example, if you compiled an application using release R2020b of MATLAB, end users must have version 9.9 or later of MATLAB Runtime installed. Use `mcrversion` to return the version number of MATLAB Runtime.
- The MATLAB paths in a MATLAB Runtime instance are fixed and cannot be changed. To change them, you must first customize them within MATLAB.

### Performance Considerations for MATLAB Runtime

MATLAB Compiler SDK was designed to work with a large range of applications that use the MATLAB programming language. Because of this, run-time libraries are large.

Since MATLAB Runtime provides full support for the MATLAB language, including the Java programming language, starting a compiled application takes approximately the same amount of time as starting MATLAB. The amount of resources consumed by MATLAB Runtime is necessary in order to retain the power and functionality of a full version of MATLAB.

Calls into MATLAB Runtime are serialized, so calls into MATLAB Runtime are threadsafe. This can impact performance.

### See Also

`mcrversion` | `compiler.runtime.download`

## **Related Examples**

- “Install and Configure MATLAB Runtime”

# Distribute to End Users

---

- “Deploy Components to End Users” on page 6-2
- “MATLAB Runtime Run-Time Options” on page 6-5
- “MATLAB Runtime User Data Interface” on page 6-7
- “Specify Parallel Computing Toolbox Profile in .NET Application” on page 6-8
- “MATLAB Runtime Component Cache and Deployable Archive Embedding” on page 6-12
- “Impersonation Implementation Using ASP.NET” on page 6-13
- “Enhanced XML Documentation Files” on page 6-16

## Deploy Components to End Users

### In this section...

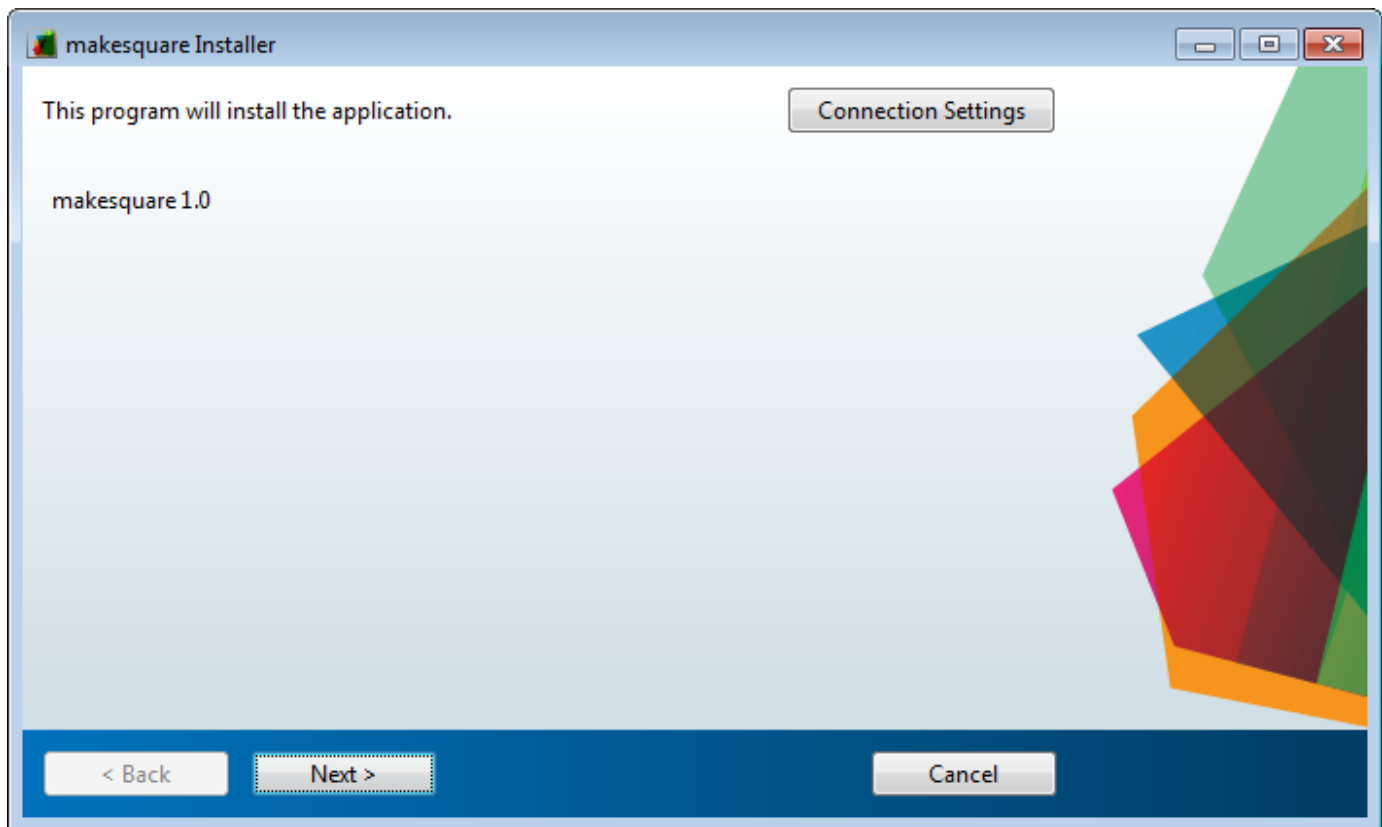
“Running the Component Installer” on page 6-2

“MATLAB Runtime” on page 6-3

### Running the Component Installer

The **Library Compiler** app creates an installer for the generated .NET component. After compilation is complete, you can find this installer in the `for_redistribution` folder in your project folder. By default, the compiler names the installer `MyAppInstaller_web.exe` or `MyAppInstaller_mcr.exe`, depending on which packaging option you chose. Using the Application Information area of the Library Compiler, you can customize the look of the installer.

For example, when an end user double-clicks the component installer, the first screen identifies your component by name and version number.



By clicking **Next** on each screen, the installer leads you through the installation process. During installation, you can specify the installation folder.

The installer also automatically downloads and installs MATLAB Runtime if needed.

## MATLAB Runtime

MATLAB Runtime is an execution engine made up of the same shared libraries MATLAB uses to enable execution of MATLAB files on systems without an installed version of MATLAB.

MATLAB Runtime is available to download from the web to simplify the distribution of your applications created using the MATLAB Compiler or the MATLAB Compiler SDK. Download the MATLAB Runtime from the MATLAB Runtime product page or use the `compiler.runtime.download` MATLAB function.

The MATLAB Runtime installer performs the following actions:

- 1 Install the MATLAB Runtime.
- 2 Install the component assembly in the folder from which the installer is run.
- 3 Copy the `MWArray` assembly to the Global Assembly Cache (GAC).

### MATLAB Runtime Prerequisites

- 1 The MATLAB Runtime installer requires administrator privileges to run.
- 2 The version of MATLAB Runtime that runs your application on the target computer must be the same as the version of MATLAB Compiler or MATLAB Compiler SDK that built the deployed code, at the same update level or newer.
- 3 Do not install the MATLAB Runtime in MATLAB installation directories.
- 4 The MATLAB Runtime installer requires approximately 2 GB of disk space.

### Add the MATLAB Runtime Installer to the Installer

This example shows how to include the MATLAB Runtime in the generated installer using one of the compiler apps. The generated installer contains all files needed to run the standalone application or shared library built with MATLAB Compiler or MATLAB Compiler SDK and properly lays them out on a target system.

- 1 On the **Packaging Options** section of the compiler interface, select one or both of the following options:
  - **Runtime downloaded from web** — This option builds an installer that downloads the MATLAB Runtime installer from the MathWorks website.
  - **Runtime included in package** — The option includes the MATLAB Runtime installer in the generated installer.
- 2 Click **Package**.
- 3 Distribute the installer to end users.

### Install the MATLAB Runtime

For instructions on how to install the MATLAB Runtime on a system, see “Install and Configure MATLAB Runtime”.

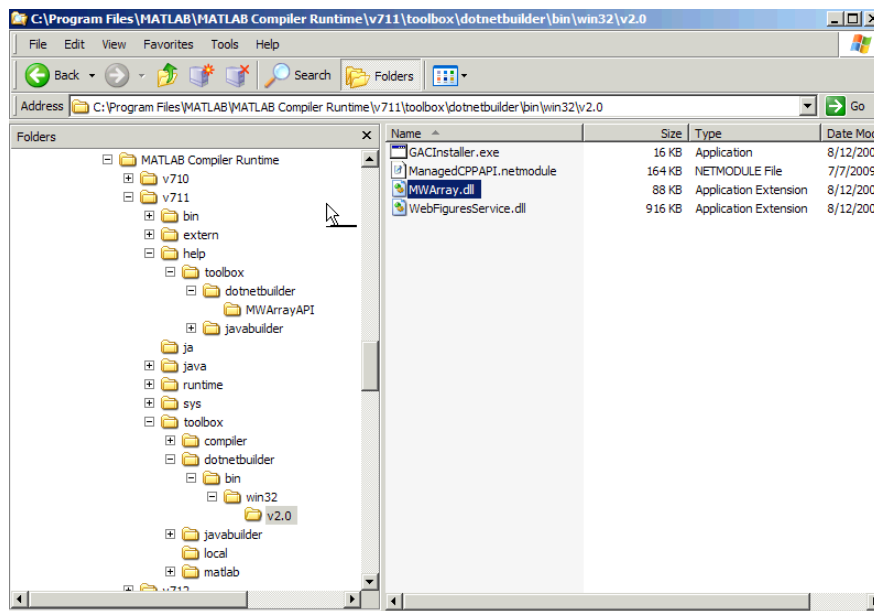
If you are given an installer containing the compiled artifacts, then MATLAB Runtime is installed along with the application or shared library. If you are given just the raw binary files, you must download and run the MATLAB Runtime installer.

**Note** On Windows, paths are set automatically by the installer. If you are running on a platform other than Windows, you must either modify the path on the target machine or use a shell script to launch the compiled application. Setting the paths enables your application executable to find MATLAB Runtime. For more information on setting the path, see “Set MATLAB Runtime Path for Deployment”.

### Where to find the MWArray API

MATLAB Runtime also includes `MWArray.dll`, which contains an API for exchanging data between your applications and MATLAB Runtime. You can find documentation for this API in the `Help` folder of the installation.

On target machines where the MATLAB Runtime installer is run, it puts the `MWArray` assembly in `<MATLAB_RUNTIME_INSTALL_DIR>\toolbox\dotnetbuilder\bin\<ARCH>\<FRAMEWORK_VERSION>`.



**Sample Directory Structure of the MATLAB Runtime Including MWArray.dll**



## MATLAB Runtime Run-Time Options

### In this section...

“What Run-Time Options Can You Specify?” on page 6-5

“Getting MATLAB Runtime Option Values Using MWMCR” on page 6-5

### What Run-Time Options Can You Specify?

You can pass the options `-nojvm` and `-logfile` to MATLAB Compiler SDK from a .NET client application using the assembly-level attributes `NOJVM` and `LOGFILE`. You retrieve values of these attributes by calling methods of the `MWMCR` class to access MATLAB Runtime attributes and state.

### Getting MATLAB Runtime Option Values Using MWMCR

The `MWMCR` class provides several methods to get MATLAB Runtime option values. The following table lists methods supported by this class.

MWMCR Method	Purpose
<code>MWMCR.IsMCRInitialized()</code>	Returns <code>true</code> if the MATLAB Runtime run-time is initialized, otherwise returns <code>false</code> .
<code>MWMCR.IsMCRJVMEEnabled()</code>	Returns <code>true</code> if the MATLAB Runtime run-time is started with .NET Virtual Machine (JVM™), otherwise returns <code>false</code> .
<code>MWMCR.GetMCRLogFileName()</code>	Returns the name of the log file passed with the <code>LOGFILE</code> attribute.

### Default MATLAB Runtime Options

If you pass no options, MATLAB Runtime starts with default option values:

MATLAB Runtime Run-Time Option	Default Option Values
.NET Virtual Machine (JVM)	<code>NOJVM(false)</code>
Log file usage	<code>LOGFILE(null)</code>

These options are all write-once, read-only properties.

Use the following attributes to represent the MATLAB Runtime options you want to modify.

MWMCR Attribute	Purpose
<code>NOJVM</code>	Lets users start MATLAB Runtime with or without a JVM. It takes a Boolean as input. For example, <code>NOJVM(true)</code> starts MATLAB Runtime without a JVM.
<code>LOGFILE</code>	Lets users pass the name of a log file, taking the file name as input. For example, <code>LOGFILE("logfile3.txt")</code> .

**Passing MATLAB Runtime Option Values from a C# Application**

Following is an example of how MATLAB Runtime option values are passed from a client-side C# application:

```
[assembly: NOJVM(false), LOGFILE("logfile3.txt")]
namespace App1
{
    class Program
    {
        static void Main(string[] args)
        {
            Console.WriteLine("In side main...");
            try
            {
                myclass cls = new myclass();
                cls.hello();
                Console.WriteLine("Done!!");
                Console.ReadLine();
            }
            catch (Exception ex)
            {
                Console.WriteLine(ex.Message);
            }
        }
    }
}
```

## MATLAB Runtime User Data Interface

This feature allows data to be shared between a MATLAB Runtime instance, the MATLAB code running on that MATLAB Runtime instance, and the wrapper code that created the MATLAB Runtime instance. Through calls to the MATLAB Runtime User Data interface API, you access MATLAB Runtime data by creating a per-instance associative array of `mxAArrays`, consisting of a mapping from string keys to `mxAArray` values. Reasons for doing this include, but are not limited to:

- You need to supply MATLAB Runtime profile information to a client running an application created with the Parallel Computing Toolbox™ software. Profiles may be supplied (and changed) on a per-execution basis. For example, two instances of the same application may run simultaneously with different profiles.
- You want to initialize MATLAB Runtime with constant values that can be accessed by all your MATLAB applications.
- You want to set up a global workspace — a global variable or variables that MATLAB and your client can access.
- You want to store the state of any variable or group of variables.

MATLAB Compiler SDK software supports a per-MATLAB Runtime instance state access through an object-oriented API. Access to a per-instance state is optional. You can access this state by adding `setmcruserdata.m` and `getmcruserdata.m` to your deployment project or by specifying them on the command line. Alternatively, you can use a helper function to call these methods as shown in “Specify Parallel Computing Toolbox Profile in .NET Application” on page 6-8.

For more information, see “Using MATLAB Runtime User Data Interface”.

## Specify Parallel Computing Toolbox Profile in .NET Application

This example shows how to use the MATLAB Runtime User Data Interface to specify the profile of a Parallel Computing Toolbox cluster in a .NET application.

For more details, see “Using MATLAB Runtime User Data Interface”.

### Step 1: Write Parallel Computing Toolbox Code

- 1 Create `sample_pct.m` in MATLAB.

This example code uses the cluster defined in the default profile for Parallel Computing Toolbox.

```
function speedup = sample_pct (n)
warning off all;
tic
if(ischar(n))
    n=str2double(n);
end
for ii = 1:n
    (cov(sin(magic(n)+rand(n,n))));
end
time1 =toc;
parpool;
tic
parfor ii = 1:n
    (cov(sin(magic(n)+rand(n,n))));
end
time2 =toc;
disp(['Normal loop time: ' num2str(time1) ...
    ', parallel loop time: ' num2str(time2) ]);
disp(['parallel speedup: ' num2str(1/(time2/time1)) ...
    ' times faster than normal']);
delete(gcf);
disp('done');
speedup = (time1/time2);
```

- 2 Run the function with the input 400.

```
a = sample_pct(400)
```

- 3 The following is an example of the output, assuming the default profile is set to local:

```
Starting parallel pool (parpool) using the 'local' profile ...
Connected to the parallel pool (number of workers: 6).
Normal loop time: 2.5651, parallel loop time: 1.6371
parallel speedup: 1.5668 times faster than normal
Parallel pool using the 'local' profile is shutting down.
done

ans =

    1.5668
```

## Step 2: Set Parallel Computing Toolbox Profile

To access the MATLAB Runtime User Data interface using a .NET component built with MATLAB Compiler SDK, you must set `mcruserdata` directly from MATLAB. There is no Java API to access `mcruserdata` as there is for C and C++ applications built with MATLAB Compiler SDK.

To set the `mcruserdata` from MATLAB, create an `init` function. This separate MATLAB function uses `setmcruserdata` to set the Parallel Computing Toolbox profile once. You then call your other functions to utilize the Parallel Computing Toolbox.

Create the following `init_sample_pct` function:

```
function init_sample_pct
% Set the Parallel Computing Toolbox Profile:
if(isdeployed)
    % Let the USER select the cluster profile.
    [profile, profpath] = uigetfile('*.*mlsettings');
    setmcruserdata('ParallelProfile', fullfile(profpath, profile));
end
```

To export an existing profile to an `.mlsettings` file, use the `parallel.exportProfile` function. For example,

```
parallel.exportProfile('local', 'mylocalsettings');
```

---

**Tip** If you need to change your profile in the application, use `parallel.importProfile` and `parallel.defaultClusterProfile`. For more information, see “Discover Clusters and Use Cluster Profiles” (Parallel Computing Toolbox).

---

## Step 3: Compile Your Function

Build the .NET component with the **Library Compiler** app or `compiler.build.dotNETAssembly` using the following information:

Field	Value
Library Name	netPctComp
Class Name	NetPctClass
Files to Compile	sample_pct.m and init_sample_pct.m

For example, if you are using `compiler.build.dotNETAssembly`, type:

```
buildResults = compiler.build.dotNETAssembly( ...
{'sample_pct.m', 'init_sample_pct.m'}, ...
'AssemblyName', 'netPctComp', ...
'ClassName', 'NetPctClass');
```

For more details, see the instructions in “Generate .NET Assembly and Build .NET Application”.

---

**Note** If you are using the GPU feature of Parallel Computing Toolbox, you must manually add the PTX and CU files.

- If you are using the Library Compiler app, click **Add files/directories** on the **Build** tab.

- If you are using a compiler.build function, use the AdditionalFiles option.
  - If you are using the mcc command, use the -a option.
- 

## Step 4: Build and Run .NET Application

Open Microsoft Visual Studio and create a C# **Console App** called DotNETPCT.

Write source code for a .NET application that accesses the MATLAB functions.

A sample C# application for this example is provided below.

```
using System;
using MathWorks.MATLAB.NET.Utility;
using MathWorks.MATLAB.NET.Arrays;
using netPctComp;
namespace PctNet
{
    class Program
    {
        static void Main(string[] args)
        {
            try
            {
                NetPctClass A = new NetPctClass();
                // Initialize the PCT setup
                A.init_sample_pct();
                double var = 400;
                MWNumericArray out1;
                MWNumericArray in1 = new MWNumericArray(var);
                out1 = (MWNumericArray)A.sample_pct(in1);
                Console.WriteLine("The speedup is {0}", out1);
                Console.ReadLine();
                // Wait for user to exit application
            }
            catch (Exception exception)
            {
                Console.WriteLine("Error: {0}", exception);
            }
        }
    }
}
```

---

**Note** This example code was written using Microsoft Visual Studio 2019.

---

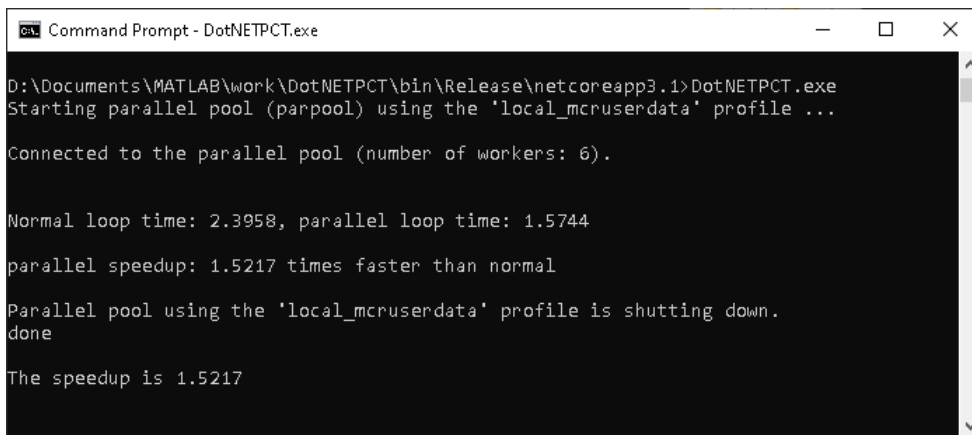
In Visual Studio, add a reference to your assembly file netPctComp.dll located in the folder where you generated or installed the assembly.

Add a reference to the MWArray API.

If MATLAB is installed on your system	<code>matlabroot\toolbox\dotnetbuilder\bin\win64\<i>&lt;version&gt;</i>\MWArray.dll</code>
If MATLAB Runtime is installed on your system	<code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\toolbox\dotnetbuilder\bin\win64\<i>&lt;version&gt;</i>\MWArray.dll</code>

Build and run the DotNETPCT application in Visual Studio.

The DotNETPCT application prompts you to select the cluster profile to use. After you select the `.mlsettings` file, the application displays output similar to the following:



```

Command Prompt - DotNETPCT.exe
D:\Documents\MATLAB\work\DotNETPCT\bin\Release\netcoreapp3.1\DotNETPCT.exe
Starting parallel pool (parpool) using the 'local_mcruserdata' profile ...
Connected to the parallel pool (number of workers: 6).

Normal loop time: 2.3958, parallel loop time: 1.5744
parallel speedup: 1.5217 times faster than normal
Parallel pool using the 'local_mcruserdata' profile is shutting down.
done
The speedup is 1.5217

```

## See Also

[getmcruserdata](#) | [setmcruserdata](#)

## Related Examples

- “Using MATLAB Runtime User Data Interface”
- “Discover Clusters and Use Cluster Profiles” (Parallel Computing Toolbox)

## MATLAB Runtime Component Cache and Deployable Archive Embedding

Deployable archive data is automatically embedded directly in .NET Assemblies by default and extracted to a temporary folder.

Automatic embedding enables usage of the MATLAB Runtime component cache features through environment variables.

These variables allow you to specify the following:

- Define the default location where you want the deployable archive to be automatically extracted
- Add diagnostic error printing options that can be used when automatically extracting the deployable archive, for troubleshooting purposes
- Tuning the MATLAB Runtime component cache size for performance reasons.

Use the following environment variables to change these settings.

Environment Variable	Purpose	Notes
MCR_CACHE_ROOT	When set to the location of where you want the deployable archive to be extracted, this variable overrides the default per-user component cache location. This is true for embedded .ctf files only.	On macOS, this variable is ignored in MATLAB R2020a and later. The app bundle contains the files necessary for runtime.
MCR_CACHE_SIZE	When set, this variable overrides the default component cache size.	The initial limit for this variable is 32M (megabytes). This may, however, be changed after you have set the variable the first time. Edit the file <code>.max_size</code> , which resides in the file designated by running the <code>mrcachedir</code> command, with the desired cache size limit.

---

**Note** If you run `mcc` specifying conflicting wrapper and target types, the archive will not be embedded into the generated component. For example, if you run:

```
mcc -W lib:myLib -T link:exe test.m test.c
```

the generated `test.exe` will not have the archive embedded in it, as if you had specified a `-C` option to the command line.

---

**Caution** Do not extract the files within the .ctf file and place them individually under version control. Since the .ctf file contains interdependent MATLAB functions and data, the files within it must be accessed only by accessing the .ctf file. For best results, place the entire .ctf file under version control.

---



## Impersonation Implementation Using ASP.NET

When running third-party software (for example, SQL Server®) there are times when it is necessary to use impersonation to perform Windows authentication in an ASP.NET application.

In deployed applications, impersonated credentials are passed in from IIS. However, since impersonation operates on a per-thread basis, this can sometimes present problems when processing the MATLAB Runtime thread in a multi-threaded deployed application.

Use the following examples to turn impersonation on and off in your MATLAB file, to avoid problems stemming from MATLAB Runtime thread processing issues.

### Turning On Impersonation in a MATLAB MEX-file

```
#include mex.h
#include windows.h

/*
 *This mex function is called with a single int which
 *represents the user
 *identity token. We use this token to impersonate a
 *user on the interpreter
 *thread. This acts as a workaround for ASP.NET
 *applications that use
 *impersonation to pass the proper credentials
 *to SQL Server for windows
 *authentication. The function returns non zero status
 *for success, zero otherwise.
 */
void mexFunction( int          nlhs,
                  mxArray *    plhs[],
                  int          nrhs,
                  const mxArray * prhs[] )
{
    plhs[0] = mxCreateDoubleScalar(0); //return status

    HANDLE hToken =
        reinterpret_cast(*(mwSize *)mxGetData(prhs[0]));

    if(nrhs != 1)
    {
        mexErrMsgTxt("Incorrect number of input argument(s).
                      Expecting 1.");
    }

    int hr;

    if(!(hr = ImpersonateLoggedOnUser(hToken)))
    {
        mexErrMsgTxt("Error impersonating.\n");
    }

    *(mxGetPr(plhs[0])) = hr;
}
}
```

### Turning Off Impersonation in a MATLAB MEX-file

```
#include mex.h
#include windows.h

/*
 *This mex function reverts to the old identity on the
 interpreter thread */
void mexFunction( int          nlhs,
                  mxArray *    plhs[],
                  int          nrhs,
                  const mxArray * prhs[] )
{
    if(!RevertToSelf())
    {
        mexErrMsgTxt("Failed to revert to the old
                      identity.");
    }
}
```

### Code Added to Support Impersonation in ASP.NET Application

```
Monitor.Enter(someObj);

DeployedComponent.DeployedComponentClass myComp;

try
{
    System.Security.Principal.WindowsIdentity myIdentity =
        System.Security.Principal.WindowsIdentity.GetCurrent();

    //short circuit if user app is not impersonated
    if(myIdentity.IsImpersonated())
    {
        myComp = new DeployedComponent.
            DeployedComponentClass ();

        //Run Users code

        MArray[] output = myComp.impersonateUser(1,
            getToken());
    }
    else
    {
        //Run Users code
    }
}
Catch(Exception e)
{
}
finally
{
    if(myComp!=null)
        myComp.stopImpersonation();
    Monitor.Exit(someObj);
}

//
```

```
//  
//Utility method to read the token for the current user  
//and wraps it in a MWArray private MWNumericArray getToken()  
  
{  
    System.Security.Principal.WindowsIdentity myIdentity =  
        System.Security.Principal.WindowsIdentity.GetCurrent();  
  
    MWNumericArray a = null;  
  
    if (IntPtr.Size == 4)  
    {  
        int intToken = myIdentity.Token.ToInt32();  
        a = new MWNumericArray(intToken, false);  
    }  
    else  
    {  
        Int64 intToken = myIdentity.Token.ToInt64();  
        a = new MWNumericArray(intToken, false);  
    }  
    return a;  
}
```

## Enhanced XML Documentation Files

Every MATLAB Compiler SDK .NET assembly produced is accompanied by a `readme.txt` file. This file outlines the contents of auto-generated documentation templates included with your built component. The documentation templates are HTML and XML files that can be read and processed by any number of third-party tools.

- `MWArray.xml` — This file describes the `MWArray` data conversion classes and their associated methods. Documentation for `MWArray` classes and their methods is available [here](#).
- `component_name.xml` — This file contains the code comments for your component. Using a third party documentation tool, you can combine this file with `MWArray.xml` to produce a complete documentation file that can be packaged with the component assembly for distribution to end users.
- `component_name_overview.html` — Optionally include this file in the generated documentation file. It contains an overview of the steps needed to access the component and how to use the data conversion classes, contained in the `MWArray` class hierarchy, to pass arguments to the generated component and return the results.

# Type-Safe Interfaces, WCF, and MEF

---

- “Type-Safe Interfaces” on page 7-2
- “Implement Type-Safe Interface and Integrate into .NET Application” on page 7-8
- “Create Managed Extensibility Framework Plug-Ins” on page 7-13

## Type-Safe Interfaces

MATLAB data types are incompatible with native .NET types. To send data between your application and .NET, you perform these tasks:

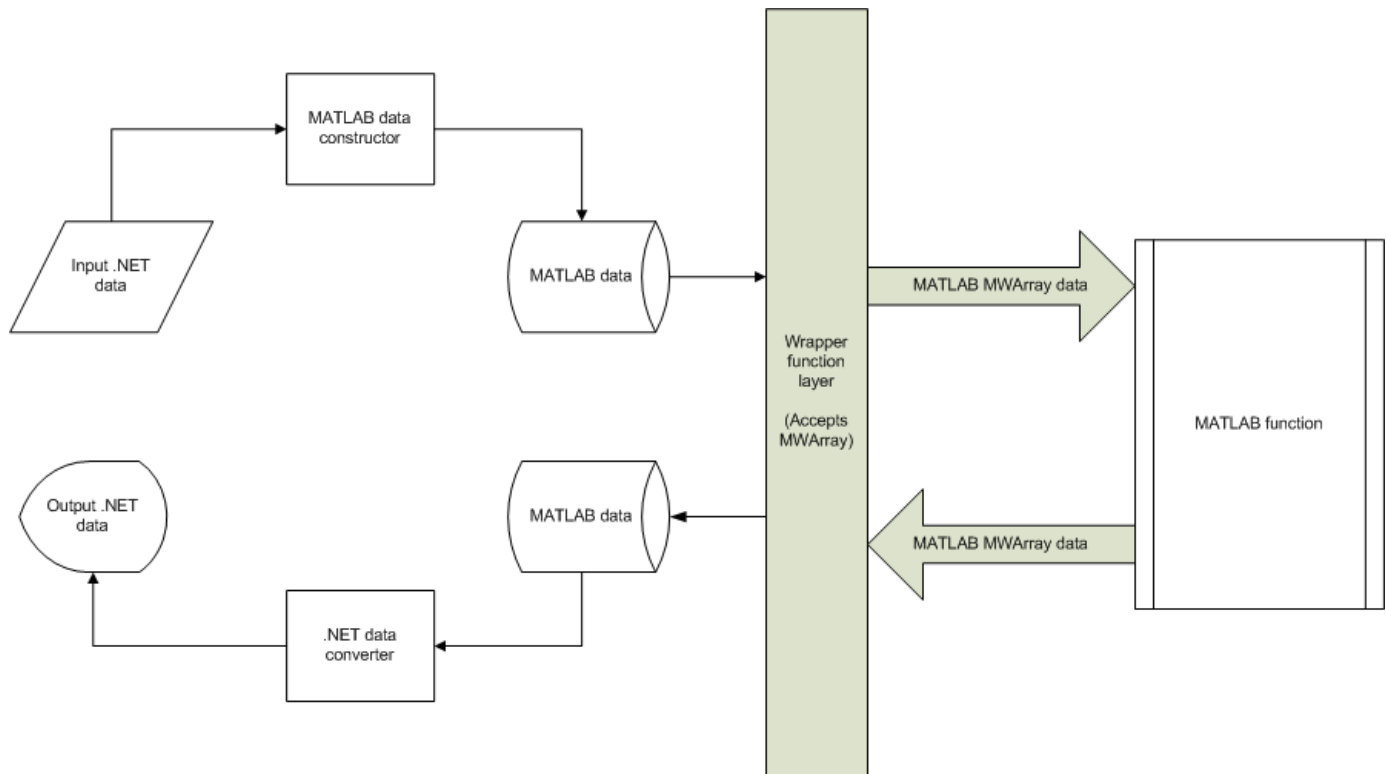
- 1 Marshal data from .NET input data to a deployed function by creating an `MWArray` object from native .NET data. The `public` functions in a deployed component return `MWArray` objects.
- 2 Marshal the output MATLAB data in an `MWArray` into native .NET data by calling one of the `MWArray` marshaling methods (`ToArray()`, for example).

While you can marshal the data manually using `MWArray` data types, using a type-safe interface simplifies the process.

### Manual Data Marshaling Without a Type-Safe Interface

Manually marshaling data adds complexity and potential failure points to the task of integrating deployed components into a .NET application. This is particularly true for these reasons:

- **Your application cannot detect type mismatch errors until run time.** For example, you might accidentally create an `MWArray` from a string and pass the array to a deployed function that expects a number. Because the wrapper code generated by MATLAB Compiler SDK expects an `MWArray`, the .NET compiler is unable to detect this error and the deployed function either throws an exception or returns the wrong answer.
- **Your end users must learn how to use the `MWArray` data type** or alternately mask the `MWArray` data type behind a manually written (and manually maintained) API. This introduces unwanted training time and places resource demands on a potentially overcommitted staff.

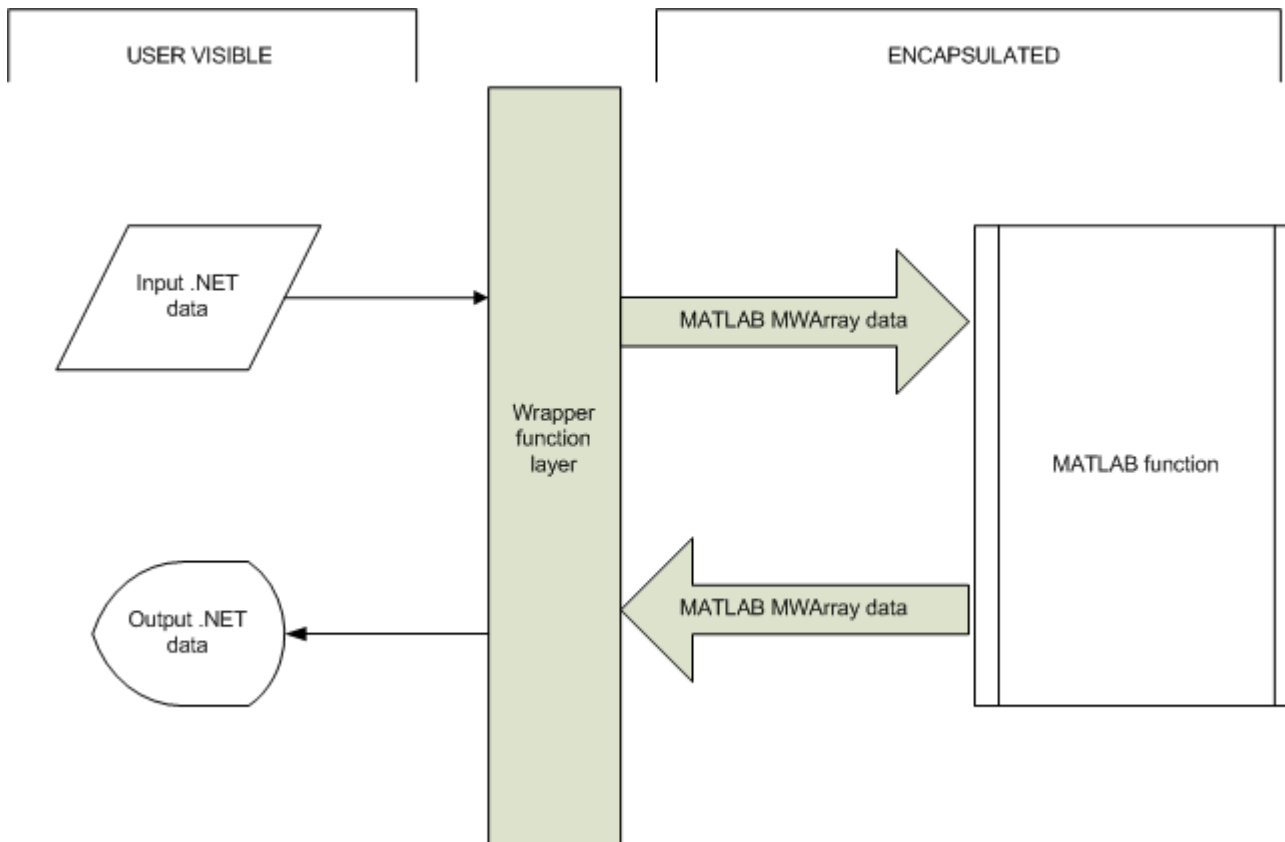


### Data Marshaling Without a Type-Safe Interface

You may find `MArray` methods more efficient when passing large data values in loops to one or more deployed functions. In such cases, creating an `MArray` object allows you to marshal the data only once, whereas type-safe interfaces marshal inputs on every call.

### Simplified Data Marshaling With a Type-Safe Interface

You can avoid performing `MArray` data marshaling by using type-safe interfaces. Such interfaces minimize explicit type conversions by hiding the `MArray` type from the calling application. Using type-safe interfaces allows .NET developers to work directly with familiar native data types.



### Data Marshaling With a Type-Safe Interface

Some of the reasons to implement type-safe interfaces include:

- **You avoid training and coding costs** associated with teaching end users to work with the `MArray` API.
- **You minimize cost of data you must marshal** by either placing `MArray` objects in type-safe interfaces or by calling `MArray` functions in the deployed MATLAB code.
- **Flexibility – you mix type-safe interfaces with manual data marshaling** to accommodate data of varying sizes and access patterns. For example, you may have a few large data objects (images, for example) that would incur excess cost to your organization if managed with a type-safe interface. By mixing type-safe interfaces and manual marshaling, smaller data types can be managed automatically with the type-safe interface and your large data can be managed on an as-needed basis.

For an example on implementing type-safe interfaces, see “Implement Type-Safe Interface and Integrate into .NET Application” on page 7-8.

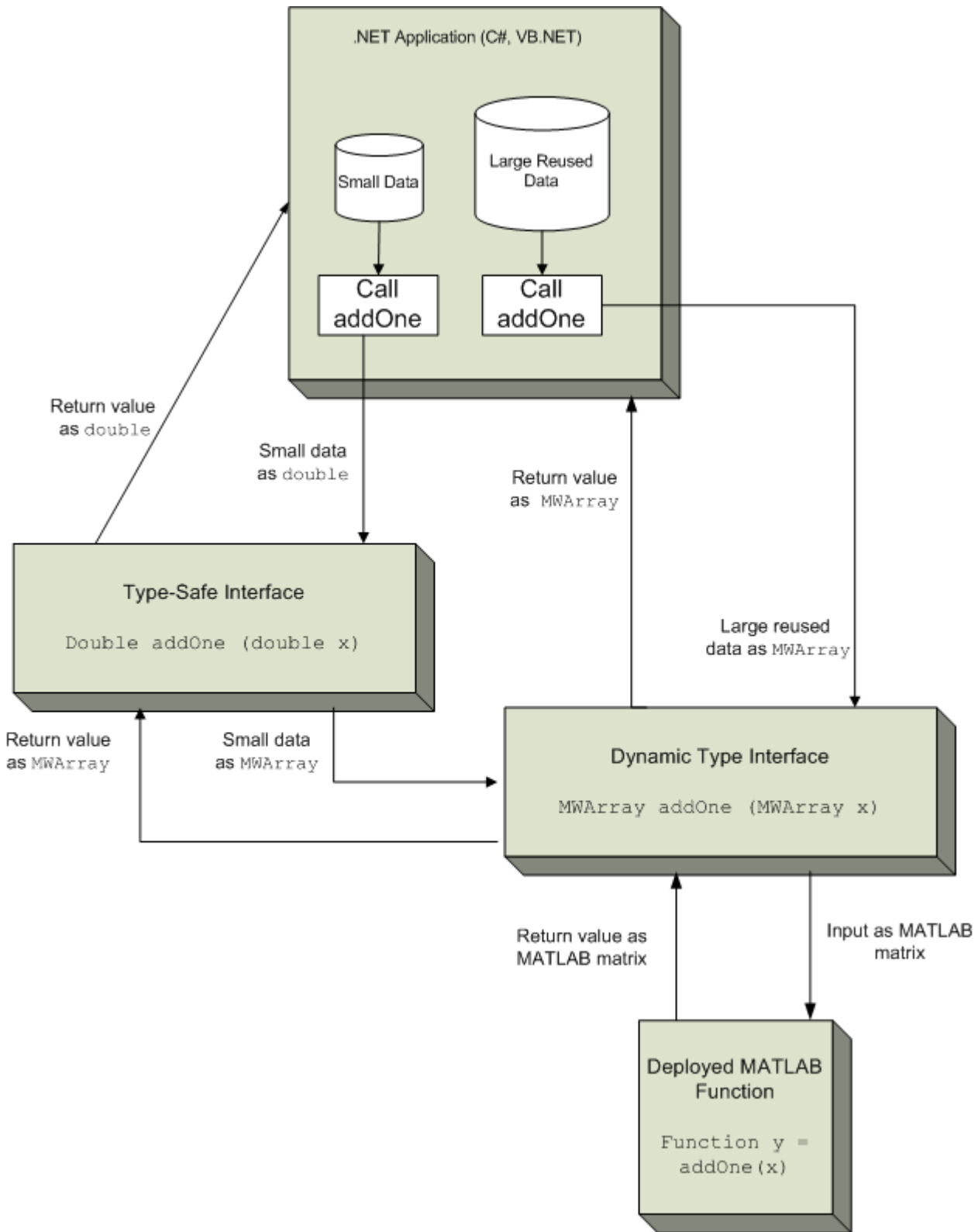
### How Type-Safe Interfaces Work

Every MATLAB Compiler SDK .NET assembly exports one or more public methods that accept and return data using `MArray` objects. Adding a type-safe interface to a MATLAB Compiler SDK assembly creates another set of methods (with the same names) that accept and return native .NET types.



You may create multiple type-safe interface methods for a single MATLAB function. Type-safe interface methods follow the standard .NET methods for overloading.

The following figure illustrates the data paths between the .NET host application and the deployed MATLAB function through a type-safe interface.



The MATLAB function `addOne` returns its input plus one. Deploying `addOne` with a type-safe interface creates two .NET `addOne` methods:

- One that accepts and returns .NET `double`
- One that accepts and returns `MWArray`

Notice that the type-safe methods co-exist with the `MWArray` methods. Your .NET application may mix and match calls to either type of method, as appropriate.

## See Also

### Related Examples

- “Implement Type-Safe Interface and Integrate into .NET Application” on page 7-8

## Implement Type-Safe Interface and Integrate into .NET Application

This example shows how to implement a type-safe interface and integrate it into a .NET application.

Type-safe interfaces allow you to work directly with familiar native data types instead of using the `MWArray` API. Adding a type-safe interface to a .NET assembly creates an additional set of methods that accept and return native .NET types.

### Write and Test Your MATLAB Code

Create your MATLAB program and then test the code before implementing a type-safe interface. The functions in your MATLAB program must match the declarations in your native .NET interface.

For this example, save the following code as `multiply.m`. The function returns the multiplication of the inputs `x` and `y`.

```
function z = multiply(x,y)
z = x * y;
```

Test the function at the MATLAB command prompt.

```
multiply([1 4 7; 2 5 8; 3 6 9],[1 4 7; 2 5 8; 3 6 9])
```

```
ans =
```

```
    30    66   102
    36    81   126
    42    96   150
```

### Implement Type-Safe Interface

After you write and test your MATLAB code, develop a .NET type-safe interface in either C# or Visual Basic. This example uses provided C# source code for the interface.

- 1 Open Microsoft Visual Studio and create a new **Class Library (.NET Framework)** project named `IMultiply`.
- 2 In the Solution Explorer window, rename the `Class1.cs` file to `IMultiply.cs`. In this file, you write source code for the type-safe interface that accesses the component.

In this example, the `IMultiply` interface is written in C# and specifies three overloads of `multiply`:

```
using System;

public interface IMultiply
{
    // Scalar multiplication
    System.Double multiply(System.Double x, System.Double y);

    // Multiply vector by a scalar, return a vector
    System.Double[] multiply(System.Double[] x, System.Double y);

    // Matrix multiplication
```

```

        System.Double[,] multiply(System.Double[,] x, System.Double[,] y);
    }

```

Each method in the interface must exactly match a deployed MATLAB function.

All methods have two inputs and one output (to match the MATLAB `multiply` function), though the parameter data type varies.

- 3 Go to **Build** and then **Configuration Manager**, and change the platform from **Any CPU** to **x64**.
- 4 Build the project with Microsoft Visual Studio.

The file `IMultiply.dll` is generated in the build folder.

This example assumes your assembly contains only `IMultiply`. Realistically, it is more likely that the type-safe interface will already be part of a compiled assembly. The assembly can be compiled even before the MATLAB function is written.

## Create .NET Assembly Using Library Compiler App

Generate the type-safe interface with the .NET assembly using the **Library Compiler** app. Alternatively, if you want to create a .NET assembly from the MATLAB command window using a programmatic approach, see “Create .NET Assembly Using `compiler.build.dotNETAssembly`” on page 7-9.

- 1 Create a Library Compiler project and select **.NET Assembly** from the **Type** list.
- 2 Specify the following values:

Field	Value
<b>Library Name</b>	Multiply
<b>Class Name</b>	Arithmetic
<b>File to Compile</b>	multiply.m

- 3 Expand the **Additional Runtime Settings** section.
- 4 In the **Type-Safe API** section, do the following:
  - a Select **Enable Type-Safe API**.
  - b In the **Interface assembly** field, specify the location of the type-safe interface assembly `IMultiply.dll` that you built.
  - c Select the `IMultiply` interface from the **.NET interface** drop-down box.
  - d Leave the **Namespace** field blank.
  - e Specify the `Arithmetic` class in the **Wrapped Class** field.
- 5 Click the **Package** button to build the project.

## Create .NET Assembly Using `compiler.build.dotNETAssembly`

As an alternative to the **Library Compiler** app, you can generate the type-safe interface using a programmatic approach using the following steps. If you have already created an assembly using the **Library Compiler**, see “Integrate .NET Assembly Into .NET Application” on page 7-10.

- 1 Build the .NET assembly using the `compiler.build.dotNETAssembly` function. Use name-value arguments to specify the assembly name and class name.

```

compiler.build.dotNETAssembly('multiply.m', ...
    'AssemblyName','Multiply', ...
    'ClassName','Arithmetic');

```

- 2 Navigate to the generated MultiplydotNETAssembly folder.
- 3 Generate the type-safe interface by using the ntswrap command from MATLAB:

```
ntswrap('-c','Multiply.Arithmetic', ...
        '-a','IMultiply.dll', ...
        '-i','IMultiply');
```

Not all arguments are compatible with each other. See ntswrap for details on all command options.

---

**Tip** If the IMultiply.dll assembly is not in the current folder, specify the full path.

---

This command generates the assembly ArithmeticIMultiply.dll that contains a type-safe API for the MATLAB Compiler SDK class Arithmetic in the namespace MultiplyNative.

## Integrate .NET Assembly Into .NET Application

After creating your .NET assembly, you can integrate it into any .NET application. You can use this example .NET application code as a guide to write your own .NET application.

Compile the .NET program using Microsoft Visual Studio by doing the following steps:

- 1 Open Microsoft Visual Studio and create a C# **Console App (.NET Framework)** called MultiplyApp.
- 2 Copy the following source code into the generated Program.cs in your project:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;

namespace MultiplyApp
{
    class Program
    {
        delegate String VectorToString<T>(IEnumerable<T> v);
        delegate IEnumerable<String> MatrixToString<T>(T[,] m);

        static void Main(string[] args)
        {
            Console.WriteLine("\nStarting application...\n");

            //Create an instance of the Type-safe API
            IMultiply m = new ArithmeticIMultiply();

            // Scalar multiplication
            double x = 17, y = 3.14159;
            double z = m.multiply(x, y);
            System.Console.WriteLine("{0} * {1} = {2}\n", x, y, z);

            // Vector times scalar
            double[] v = new double[] { 2.5, 81, 64 };
            double s = 11;
            double[] d = m.multiply(v, s);

            VectorToString<double> vec2str = (vec =>
                vec.Select(n => n.ToString()).Aggregate((str, next) => str + " " + next));

            System.Console.WriteLine("[ {0} ] * {1} = [ {2} ]\n",
                vec2str(v), s, vec2str(d));

            // Matrix multiplication
            double[,] magic = new double[,] { // 3x3 magic square
                { 8, 1, 6 },
                { 3, 5, 7 },
                { 4, 9, 2 } };
            double[,] squareSquared = m.multiply(magic, magic);
```

```

        MatrixToString<double> mat2str = mat =>
            mat.EnumerateRows<double>().Select(r => vec2str(r));

        PrintParallel(mat2str(magic), " * ".Select(c => c.ToString()),
            mat2str(magic), " = ".Select(c => c.ToString()),
            mat2str(squareSquared));

        Console.WriteLine("\nClosing application...");
    }

    public static void PrintParallel<T>(params IEnumerable<T>[] sources)
    {
        int max = sources.Select(s => s.Count()).Max();
        for (int i = 0; i < max; i++)
        {
            foreach (var src in sources)
                System.Console.Write("{0} ", src.ElementAt(i));
            System.Console.WriteLine();
        }
    }
}

public static class ArrayExtensions
{
    public static IEnumerable<IEnumerable<T>> EnumerateRows<T>(this Array a)
    {
        return Enumerable.Range(0, a.GetLength(1)).Select(row =>
            a.ToIEnumerable<T>().Skip(row * a.GetLength(0)).Take(a.GetLength(0)));
    }

    public static IEnumerable<T> ToIEnumerable<T>(this Array a)
    {
        foreach (var item in a)
            yield return (T)item;
    }
}
}
}

```

- 3** Add references in the project to the following files.

This reference:	Defines:
IMultiply.dll	The .NET native type interface assembly IMultiply
ArithmeticIMultiply.dll	The generated type-safe API
MultiplyNative.dll	The generated .NET assembly

**Note** Unlike other .NET deployment scenarios, you do not need to reference `MWArray.dll` in the server program source code. The `MWArray` data types are hidden behind the type-safe API in `ArithmeticIMultiply`.

- 4** Go to **Build** and then **Configuration Manager**, and change the platform from **Any CPU** to **x64**.  
**5** Compile and run the program with Microsoft Visual Studio.

The program displays the following output:

```
Starting application...
```

```
17 * 3.14159 = 53.40703
```

```
[ 2.5 81 64 ] * 11 = [ 27.5 891 704 ]
```

```
8 1 6   8 1 6   91 67 67
3 5 7 * 3 5 7 = 67 91 67
4 9 2   4 9 2   67 67 91
```

```
Closing application...
```

## Tips

- In a MATLAB function, declaration outputs appear before inputs. For example, in the `multiply` function, the output `z` appears before the inputs `x` and `y`. This ordering is not required for .NET interface functions. Inputs may appear before or after outputs, or the two may be mixed together.
- MATLAB Compiler SDK matches .NET interface functions to public MATLAB functions by function name and argument count. In the `multiply` example, both the .NET interface function and the MATLAB function must be named `multiply`, and both functions must have an equal number of arguments defined.
- The number and relative order of input and output arguments is critical.
  - In evaluating parameter order, only the order of like parameters (inputs or outputs) is considered, regardless of where they appear in the parameter list.
  - A function in the interface may have fewer inputs than its corresponding MATLAB function, but not more.
- Argument mapping occurs according to argument order rather than argument name.
- The function return value, if specified, counts as the first output.
- You must use `out` parameters for multiple outputs.
  - Alternately, the `ref` parameter can be used for `out`, as `ref` and `out` are synonymous.
- MATLAB does not support overloading of functions. Thus, all user-supplied overloads of a function with a given name will map to a function generated by MATLAB Compiler SDK.

See “[.NET Types to MATLAB Types](#)” on page 13-3 for complete guidelines in managing data conversion with type-safe interfaces.

## See Also

`compiler.build.dotNETAssembly` | `ntswrap`

## Related Examples

- “[Type-Safe Interfaces](#)” on page 7-2



## Create Managed Extensibility Framework Plug-Ins

### In this section...

“Prerequisites” on page 7-13

“Addition and Multiplication Applications with MEF” on page 7-13

“Create an MEFHost Assembly” on page 7-14

“Create a Contract Interface Assembly” on page 7-14

“Create a Metadata Attribute Assembly” on page 7-15

“Add Contract and Attributes References to MEFHost” on page 7-16

“Compile Your Code in Microsoft Visual Studio” on page 7-16

“Write MATLAB Functions for MEF Parts” on page 7-16

“Create Metadata Files” on page 7-16

“Build .NET Components from MATLAB Functions and Metadata” on page 7-17

“Install MEF Parts” on page 7-18

“Run the MEF Host Program” on page 7-18

The Managed Extensibility Framework (MEF) is a library for creating lightweight, extensible applications.

For up-to-date information regarding MEF, refer to the MSDN article “Managed Extensibility Framework.”

### Prerequisites

Before running this example, keep the following in mind:

- You must be running at least Microsoft Visual Studio 2010 to create MEF applications. If you can't use Microsoft Visual Studio 2010, you can't run this example code, or any other program that uses MEF. End users do not need Microsoft Visual Studio 2010 to run applications using MEF.
- You must be running at least Microsoft .NET Framework 4.0 to use the MEF feature.
- The easiest way to use MEF is through the type-safe API.

### Addition and Multiplication Applications with MEF

This MEF example application consists of an MEF host and two parts. The parts implement a very simple interface (`ICompute`) which defines three overloads of a single function (`compute`).

Each part performs simple arithmetic. In one part, the `compute` function adds one (1) to its input. In the other part, `compute` multiplies its input by two (2). The MEF host loads both parts and calls their `compute` functions twice.

To run this example, you'll create a new solution containing three projects:

- MEF host
- Contract interface assembly
- Strongly-typed metadata attribute assembly

## Where To Find Example Code for MEF

Selected example code can be found, along with some Microsoft Visual Studio projects, in `matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET`. This code has been tested to be compliant with Microsoft Visual Studio 2010 running on Microsoft .NET Framework version 4.0 or higher.

## Create an MEFHost Assembly

- 1 Start Microsoft Visual Studio 2010.
- 2 Click **File > New > Project**.
- 3 In the **Installed Templates** pane, click **Visual C#** to filter the list of available templates.
- 4 Select the **Console Application** template from the list.
- 5 In the **Name** field, enter `MEFHost`.
- 6 Click **OK**. Your project is created.
- 7 Replace the contents of the default `Program.cs` with the `MEFHost.cs` code. For information about locating example code, see “Where to Find Example Code,” above.
- 8 In the **Solution Explorer** pane, select the project **MEFHost** and right-click. Select **Add Reference**.
- 9 Click **Assemblies > Framework** and add a reference to `System.ComponentModel.Composition`.
- 10 To prevent security errors, particularly if you have a non-local installation of MATLAB, add an application configuration file to the project. This XML file instructs the MEF host to trust assemblies loaded from the network. If your project does not include this configuration file, your application fails at run time.
  - a Select the **MEFHost** project in the **Solution Explorer** pane and right-click.
  - b Click **Add > New Item**.
  - c From the list of available items, select **Application Configuration File**.
  - d Name the configuration file `App.config` and click **Add**.
  - e Replace the automatically-generated contents of `App.config` with this configuration:

```
<?xml version="1.0" encoding="utf-8" ?>
<configuration>
  <runtime>
    <loadFromRemoteSources enabled="true" />
  </runtime>
</configuration>
```

You have finished building the first project, which builds the MEF host.

Next, you add a C# class library project for the MEF contract interface assembly.

## Create a Contract Interface Assembly

- 1 In Visual Studio, click **File > New > Project**.
- 2 In the **Installed Templates** pane, click **Visual C#** to filter the list of available templates.
- 3 Select the **Class Library** template from the list.

- 4 In the **Name** field, enter `Contract`.

---

**Note** Ensure `Add to solution` is selected in the **Solution** drop-down box.

---

- 5 Click **OK**. Your project is created.
- 6 Replace the contents of the default `Class1.cs` with the following `ICompute` interface code:

```
namespace Contract
{
    public interface ICompute
    {
        double compute(double y);
        double[] compute(double[] y);
        double[,] compute(double[,] y);
    }
}
```

You have finished building the second project, which builds the `Contract Interface Assembly`.

Since strongly-typed metadata requires that you decorate MEF parts with a custom metadata attribute, in the next step you add a C# class library project. This project builds an attribute assembly to your MEFHost solution.

## Create a Metadata Attribute Assembly

- 1 In Visual Studio, click **File > New > Project**.
- 2 In the **Installed Templates** pane, click **Visual C#** to filter the list of available templates.
- 3 Select the **Class Library** template from the list.
- 4 In the **Name** field, enter `Attribute`.

---

**Note** Ensure `Add to solution` is selected in the **Solution** drop-down box.

---

- 5 Click **OK**. Your project is created.
- 6 In the generated assembly code, change the namespace from `Attribute` to `MEFHost`. Your namespace code should now look like the following:

```
namespace MEFHost
{
    public class Class1
    {
    }
}
```

- 7 In the **MEFHost** namespace, replace the contents of the default class `Class1.cs` with the following code for the `ComputationTypeAttribute` class:

```
using System.ComponentModel.Composition;
[MetadataAttribute]
[AttributeUsage(AttributeTargets.Class, AllowMultiple=false)]
public class ComputationTypeAttribute: ExportAttribute
{
}
```

```
        public ComputationTypeAttribute() :  
            base(typeof(Contract.ICompute)) { }  
        public Operation FunctionType { get; set; }  
        public double Operand { get; set; }  
    }  
  
    public enum Operation  
    {  
        Plus,  
        Times  
    }  
}
```

- 8 Navigate to the **.NET** tab and add a reference to `System.ComponentModel.Composition.dll`.

## Add Contract and Attributes References to MEFHost

Before compiling your code in Microsoft Visual Studio:

- 1 In your **MEFHost** project, add references to the **Contract** and **Attribute** projects.
- 2 In your **Attribute** project, add a reference to the **Contract** project.

## Compile Your Code in Microsoft Visual Studio

Build all your code by selecting the solution name **MEFHost** in the **Solution Explorer** pane, right-clicking, and selecting **Build Solution**.

In doing so, you create the following binaries in `MEFHost/bin/Debug`:

- `Attribute.dll`
- `Contract.dll`
- `MEFHost.exe`

## Write MATLAB Functions for MEF Parts

Create two MATLAB functions. Each must be named `compute` and stored in separate folders, within your Microsoft Visual Studio project:

### MEFHost/Multiply/compute.m

```
function y = compute(x)  
    y = x * 2;
```

### MEFHost/Add/compute.m

```
function y = compute(x)  
    y = x + 1;
```

## Create Metadata Files

Create a metadata file for each MATLAB function.

- 1 For `MEFHost/Add/compute.m`:

**a** Name the metadata file `MEFHost/Add/Add.metadata`.

**b** In this file, enter the following metadata on one line:

```
[MEFHost.ComputationType(FunctionType=MEFHost.Operation.Plus, Operand=1)]
```

**2** For `MEFHost/Multiply/compute.m`:

**a** Name the metadata file `MEFHost/Multiply/Multiply.metadata`.

**b** In this file, enter the following metadata on one line:

```
[MEFHost.ComputationType(FunctionType=MEFHost.Operation.Times, Operand=2)]
```

## Build .NET Components from MATLAB Functions and Metadata

In this step, use the **Library Compiler** app to create .NET components from the MATLAB functions and associated metadata.

Use the information in these tables to create both **Addition** and **Multiplication** projects.

**Note** Since you are deploying two functions, you need to run the **Library Compiler** app *twice*, once using the `Addition.prj` information and once using the `Multiplication.prj` information.


### Addition.prj

Library Name	Addition
Class Name	Add
File to Compile	MEFHost/Add/compute.m

### Multiplication.prj

Library Name	Multiplication
Class Name	Multiply
File to Compile	MEFHost/Multiply/compute.m

**1** Create your component, following the instructions in “Generate .NET Assembly and Build .NET Application”.

**2** Modify project settings ( > **Settings**) on the **Type Safe API** tab, for whatever project you are building (**Addition** or **Multiplication**).

Project Setting	Addition.prj	Multiplication.prj
Enable Type Safe API	Checked	Checked
Interface Assembly	MEFHost/bin/Debug/Contract.dll	MEFHost/bin/Debug/Contract.dll
MEF metadata	MEFHost/Add/Add.metadata	MEFHost/Multiply/Multiply.metadata
Attribute Assembly	MEFHost/bin/Debug/Attribute.dll	MEFHost/bin/Debug/Attribute.dll

Wrapped Class	Add	Multiply
---------------	-----	----------

- 3 Click the Package button.

## Install MEF Parts

The two components you have built are MEF parts. You now need to move the generated parts into the catalog directory so your application can find them:

- 1 Create a parts folder named `MEFHost/Parts`.
- 2 If necessary, modify the path argument that is passed to the `DirectoryCatalog` constructor in your MEF host program. It must match the full path to the `Parts` folder that you just created.

---

**Note** If you change the path after building the MEF host a first time, you must rebuild the MEF host again to pick up the new `Parts` path.

---

- 3 Copy the two `componentNative.dlls` (`Addition` and `Multiplication`) and `AddICompute.dll` and `MultiplyICompute.dll` assemblies from your into `MEFHost/Parts`.

---

**Note** You do not need to reference any of your MEF part assemblies in the MEF host program. The host program uses a `DirectoryCatalog`, which means it automatically searches for (and loads) parts that it finds in the specified folder. You can add parts at any time, without having to recompile or relink the MEF host application. You do not need to copy `Addition.dll` or `Multiplication.dll` to the `Parts` directory.

---

## Run the MEF Host Program

MATLAB-based MEF parts require MATLAB Runtime, like all deployed MATLAB code.

Before you run your MEF host, ensure that the correct version of MATLAB Runtime is available and that `matlabroot/runtime/arch` is on your path.

- 1 From a command window, run the following. This example assumes you are running from `c:\Work`.

```
c:\Work> MEFHost\bin\Debug\MEFHost.exe
```

- 2 Verify you receive the following output:

```
8 Plus 1 = 9
9 Times 2 = 18
16 Plus 1 = 17
1.5707963267949 Times 2 = 3.14159265358979
```

---

**Note** If you receive an exception indicating that a type initializer failed, ensure that you have .NET security permissions set to allow applications to load assemblies from a network.

---

# Windows Communications Foundation Based Components

---

## Create Windows Communications Foundation Component

### In this section...

“Write and Test Your MATLAB Code” on page 8-2  
 “Implement WCF Interface” on page 8-2  
 “Create .NET Assembly Using Library Compiler App” on page 8-3  
 “Create .NET Assembly Using compiler.build.dotNETAssembly” on page 8-4  
 “Develop Server Program Using WCF Interface” on page 8-5  
 “Generate Proxy Code for Clients” on page 8-7  
 “Develop Client Program Using WCF Interface” on page 8-7  
 “Tips” on page 8-9

The following example shows you how to implement a Windows Communications Foundation (WCF) component using a type-safe interface and integrate it into a client-server .NET application.

For an additional example and data conversion rules regarding type-safe interfaces, see “Implement Type-Safe Interface and Integrate into .NET Application” on page 7-8.

For up-to-date information regarding WCF, see What Is Windows Communication Foundation in the Microsoft documentation.

### Write and Test Your MATLAB Code

Create your MATLAB program and then test the code before implementing a type-safe interface. The functions in your MATLAB program must match the declarations in your native .NET interface.

For this example, save the following code as `addOne.m`.

```
function y = addOne(x)
% Input must be either a scalar or a matrix of single or multiple dimensions

    if ~isnumeric(x)
        error('Input must be numeric. Input was %s.', class(x));
    end
    y = x + 1;
end
```

At the MATLAB command prompt, enter `addOne([1,2,3])`.

The output is:

```
2     3     4
```

### Implement WCF Interface

After you write and test your MATLAB code, develop an interface in either C# or Visual Basic that supports the native types through the API.

- 1 Open Microsoft Visual Studio and create a new **Class Library (.NET Framework)** project named `IAddOne`.
- 2 In the Solution Explorer window within Visual Studio, rename the `Class1.cs` file to `IAddOne.cs`. In this file, write source code for the WCF interface that accesses the component.



In this example, the `IAddOne` interface is written in C# and specifies six overloads of `addOne`:

### IAddOne.cs

```
using System;
using System.ServiceModel;

[ServiceContract]
public interface IAddOne
{
    [OperationContract(Name = "addOne_1")]
    int addOne(int x);

    [OperationContract(Name = "addOne_2")]
    void addOne(ref int y, int x);

    [OperationContract(Name = "addOne_3")]
    void addOne(int x, ref int y);

    [OperationContract(Name = "addOne_4")]
    System.Double addOne(System.Double x);

    [OperationContract(Name = "addOne_5")]
    System.Double[] addOne(System.Double[] x);

    [OperationContract(Name = "addOne_6")]
    System.Double[][] addOne(System.Double[][] x);
}
```

Note that in the WCF implementation of `addOne`, you decorate the methods with the `OperationContract` property. You give each method a unique operation name, which you specify with the `Name` property of `OperationContract`

---

**Note** When using WCF, your overloaded functions *must* have unique names.

---

Each method in the interface must exactly match a deployed MATLAB function. All methods have one input and one output (to match the MATLAB `addOne` function), though the type and position of these parameters varies.

- 3** Go to **Build > Configuration Manager** and change the platform from **Any CPU** to **x64**.
- 4** Build the project with Microsoft Visual Studio. The file `IAddOne.dll` is generated in the build folder.

---

**Note** This example assumes your assembly contains only `IAddOne`. Realistically, it is more likely that `IAddOne` will already be part of a compiled assembly. The assembly may be complete even before the MATLAB function is written.

---

## Create .NET Assembly Using Library Compiler App

The **Library Compiler** app generates the type-safe API when you build your component, if the following options are selected.

- 1** Create a Library Compiler project and select **.NET Assembly** from the **Type** list.

- 2 Use the following values:

Library Name	AddOneComp
Class Name	Mechanism
File to Compile	addOne.m

- 3 Expand the **Additional Runtime Settings** section.

In the **Type-Safe** API section, do the following:

- 1 Select **Enable Type-Safe API**.
- 2 In the **Interface assembly** field, specify the location of the type-safe/WCF interface assembly `IAddOne.dll` that you built.
- 3 Select the `IAddOne` interface from the **.NET interface** drop-down box.

---

**Tip** If the drop-down is blank, the Library Compiler may have been unable to find any .NET interfaces in the assembly you selected.

---

- 4 Leave the **Namespace** and **MEF metadata** fields blank.
  - 5 Specify the `Mechanism` class in the **Wrapped Class** field.
- 4 Click the **Package** button to build the project.

The file `AddOneCompNative.dll` is generated in the `for_redistribution_files_only` folder.

## Create .NET Assembly Using `compiler.build.dotNETAssembly`

---

**Note** If you have already created a .NET assembly using the **Library Compiler** app, you can skip this section. However, if you want to know how to create a .NET assembly from the MATLAB command window using a programmatic approach, follow these instructions.

---

To generate the type-safe API with your component build using the `compiler.build.dotNETAssembly` function, complete the following steps:

- 1 Build the .NET assembly using `compiler.build.dotNETAssembly`. Use name-value arguments to specify the assembly name and class name.

```
compiler.build.dotNETAssembly('addOne.m', ...  
    'AssemblyName','AddOneComp', ...  
    'ClassName','Mechanism');
```

- 2 Navigate to the generated `AddOneCompdotNETAssembly` directory.
- 3 Generate the type-safe API by using the `ntswrap` command from MATLAB:

```
ntswrap('-c','AddOneComp.Mechanism', ...  
    '-a','IAddOne.dll', ...  
    '-i','IAddOne');
```

Not all arguments are compatible with each other. See `ntswrap` for details on all command options.

---

**Tip** If the `IAddOne.dll` assembly is not in the current folder, specify the full path.

---

This command generates the assembly `MechanismIAddOne.dll` that contains a type-safe API for the MATLAB Compiler SDK class `Mechanism` in the namespace `AddOneCompNative`.

## Develop Server Program Using WCF Interface

Develop a server program that provides access (via the `WCFServiceContract`) to the overloads of `addOne` defined by the WCF `IAddOne` interface. The program references an `App.config` XML configuration file.

The WCF server program loads the WCF-based `addOne.Mechanism` component and makes it available to SOAP clients via the type-safe `mechanismIAddOne` interface.

---

**Tip** When writing your interface, you will be coding to handle jagged arrays, as opposed to rectangular arrays. For more information, see “Jagged Array Processing” on page 2-15.

---

Compile the server program using Microsoft Visual Studio by doing the following steps:

- 1 Open Microsoft Visual Studio and create a C# **Console App (.NET Framework)** called `AddOneApp`.
- 2 Copy the following source code into the generated `Program.cs` in your project:

### WCF Server Program

```
using System;
using System.Text;
using System.ServiceModel;

namespace AdditionServer
{
    class Program
    {
        static void Main(string[] args)
        {
            try
            {
                using (ServiceHost host = new ServiceHost(typeof(MechanismIAddOne)))
                {
                    host.Open();
                    Console.WriteLine("Addition Server is up running.....");
                    Console.WriteLine("Press any key to close the service.");
                    Console.ReadLine();
                    Console.WriteLine("Closing service...");
                }
            }
            catch (Exception ex)
            {
                Console.WriteLine(ex.Message);
            }
        }
    }
}
```

- 3 Add the following configuration file `App.config` to your project. You may need to modify the listed .NET Framework version.

### App.config XML file

```
<?xml version="1.0" encoding="utf-8" ?>
<configuration>
  <startup>
    <supportedRuntime version="v4.0" sku=".NETFramework,Version=v4.6.1" />
  </startup>
  <system.web>
    <compilation debug="true" />
  </system.web>
  <system.serviceModel>
```

```

<services>
  <service behaviorConfiguration=
    "Addition.ServiceBehavior" name="MechanismIAddOne">
    <endpoint
      address=""
      binding="wsHttpBinding"
      contract="IAddOne"
      name="HttpBinding" />
    <endpoint
      address=""
      binding="netTcpBinding"
      contract="IAddOne"
      name="netTcpBinding" />
    <endpoint
      address="mex"
      binding="mexHttpBinding"
      contract="IMetadataExchange"
      name="MexHttpBinding" />
    <endpoint
      address="mex"
      binding="mexTcpBinding"
      contract="IMetadataExchange"
      name="MexTCPBinding" />
    <host>
      <baseAddresses>
        <add baseAddress=
          "http://localhost:8001/AdditionServer/" />
        <add baseAddress=
          "net.tcp://localhost:8002/AdditionServer/" />
      </baseAddresses>
    </host>
  </service>
</services>
<behaviors>
  <serviceBehaviors>
    <behavior name="Addition.ServiceBehavior">
      <serviceMetadata httpGetEnabled="True" httpGetUrl=
        "http://localhost:8001/AdditionServer/mex" />
      <!-- To receive exception details in faults for debugging purposes,
        set the value below to true. Set to false before
        deployment to avoid disclosing exception
        information -->
      <serviceDebug includeExceptionDetailInFaults="True" />
    </behavior>
  </serviceBehaviors>
</behaviors>
</system.serviceModel>
</configuration>

```

- 4 Add references in the project to the following files:

This reference:	Defines:
IAddOne.dll	The .NET native type interface IAddOne
MechanismIAddOne.dll	The generated type-safe API
AddOneCompNative.dll	The generated .NET assembly

**Note** Unlike other .NET deployment scenarios, you do not need to reference `MWArray.dll` in the server program source code. The `MWArray` data types are hidden behind the type-safe API in `MechanismIAddOne`.

- 5 Add a reference to `System.ServiceModel`, which is listed under **Assemblies**.  
 6 Go to **Build > Configuration Manager** and change the platform from **Any CPU** to **x64**.  
 7 Compile and run the server program with Microsoft Visual Studio.

The program displays the following output:

```
Addition Server is up running.....
Press any key to close the service.
```

Pressing a key results in the following.

Closing service....

## Generate Proxy Code for Clients

Configure your clients to communicate with the server by running the automatic proxy generation tool `svcutil.exe`. Most versions of Microsoft Visual Studio can automatically generate client proxy code from server metadata.

---

**Caution** Before you generate your client proxy code using this step, the server *must* be available and running. Otherwise, the client will not find the server.

---

- 1 Create a client project in Microsoft Visual Studio.
- 2 Add references by using either of these two methods.

Method 1	Method 2
<p><b>a</b> In the Solutions Explorer pane, right-click <b>References</b>.</p> <p><b>b</b> Select <b>Add Service Reference</b>. The Add Service Reference dialog box appears.</p> <p><b>c</b> In the <b>Address</b> field, enter: <code>http://localhost:8001/Addition/</code></p> <hr/> <p><b>Note</b> Be sure to include the / following Addition.</p> <hr/> <p><b>d</b> In the <b>Namespace</b> field, enter <code>AdditionProxy</code>.</p> <p><b>e</b> Click <b>OK</b>.</p>	<p><b>a</b> Enter the following command from your client application directory to generate <code>AdditionProxy.cs</code>, which contains client proxy code. This command also generates configuration file <code>App.config</code>.</p> <pre>svcutil.exe /t:code http://localhost:8001/AddMaster//out:AdditionProxy.cs /config:App.config</pre> <hr/> <p><b>Note</b> Enter the above command on one line, without breaks.</p> <hr/> <p><b>b</b> Add <code>AdditionProxy.cs</code> and <code>App.config</code> to your client project</p>

---

**Note** When running a self-hosted application, you may encounter issues with port reservations. Use the tool `netsh` to modify your port configurations, as necessary.

---

## Develop Client Program Using WCF Interface

At start-up, the client program connects to the `AdditionService` provided by the Addition WCF service. Instead of directly invoking the methods of the type-safe mechanism `IAddOne` interface, the WCF client uses the method names defined in the `OperationContract` attributes of `IAddOne`.

Compile the client program using Microsoft Visual Studio by doing the following:

- 1 Open Microsoft Visual Studio and create a C# **Console App (.NET Framework)** called `AdditionClient`.
- 2 Copy the following source code into the generated `Program.cs` in your project:

## WCF Client Program

```

using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.ServiceModel;

namespace AdditionClient
{
    class Program
    {
        static void Main(string[] args)
        {
            try
            {
                // Connect to Addition Service
                Console.WriteLine("\nConnecting to Addition Service through Http connection...");

                AdditionClient.AdditionProxy.AddOneClient Addition = new AdditionClient.AdditionProxy.AddOneClient("HttpBinding");

                Console.WriteLine("\nConnected to Addition Service...\n");

                // Output as return value
                int one = 10;
                int two = Addition.addOne_1(one);
                Console.WriteLine("addOne({0}) = {1}",
                                one, two);

                // Output: first parameter
                int i16 = 16;
                int o17 = 0;
                Addition.addOne_2(ref o17, i16);
                Console.WriteLine("addOne({0}) = {1}", i16, o17);

                // Output: second parameter
                int three = 0;
                Addition.addOne_3(two, ref three);
                Console.WriteLine("addOne({0}) = {1}",
                                two, three);

                // Scalar doubles
                System.Double i495 = 495.0;
                System.Double third =
                    Addition.addOne_4(i495);
                Console.WriteLine("addOne({0}) = {1}",
                                i495, third);

                // Vector addition
                System.Double[] i = { 30, 60, 88 };
                System.Double[] o = Addition.addOne_5(i);
                Console.WriteLine(
                    "addOne([ {0} {1} {2} ]) = [ {3} {4} {5} ]",
                    i[0], i[1], i[2], o[0], o[1], o[2]);
            }
            catch (Exception ex)
            {
                Console.WriteLine(ex.Message);
            }

            Console.WriteLine("\nPress any key to close the client application.");
            Console.ReadLine();
            Console.WriteLine("Closing client...");
        }
    }
}

```

- 3 If you are not already referencing `System.ServiceModel`, add it to your Visual Studio project.
- 4 Go to **Build > Configuration Manager** and change the platform from **Any CPU** to **x64**.
- 5 Compile the WCF client program with Microsoft Visual Studio.
- 6 Run the program from the command line with administrator access.

The program displays the following output:

```

Connecting to Addition Service through Http connection...
Connected to Addition Service...

```

```
addOne(1) = 2
addOne(16) = 17
addOne(2) = 3
addOne(495) = 496
addOne([30 60 88]) = [31 61 89]
addOne([0 2; 3 1]) = [1 3; 4 2]
Press any key to close the client application.
```

Pressing a key results in the following:

```
Closing client....
```

## Tips

- If you want to use WCF, the easiest way to do so is through the type-safe API.
- WCF and .NET remoting are not compatible in the same deployment project or component.
- This example requires both client and server to use message sizes larger than the WCF defaults. For information about changing the default message size, see the MSDN article regarding the `maxreceivedmessagesize` property.

## See Also

`compiler.build.dotNETAssembly | ntswrap` | “.NET Remoting and Windows Communications Foundation” on page 9-2 | “Type-Safe Interfaces” on page 7-2

## Related Examples

- “Implement Type-Safe Interface and Integrate into .NET Application” on page 7-8





# .NET Remoting

---

- “.NET Remoting and Windows Communications Foundation” on page 9-2
- “Compare MWArray and Native .NET API for Remotable Assemblies” on page 9-4
- “Create Remotable .NET Assembly” on page 9-6
- “Access Remotable .NET Assembly Using MWArray API” on page 9-9
- “Access Remotable .NET Assembly Using Native .NET API: Magic Square” on page 9-14
- “Access Remotable .NET Assembly Using Native .NET API: Cell and Struct” on page 9-19

## .NET Remoting and Windows Communications Foundation

### In this section...

“.NET Remoting” on page 9-2

“Windows Communications Foundation” on page 9-2

“What’s the Difference Between WCF and .NET Remoting?” on page 9-3

### .NET Remoting

Remotable .NET components allow you to access MATLAB functionality remotely as part of a distributed system consisting of multiple applications, domains, browsers, or machines.

Before you enable .NET remoting for your deployable component, be aware that you cannot enable both .NET remoting and Windows Communication Foundation.

#### Benefits of .NET Remoting

There are many reasons to create remotable components:

- **Cost savings** — Changes to business logic do not require you to roll out new software to every client. Instead, you can confine new updates to a small set of business servers.
- **Increased security for web applications** — .NET Remoting allows your database, for example, to reside behind one or more firewalls.
- **Software Compatibility** — Remotable components employ standard formatting protocols like SOAP (Simple Object Access Protocol), which can significantly enhance the compatibility of the component with libraries and applications.
- **Ability to run applications as Windows services** — To run as a Windows service, you must have access to a remotable component hosted by the service. Applications implemented as a Windows service provide many benefits to application developers who require an automated server running as a background process independent of a particular user account.
- **Flexibility to isolate native code binaries that were previously incompatible** — Mix native and managed code without restrictions.

### Windows Communications Foundation

Windows Communication Foundation (WCF) is an application programming interface in the .NET Framework for building service-oriented applications. Servers implement multiple services that can be consumed by multiple clients. Services are loosely coupled to each other.

Services typically have a WSDL interface (Web Services Description Language), which any WCF client can use to consume the service. A WCF client connects to a service via an endpoint. Each service exposes itself via one or more endpoints. An endpoint has an address, which is a URL specifying where the endpoint can be accessed, and binding properties that specify how the data will be transferred.

#### For More information About WCF

For up-to-date information regarding WCF, see What Is Windows Communication Foundation in the Microsoft documentation.

## **What's the Difference Between WCF and .NET Remoting?**

WCF is an end-to-end web service. Many of the advantages afforded by .NET Remoting—a wide selection of protocol interoperability, for instance—can be achieved with a WCF interface, in addition to having access to a richer, more flexible set of native data types. .NET Remoting can only support native objects.

WCF offers more robust choices in most every aspect of web-based development, even implementation of a Java client, for example.

## Compare MWArray and Native .NET API for Remotable Assemblies

The two data conversion APIs that marshal and format data across the managed (.NET) and unmanaged (MATLAB) code boundary are `MWArray` and the native .NET API. Each API has advantages, limitations, and particular applications for which it is best suited.

The `MWArray` API, which consists of the `MWArray` class and several derived types that map to MATLAB data types, is the standard API that has been used since the introduction of MATLAB Compiler SDK. It provides full marshaling and formatting services for all basic MATLAB data types including sparse arrays, structures, and cell arrays. This API requires MATLAB Runtime to be installed on the target machine, as it makes use of several primitive MATLAB functions. For information about using this API, see “Access Remotable .NET Assembly Using `MWArray` API” on page 9-9.

The Native API was designed especially, though not exclusively, to support .NET remoting. It allows you to pass arguments and return values using standard .NET types when calling the deployed MATLAB function. Here, data marshaling is still used, but it is not explicit in the client code. This feature is especially useful for clients that access a remotable component using the native interface API, as it does not require the client machine to have MATLAB Runtime installed. In addition, as only native .NET types are used in this API, there is no need to learn the semantics of a new set of data conversion classes. This API does not directly support .NET analogs for the MATLAB structure and cell array types. For information about using this API, see “Access Remotable .NET Assembly Using Native .NET API: Magic Square” on page 9-14.

### Features of the `MWArray` API Compared With the Native .NET API

	<b>MWArray API</b>	<b>Native .NET API</b>
Marshaling/formatting for all basic MATLAB types	X	
Pass arguments and return values using standard .NET types		X
Access to remotable component from client without installed MATLAB		X
Access to remotable component from client without installed MATLAB Runtime (see “Access Remotable .NET Assembly Using Native .NET API: Cell and Struct” on page 9-19).		X

### Using Native .NET Structure and Cell Arrays

The MATLAB Compiler SDK native .NET API accepts standard .NET data types for inputs and outputs to MATLAB function calls.

These standard .NET data types are wrapped by the `Object` class—the base class for all .NET data types. This object representation is sufficient as long as the MATLAB functions have numeric, logical,

or string inputs or outputs. It does not work well for MATLAB data types like structure (struct) and cell arrays, since the native representation of these array types results in a multi-dimensional Object array that is difficult to comprehend or process. Instead, MATLAB Compiler SDK provides a special class hierarchy for struct and cell array representation designed to easily interface with the native .NET API. See “Access Remotable .NET Assembly Using Native .NET API: Cell and Struct” on page 9-19 for details.

## **See Also**

### **Related Examples**

- “Create Remotable .NET Assembly” on page 9-6
- “Create Windows Communications Foundation Component” on page 8-2

## Create Remotable .NET Assembly

### In this section...

“Preparation” on page 9-6

“Build Remotable Component Using Library Compiler App” on page 9-6

“Build Remotable Component Using compiler.build.dotNETAssembly” on page 9-7

“Files Generated by the Compilation Process” on page 9-7

This example shows how to create a remotable .NET assembly using MATLAB Compiler SDK.

### Preparation

- 1 Decide whether you plan to use the `MWArray` API or the native .NET API. For more information, see “Compare `MWArray` and Native .NET API for Remotable Assemblies” on page 9-4.
  - **If using the `MWArray` API**, copy the following folder that ships with the MATLAB product to your working folder:

```
matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\MagicRemoteExample\MWArrayAPI\MagicSquareRemoteComp
```

After you copy the files, at the MATLAB command prompt, change the working folder (navigate) to the new `MagicSquareRemoteComp` subfolder in your working folder.

- **If using the native .NET API**, copy the following folder that ships with the MATLAB product to your working folder:

```
matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET\MagicRemoteExample\NativeAPI\MagicSquareRemoteComp
```

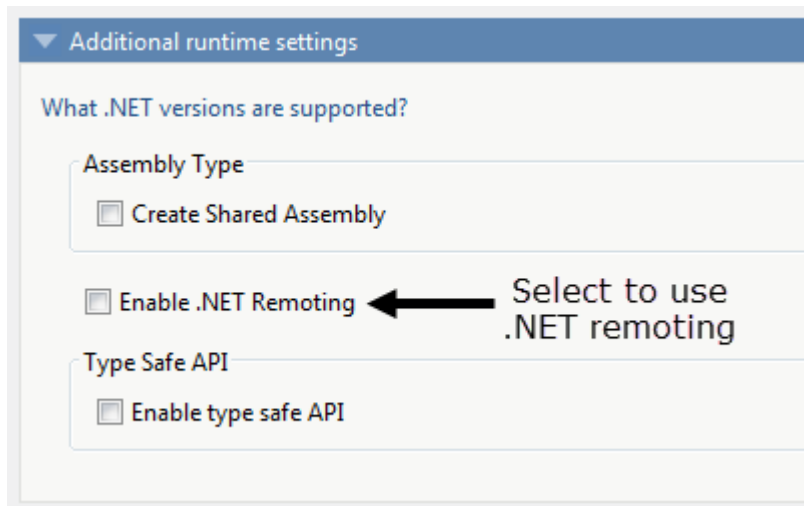
After you copy the file, at the MATLAB command prompt, change the working folder (navigate) to the new `MagicSquareRemoteComp` subfolder in your working folder.

- 2 Write the MATLAB function. Your MATLAB code does not require any additions to support .NET remoting. The following code for the `makesquare` function is in the file `makesquare.m` in the `MagicSquareRemoteComp` subfolder:

```
function y = makesquare(x)
y = magic(x);
```

### Build Remotable Component Using Library Compiler App

- 1 Click the **Library Compiler** app in the apps gallery, or type `libraryCompiler` at the MATLAB command prompt.
- 2 In the **Additional Runtime Settings** area, select **Enable .NET Remoting**.



- 3 Build the .NET component using the following values.

Field	Value
Library Name	MagicRemoteComp
Class Name	MagicClass
File to Compile	makesquare.m

For more details, see the instructions in “Generate .NET Assembly and Build .NET Application”.

## Build Remotable Component Using `compiler.build.dotNETAssembly`

As an alternative to the **Library Compiler** app, you can create a .NET assembly using a programmatic approach.

From the MATLAB prompt, issue the following command:

```
buildResults = compiler.build.dotNETAssembly('makesquare.m', ...
    'AssemblyName','MagicRemoteComp', ...
    'ClassName','MagicClass', ...
    'EnableRemoting','on');
```

---

**Note** The generated assembly does not include MATLAB Runtime or an installer. To create an installer using the `buildResults` object, see `compiler.package.installer`.

---

## Files Generated by the Compilation Process

After compiling the components, ensure you have the following files in your `for_redistribution_files_only` folder or designated output folder:

- `MagicRemoteComp.dll` — The MArray API component implementation assembly used by the server.
- `IMagicRemoteComp.dll` — The MArray API component interface assembly used by the client.
- `MagicRemoteCompNative.dll` — The native .NET API component implementation assembly used by the server.

- `IMagicRemoteCompNative.dll` — The native .NET API component interface assembly used by the client. You do not need to install MATLAB Runtime on the client when using this interface.

**See Also**

`compiler.build.dotNETAssembly` | **Library Compiler** | `mcc` | `deploytool`



## Access Remotable .NET Assembly Using MWArray API

After you create the remotable component, you can set up a console server and client using the MWArray API. For more information on choosing the right API for your access needs, see “Compare MWArray and Native .NET API for Remotable Assemblies” on page 9-4.

### Coding and Building the Hosting Server Application and Configuration File

The server application hosts the remote component built in “Create Remotable .NET Assembly” on page 9-6.

Build the server using the Microsoft Visual Studio project file `MagicSquareServer\MagicSquareMWServer.csproj`:

- 1 Change the references for the generated component assembly to `MagicSquareComp\for_redistribution_files_only\MagicSquareComp.dll`.
- 2 Select the appropriate build platform.
- 3 Select **Debug** or **Release** mode.
- 4 Build the `MagicSquareMWServer` project.
- 5 Supply the configuration file for the `MagicSquareMWServer`.

#### MagicSquareServer Code

Use the C# code for the server located in the file `MagicSquareServer\MagicSquareServer.cs`:

#### MagicSquareServer.cs

```
using System;
using System.Runtime.Remoting;

namespace MagicSquareServer
{
    class MagicSquareServer
    {
        static void Main(string[] args)
        {
            RemotingConfiguration.Configure(@"..\..\..\..\MagicSquareServer.exe.config");
            Console.WriteLine("Magic Square Server started...");
            Console.ReadLine();
        }
    }
}
```

This code does the following processing:

- Reads the associated configuration file to determine
  - The name of the component that it will host
  - The remoting protocol and message formatting to use
  - The lease time for the remote component
- Signals that the server is active and waits for a carriage return to be entered before terminating.

#### MagicSquareServer Configuration File

The configuration file for the `MagicSquareServer` is in the file `MagicSquareServer\MagicSquareServer.exe.config`. The entire configuration file, written in XML, follows:

```
<?xml version="1.0" encoding="utf-8" ?>
<configuration>
  <system.runtime.remoting>
    <application>
      <service>
        <wellknown mode="SingleCall"
          type="MagicSquareComp.MagicSquareClass, MagicSquareComp"
          objectUri="MagicSquareClass.remote" />
      </service>
      <lifetime leaseTime= "5M" renewOnCallTime="2M"
        leaseManagerPollTime="10S" />
      <channels>
        <channel ref="tcp" port="1234">
          <serverProviders>
            <formatter ref="binary" typeFilterLevel="Full" />
          </serverProviders>
        </channel>
      </channels>
    </application>
    <debug loadTypes="true"/>
  </system.runtime.remoting>
</configuration>
```

This code specifies:

- The mode in which the remote component will be accessed—in this case, single call mode
- The name of the remote component, the component assembly, and the object URI (uniform resource identifier) used to access the remote component
- The lease time for the remote component
- The remoting protocol (TCP/IP) and port number
- The message formatter (binary) and the permissions for the communication channel (full trust)
- The server debugging option

## Build Client Application and Configuration File

The client application, running in a separate process, accesses the remote component running in the server application you built previously. (See “Coding and Building the Hosting Server Application and Configuration File” on page 9-9.

Next, build the remote client using the Microsoft Visual Studio project file `MagicSquareClient\MagicSquareMWClient.csproj`. This file references both the shared data conversion assembly `matlabroot\toolbox\dotnetbuilder\bin\win64\v4.0\MWArray.dll` and the generated component interface assembly `MagicSquareComp\for_redistribution_files_only\IMagicSquareComp`.

To create the remote client using Microsoft Visual Studio:

- 1 Select the appropriate build platform.
- 2 Select **Debug** or **Release** mode.
- 3 Build the `MagicSquareMWClient` project.
- 4 Supply the configuration file for the `MagicSquareMWServer`.

### MagicSquareClient Code

Use the C# code for the client located in the file `MagicSquareClient\MagicSquareClient.cs`.

## MagicSquareClient.cs

```

using System;
using System.Configuration;
using System.Runtime.Remoting;
using System.Runtime.Remoting.Channels;
using System.Runtime.Remoting.Channels.Http;

using System.Collections;
using System.Runtime.Serialization.Formatters;
using System.Runtime.Remoting.Channels.Tcp;

using MathWorks.MATLAB.NET.Utility;
using MathWorks.MATLAB.NET.Arrays;

using IMagicSquareComp;

namespace MagicSquareClient
{
    class MagicSquareClient
    {
        static void Main(string[] args)
        {
            try
            {
                RemotingConfiguration.Configure
                    ("MagicSquareClient.exe.config");

                String urlServer=
                    ConfigurationSettings.AppSettings["MagicSquareServer"];

                IMagicSquareClass magicSquareComp=
                    (IMagicSquareClass)Activator.GetObject
                        (typeof(IMagicSquareClass),
                         urlServer);

                // Get user specified command line arguments or set default
                double arraySize= (0 != args.Length)
                    ? Double.Parse(args[0]) : 4;

                // Compute the magic square and print the result
                MWNumericArray magicSquare=
                    (MWNumericArray)magicSquareComp.makesquare
                        (arraySize);

                Console.WriteLine("Magic square of order {0}\n\n{1}",
                    arraySize, magicSquare);
            }
            catch (Exception exception)
            {
                Console.WriteLine(exception.Message);
            }

            Console.ReadLine();
        }
    }
}

```

This code does the following:

- The client reads the associated configuration file to get the name and location of the remotable component.
- The client instantiates the remotable object using the static `Activator.GetObject` method
- From this point, the remoting client calls methods on the remotable component exactly as it would call a local component method.

## MagicSquareClient Configuration File

The configuration file for the magic square client is in the file `MagicSquareClient\MagicSquareClient.exe.config`. The configuration file, written in XML, is shown here:

```

<?xml version="1.0" encoding="utf-8" ?>
<configuration>

```

```
<appSettings>
  <add key="MagicSquareServer"
    value="tcp://localhost:1234/MagicSquareClass.remote"/>
</appSettings>
<system.runtime.remoting>
  <application>
    <channels>
      <channel name="MagicSquareChannel" ref="tcp" port="0">
        <clientProviders>
          <formatter ref="binary" />
        </clientProviders>
        <serverProviders>
          <formatter ref="binary" typeFilterLevel="Full" />
        </serverProviders>
      </channel>
    </channels>
  </application>
</system.runtime.remoting>
</configuration>
```

This code specifies:

- The name of the remote component server and the remote component URI (uniform resource identifier)
- The remoting protocol (TCP/IP) and port number
- The message formatter (binary) and the permissions for the communication channel (full trust)

## Start Server Application

Starting the server by doing the following:

- 1 Open a DOS or UNIX® command window and navigate to `MagicSquareServer\bin\x86\v4.0\Debug`.
- 2 Run `MagicSquareServer.exe`. You will see the message:  
Magic Square Server started...

## Start Client Application

Start the client by doing the following:

- 1 Open a DOS or UNIX command window and navigate to `MagicSquareClient\bin\x86\v4.0\Debug`.
- 2 Run `MagicSquareClient.exe`. After MATLAB Runtime initializes, you should see the following output:

```
Magic square of order 4
```

```
162313
511108
97612
414151
```

## See Also

### Related Examples

- “Access Remotable .NET Assembly Using Native .NET API: Magic Square” on page 9-14
- “Access Remotable .NET Assembly Using Native .NET API: Cell and Struct” on page 9-19

## Access Remotable .NET Assembly Using Native .NET API: Magic Square

### Why Use the Native .NET API?

After the remotable component has been created, you can set up a server application and client using the native .NET API. For more information on choosing the right API for your access needs, see “Compare MArray and Native .NET API for Remotable Assemblies” on page 9-4.

Some reasons you might use the native .NET API instead of the MArray API are:

- You want to pass arguments and return values using standard .NET types, and you or your users don't work extensively with data types specific to MATLAB.
- You want to access your component from a client machine without an installed version of MATLAB.

For information on accessing your component using the MArray API, see “Access Remotable .NET Assembly Using MArray API” on page 9-9.

### Coding and Building the Hosting Server Application and Configuration File

The server application will host the remote component you built in “Create Remotable .NET Assembly” on page 9-6.

The client application, running in a separate process, will access the remote component hosted by the server application. Build the server with the Microsoft Visual Studio project file `MagicSquareServer\MagicSquareServer.csproj`:

- 1 Change the reference for the generated component assembly to `MagicSquareComp\for_redistribution_files_only\MagicSquareCompNative.dll`.
- 2 Select the appropriate build platform.
- 3 Select **Debug** or **Release** mode.
- 4 Build the `MagicSquareServer` project.
- 5 Supply the configuration file for the `MagicSquareServer`.

#### MagicSquareServer Code

The C# code for the server is in the file `MagicSquareServer\MagicSquareServer.cs`. The `MagicSquareServer.cs` server code is shown here:

```
using System;
using System.Runtime.Remoting;

namespace MagicSquareServer
{
    class MagicSquareServer
    {
        static void Main(string[] args)
        {
            RemotingConfiguration.Configure
                (@"..\\..\\..\\..\\MagicSquareServer.exe.config");
        }
    }
}
```

```

        Console.WriteLine("Magic Square Server started...");
        Console.ReadLine();
    }
}

```

This code does the following:

- Reads the associated configuration file to determine the name of the component that it will host, the remoting protocol and message formatting to use, as well as the lease time for the remote component.
- Signals that the server is active and waits for a carriage return to be entered before terminating.

### MagicSquareServer Configuration File

The configuration file for the MagicSquareServer is in the file MagicSquareServer\MagicSquareServer.exe.config. The entire configuration file, written in XML, is shown here:

```

<?xml version="1.0" encoding="utf-8" ?>
<configuration>
  <system.runtime.remoting>
    <application>
      <service>
        <wellknown mode="SingleCall"
          type="MagicSquareCompNative.MagicSquareClass,
            MagicSquareCompNative"
          objectUri="MagicSquareClass.remote" />
      </service>
      <lifetime leaseTime= "5M" renewOnCallTime="2M"
        leaseManagerPollTime="10S" />
      <channels>
        <channel ref="tcp" port="1234">
          <serverProviders>
            <formatter ref="binary" typeFilterLevel="Full" />
          </serverProviders>
        </channel>
      </channels>
    </application>
    <debug loadTypes="true"/>
  </system.runtime.remoting>
</configuration>

```

This code specifies:

- The mode in which the remote component will be accessed—in this case, single call mode
- The name of the remote component, the component assembly, and the object URI (uniform resource identifier) used to access the remote component
- The lease time for the remote component
- The remoting protocol (TCP/IP) and port number
- The message formatter (binary) and the permissions for the communication channel (full trust)
- The server debugging option

### Coding and Building the Client Application and Configuration File

The client application, running in a separate process, accesses the remote component running in the server application built in “Coding and Building the Hosting Server Application and Configuration File” on page 9-14. Build the remote client using the Microsoft Visual Studio project file MagicSquareClient\MagicSquareClient.csproj. To create the remote client using Microsoft Visual Studio:

- 1 Change the reference for the generated component assembly to `MagicSquareComp\for_redistribution_files_only\MagicSquareCompNative.dll`.
- 2 Change the reference for the generated interface assembly to `MagicSquareComp\for_redistribution_files_only\IMagicSquareCompNative.dll`.
- 3 Select the appropriate build platform.
- 4 Select **Debug** or **Release** mode.
- 5 Build the `MagicSquareClient` project.
- 6 Supply the configuration file for the `MagicSquareServer`.

### MagicSquareClient Code

The C# code for the client is in the file `MagicSquareClient\MagicSquareClient.cs`.

#### MagicSquareClient.cs

```
using System;
using System.Configuration;
using System.Runtime.Remoting;
using System.Runtime.Remoting.Channels;
using System.Runtime.Remoting.Channels.Http;

using System.Collections;
using System.Runtime.Serialization.Formatters;
using System.Runtime.Remoting.Channels.Tcp;

using IMagicSquareCompNative;

namespace MagicSquareClient
{
    class MagicSquareClient
    {
        static void Main(string[] args)
        {
            try
            {
                RemotingConfiguration.Configure(
                    @"MagicSquareClient.exe.config");

                String urlServer=
                    ConfigurationSettings.AppSettings["MagicSquareServer"];

                IMagicSquareClassNative magicSquareComp=
                    (IMagicSquareClassNative)Activator.GetObject(
                        (typeof(IMagicSquareClassNative), urlServer));

                // Get user specified command line arguments or set default
                double arraySize= (0 != args.Length)
                    ? Double.Parse(args[0]) : 4;

                // Compute the magic square and print the result
                double[,] magicSquare=
                    (double[,])magicSquareComp.makesquare(arraySize);

                Console.WriteLine("Magic square of order {0}\n", arraySize);

                // Display the array elements:
                for (int i = 0; i < (int)arraySize; i++)
                    for (int j = 0; j < (int)arraySize; j++)
                        Console.WriteLine(
                            "Element({0},{1})= {2}", i, j, magicSquare[i, j]);
            }
            catch (Exception exception)
            {
                Console.WriteLine(exception.Message);
            }

            Console.ReadLine();
        }
    }
}
```



This code does the following:

- The client reads the associated configuration file to get the name and location of the remotable component.
- The client instantiates the remotable object using the static `Activator.GetObject` method
- From this point, the remoting client calls methods on the remotable component exactly as it would call a local component method.

### MagicSquareClient Configuration File

The configuration file for the magic square client is in the file `MagicSquareClient\MagicSquareClient.exe.config`. The configuration file, written in XML, is shown here:

```
<?xml version="1.0" encoding="utf-8" ?>
<configuration>
  <appSettings>
    <add key="MagicSquareServer"
        value="tcp://localhost:1234/MagicSquareClass.remote"/>
  </appSettings>
  <system.runtime.remoting>
    <application>
      <channels>
        <channel name="MagicSquareChannel" ref="tcp" port="0">
          <clientProviders>
            <formatter ref="binary" />
          </clientProviders>
          <serverProviders>
            <formatter ref="binary" typeFilterLevel="Full" />
          </serverProviders>
        </channel>
      </channels>
    </application>
  </system.runtime.remoting>
</configuration>
```

This code specifies:

- The name of the remote component server and the remote component URI (uniform resource identifier)
- The remoting protocol (TCP/IP) and port number
- The message formatter (binary) and the permissions for the communication channel (full trust)

### Starting the Server Application

Start the server by doing the following:

- 1 Open a DOS or UNIX command window and navigate to `MagicSquareServer\bin\x86\v4.0\Debug`.
- 2 Run `MagicSquareServer.exe`. You will see the message:  
Magic Square Server started...

### Starting the Client Application

Start the client by doing the following:

- 1 Open a DOS or UNIX command window and navigate to `MagicSquareClient\bin\x86\v4.0\Debug`.

- 2 Run `MagicSquareClient.exe`. After MATLAB Runtime initializes, you should see the following output:

Magic square of order 4

```
Element(0,0)= 16  
Element(0,1)= 2  
Element(0,2)= 3  
Element(0,3)= 13  
Element(1,0)= 5  
Element(1,1)= 11  
Element(1,2)= 10  
Element(1,3)= 8  
Element(2,0)= 9  
Element(2,1)= 7  
Element(2,2)= 6  
Element(2,3)= 12  
Element(3,0)= 4  
Element(3,1)= 14  
Element(3,2)= 15  
Element(3,3)= 1
```

# Access Remotable .NET Assembly Using Native .NET API: Cell and Struct

## Why Use the .NET API With Cell Arrays and Structs?

Using .NET representations of MATLAB struct and cell arrays is recommended if both of these are true:

- You have MATLAB functions on a server with MATLAB struct or cell data types as inputs or outputs
- You do not want or need to install MATLAB Runtime on your client machines

The native `MWArray`, `MWStructArray`, and `MWCellArray` classes are members of the `MathWorks.MATLAB.NET.Arrays.native` namespace.

The class names in this namespace are identical to the class names in `MathWorks.MATLAB.NET.Arrays`. The difference is that the native representations of struct and cell arrays have no methods or properties that require MATLAB Runtime.

The `matlabroot\toolbox\dotnetbuilder\Examples\VSVersion\NET` folder has example solutions you can practice building. The `NativeStructCellExample` folder contains native struct and cell examples.

## Building Your Component

This example demonstrates how to deploy a remotable component using native struct and cell arrays. Before you set up the remotable client and server code, build a remotable component using the instructions in “Create Remotable .NET Assembly” on page 9-6.

## The Native .NET Cell and Struct Example

The server application hosts the remote component.

The client application, running in a separate process, accesses the remote component hosted by the server application. Build the server with the Microsoft Visual Studio project file `NativeStructCellServer.csproj`:

- 1 Change the references for the generated component assembly to `component_name\for_redistribution_files_only\component_nameNative.dll`.
- 2 Select the appropriate build platform.
- 3 Select **Debug** or **Release** mode.
- 4 Build the `NativeStructCellServer` project.
- 5 Supply the configuration file for the `NativeStructCellServer`. The C# code for the server is in the file `NativeStructCellServer.cs`:

```
using System;
using System.Collections.Generic;
using System.Text;
using System.Runtime.Remoting;

namespace NativeStructCellServer
```

```

{
    class NativeStructCellServer
    {
        static void Main(string[] args)
        {
            RemotingConfiguration.Configure(
                @"NativeStructCellServer.exe.config");

            Console.WriteLine("NativeStructCell Server started...");

            Console.ReadLine();
        }
    }
}

```

This code reads the associated configuration file to determine:

- Name of the component to host
- Remoting protocol and message formatting to use
- Lease time for the remote component

In addition, the code also signals that the server is active and waits for a carriage return before terminating.

## Coding and Building the Client Application and Configuration File

The client application, running in a separate process, accesses the remote component running in the server application built in “The Native .NET Cell and Struct Example” on page 9-19. Build the remote client using the Microsoft Visual Studio project file `NativeStructCellClient\NativeStructCellClient.csproj`. To create the remote client using Microsoft Visual Studio:

- 1 Change the references for the generated component assembly to *component\_name\for\_redistribution\_files\_only\component\_nameNative.dll*.
- 2 Change the references for the generated interface assembly to *component\_name\for\_redistribution\_files\_only\Icomponent\_nameNative.dll*.
- 3 Select the appropriate build platform.
- 4 Select **Debug** or **Release** mode.
- 5 Build the `NativeStructCellClient` project.
- 6 Supply the configuration file for the `NativeStructCellClient`.

### NativeStructCellClient Code

The C# code for the client is in the file `NativeStructCellClient\NativeStructCellClient.cs`:

#### NativeStructCellClient.cs

```

using System;
using System.Collections.Generic;
using System.Text;
using System.Runtime.Remoting;
using System.Configuration;
using MathWorks.MATLAB.NET.Arrays.native;

using INativeStructCellCompNative;

// This is a simple example that demonstrates the use
// of MathWorks.MATLAB.NET.Arrays.native package.
namespace NativeStructCellClient
{

```

```

class NativeStructCellClient
{
    static void Main(string[] args)
    {
        try
        {
            RemotingConfiguration.Configure(
                @"NativeStructCellClient.exe.config");
            String urlServer =
                ConfigurationSettings.AppSettings["NativeStructCellServer"];
            INativeStructCellClassNative nativeStructCell =
                (INativeStructCellClassNative)Activator.GetObject(typeof
                    (INativeStructCellClassNative), urlServer);

            MWCellArray field_names = new MWCellArray(1, 2);
            field_names[1, 1] = "Name";
            field_names[1, 2] = "Address";

            Object[] o = nativeStructCell.createEmptyStruct(1, field_names);
            MWStructArray S1 = (MWStructArray)o[0];
            Console.WriteLine("\nEVENT 2: Initialized structure as
                received in client applications:\n\n{0}" , S1);

            //Convert "Name" value from char[,] to a string since there's
                no MWCharArray constructor on server that accepts
            //char[,] as input.
            char c = ((char[,])S1["Name"])[0, 0];
            S1["Name"] = c.ToString();

            MWStructArray address = new MWStructArray(new int[] { 1, 1 },
                new String[] { "Street", "City", "State", "Zip" });
            address["Street", 1] = "3, Apple Hill Drive";
            address["City", 1] = "Natick";
            address["State", 1] = "MA";
            address["Zip", 1] = "01760";

            Console.WriteLine("\nUpdating the 'Address' field to
                :\n\n{0}", address);
            Console.WriteLine("\n#####\n");
            S1["Address",1] = address;

            Object[] o1 = nativeStructCell.updateField(1, S1, "Name");
            MWStructArray S2 = (MWStructArray)o1[0];

            Console.WriteLine("\nEVENT 5: Final structure as
                received by client:\n\n{0}" , S2);
            Console.WriteLine("\nAddress field: \n\n{0}" , S2["Address",1]);
            Console.WriteLine("\n#####\n");
        }
        catch (Exception exception)
        {
            Console.WriteLine(exception.Message);
        }
        Console.ReadLine();
    }
}

```

This code does the following:

- The client reads the associated configuration file to get the name and location of the remotable component.
- The client instantiates the remotable object using the static `Activator.GetObject` method
- From this point, the remoting client calls methods on the remotable component exactly as it would call a local component method.

### NativeStructCellClient Configuration File

The configuration file for the `NativeStructCellClient` is in the file `NativeStructCellClient\NativeStructCellClient.exe.config`:

```

<?xml version="1.0" encoding="utf-8" ?>
<configuration>
  <appSettings>

```

```

    <add key="NativeStructCellServer" value=
        "tcp://localhost:1236/NativeStructCellClass.remote"/>
</appSettings>
<system.runtime.remoting>
  <application>
    <channels>
      <channel name="NativeStructCellChannel" ref="tcp" port="0">
        <clientProviders>
          <formatter ref="binary" />
        </clientProviders>
        <serverProviders>
          <formatter ref="binary" typeFilterLevel="Full" />
        </serverProviders>
      </channel>
    </channels>
  </application>
</system.runtime.remoting>
</configuration>

```

This code specifies:

- Name of the remote component server and the remote component URI (uniform resource identifier)
- Remoting protocol (TCP/IP) and port number
- Message formatter (binary) and the permissions for the communication channel (full trust)

## Starting the Server Application

Start the server by doing the following:

- 1 Open a DOS or UNIX command window and navigate to NativeStructCellServer\bin\x86\v4.0\Debug.
- 2 Run NativeStructCellServer.exe. The following output appears:

```

EVENT 1: Initializing the structure on server and sending
         it to client:
         Initialized empty structure:

```

```

         Name: ' '
         Address: []

```

```

#####

```

```

EVENT 3: Partially initialized structure as
         received by server:

```

```

         Name: ' '
         Address: [1x1 struct]

```

```

Address field as initialized from the client:

```

```

         Street: '3, Apple Hill Drive'
         City: 'Natick'
         State: 'MA'
         Zip: '01760'

```

```

#####

```

```
EVENT 4: Updating 'Name' field before sending the
         structure back to the client:
```

```
    Name: 'The MathWorks'
  Address: [1x1 struct]
```

```
#####
```

## Starting the Client Application

Start the client by doing the following:

- 1 Open a DOS or UNIX command window and navigate to `NativeStructCellClient\bin\x86\v4.0\Debug`.
- 2 Run `NativeStructCellClient.exe`. After MATLAB Runtime initializes, the following output appears:

```
EVENT 2: Initialized structure as
         received in client applications:
```

```
1x1 struct array with fields:
    Name
  Address
```

```
Updating the 'Address' field to :
```

```
1x1 struct array with fields:
    Street
    City
    State
    Zip
```

```
#####
```

```
EVENT 5: Final structure as received by client:
```

```
1x1 struct array with fields:
    Name
  Address
```

```
Address field:
```

```
1x1 struct array with fields:
    Street
    City
    State
    Zip
```

```
#####
```

## Coding and Building the Client Application and Configuration File with the Native MWArray, MWStructArray, and MWCellArray Classes

### createEmptyStruct.m

Initialize the structure on the server and send it to the client with the following MATLAB code:

```
function PartialStruct = createEmptyStruct(field_names)
fprintf('EVENT 1: Initializing the structure on server
        and sending it to client:\n');

PartialStruct = struct(field_names{1}, ' ', field_names{2}, []);

fprintf('        Initialized empty structure:\n\n');
disp(PartialStruct);
fprintf('\n#####\n');
```

### updateField.m

Receive the partially updated structure from the client and add more data to it, before passing it back to the client, with the following MATLAB code:

```
function FinalStruct = updateField(st, field_name)

fprintf('\nEVENT 3: Partially initialized structure as
        received by server:\n\n');

disp(st);
fprintf('Address field as initialized from the client:\n\n');
disp(st.Address);
fprintf('#####\n');

fprintf(['\nEVENT 4: Updating ''', field_name, ''
        field before sending the structure back to the client:\n\n']);
st.(field_name) = 'The MathWorks';
FinalStruct = st;
disp(FinalStruct);
fprintf('\n#####\n');
```

### NativeStructCellClient.cs

Create the client C# code:

---

**Note** In this case, you do not need MATLAB Runtime on the system path.

---

```
using System;
using System.Collections.Generic;
using System.Text;
using System.Runtime.Remoting;
using System.Configuration;
using MathWorks.MATLAB.NET.Arrays.native;

using INativeStructCellCompNative;

// This is a simple example that demonstrates the use of
// MathWorks.MATLAB.NET.Arrays.native package.
namespace NativeStructCellClient
{
    class NativeStructCellClient
    {
        static void Main(string[] args)
        {
            try
            {
```



```

RemotingConfiguration.Configure
    (@"NativeStructCellClient.exe.config");
String urlServer =
    ConfigurationSettings.AppSettings[
        "NativeStructCellServer"];
INativeStructCellClassNative nativeStructCell =
    (INativeStructCellClassNative)Activator.GetObject(typeof
        (INativeStructCellClassNative),
        urlServer);

MWCellArray field_names = new MWCellArray(1, 2);
field_names[1, 1] = "Name";
field_names[1, 2] = "Address";

Object[] o = nativeStructCell.createEmptyStruct(1,field_names);
MWStructArray S1 = (MWStructArray)o[0];
Console.WriteLine("\nEVENT 2: Initialized structure as received
    in client applications:\n\n{0}" , S1);

//Convert "Name" value from char[,] to a string since
// there's no MWCharArray constructor
// on server that accepts char[,] as input.
char c = ((char[,])S1["Name"])[0, 0];
S1["Name"] = c.ToString();

MWStructArray address =
    new MWStructArray(new int[] { 1, 1 },
        new String[] { "Street", "City", "State", "Zip" });
address["Street", 1] = "3, Apple Hill Drive";
address["City", 1] = "Natick";
address["State", 1] = "MA";
address["Zip", 1] = "01760";

Console.WriteLine("\nUpdating the
    'Address' field to :\n\n{0}", address);
Console.WriteLine("\n#####\n");
S1["Address",1] = address;

Object[] o1 = nativeStructCell.updateField(1, S1, "Name");
MWStructArray S2 = (MWStructArray)o1[0];

Console.WriteLine("\nEVENT 5: Final structure as received by
    client:\n\n{0}" , S2);
Console.WriteLine("\nAddress field: \n\n{0}" , S2["Address",1]);
Console.WriteLine("\n#####\n");
}
catch (Exception exception)
{
    Console.WriteLine(exception.Message);
}
Console.ReadLine();
}
}
}

```

### NativeStructCellServer.cs

Create the server C# code:

```

using System;
using System.Collections.Generic;
using System.Text;
using System.Runtime.Remoting;

namespace NativeStructCellServer
{
    class NativeStructCellServer
    {
        static void Main(string[] args)
        {
            RemotingConfiguration.Configure(
                @"NativeStructCellServer.exe.config");
        }
    }
}

```

```
        Console.WriteLine("NativeStructCell Server started...");  
        Console.ReadLine();  
    }  
}
```

# **.NET Assembly Integration using MATLAB Data API for .NET**

---

## Deploy MATLAB Code Within .NET Application Using MATLAB Data API for .NET

**Supported .NET Version:** .NET 5.0 or higher recommended

This example shows how to create a .NET component from a MATLAB function and integrate it with a .NET application written in C#. The workflow is supported on Windows, Linux, and macOS systems. However, .NET applications can only be published from Windows to Linux and macOS.

### Prerequisites

- Create a new work folder that is visible to the MATLAB search path. This example uses folder named `work`.
- Verify that you have met all of the MATLAB Compiler SDK .NET target requirements. For details, see “MATLAB Compiler SDK .NET Target Requirements” on page 1-2.
- End users must have an installation of MATLAB Runtime to run the application. For details, see “Install and Configure MATLAB Runtime”.

For testing purposes, you can use an installation of MATLAB instead of MATLAB Runtime.

- Verify that you have .NET 5.0 SDK or higher or Microsoft Visual Studio 2019 or higher installed. If you have version 16.8.0 of Visual Studio 2019 installed, then you do not need to install .NET 5.0 or higher separately. You can verify whether .NET 5.0 is installed by entering `dotnet --info` at a system command prompt. You can download a .NET SDK version specific to your operating system from <https://dotnet.microsoft.com/download>.

### Data Management

To exchange data between the deployed MATLAB code and the .NET application, use the MATLAB Data API for .NET. This API is also used by MATLAB Engine. For an overview, see “Call MATLAB from .NET”. For details, see:

- “Pass .NET Data Types to MATLAB Functions”
- “Handle MATLAB Data in .NET Applications”

### Create Function in MATLAB

In MATLAB, examine the MATLAB code that you want to package. For this example, create a MATLAB script named `makesquare.m`.

```
function y = makesquare(x)
y = magic(x);
```

At the MATLAB command prompt, enter `makesquare(5)`.

The output is a 5-by-5 matrix.

```
17    24     1     8    15
23     5     7    14    16
 4     6    13    20    22
10    12    19    21     3
11    18    25     2     9
```

## Create .NET Assembly Using `compiler.build.dotNETAssembly`

- 1 Save the following code in a sample file named `makesquareSample1.m`:

```
x = 5;
y = makesquare(x);
```

- 2 Build the .NET assembly using the `compiler.build.dotNETAssembly` function. Specify the interface type and sample file using name-value arguments.

```
buildResults = compiler.build.dotNETAssembly('makesquare.m',...
'Interface', 'matlab-data',...
'SampleGenerationFiles','makesquareSample1.m');
```

You can specify additional options in the `compiler.build` command by using name-value arguments. For details, see `compiler.build.dotNETAssembly`.

The `compiler.build.Results` object `buildResults` contains information on the build type, generated files, included support packages, and build options.

The function generates the following files in a folder named `makesquaredotNETAssembly` in your current working directory:

- `samples\makesquareSample1_mda.cs` — C# .NET sample file.
- `GettingStarted.html` — HTML file that contains steps on compiling .NET driver applications from the command line.
- `includedSupportPackages.txt` — Text file that lists all support files included in the assembly.
- `makesquare.ctf` — Archive containing MATLAB code.
- `mccExcludedFiles.log` — Log file that contains a list of any toolbox functions that are not included in the application. For information on nonsupported functions, see MATLAB Compiler Limitations.
- `readme.txt` — Text file that contains packaging and interface information.
- `requiredMCRProducts.txt` — Text file that contains product IDs of products required by MATLAB Runtime to run the application.
- `unresolvedSymbols.txt` — Text file that contains information on unresolved symbols.

---

**Note** The generated component does not include MATLAB Runtime or an installer. To create an installer using the `buildResults` object, see `compiler.package.installer`.

---

## Integrate MATLAB Code into .NET Application

After creating your .NET component, you can integrate it into any .NET application. This example uses the sample C# application code generated during packaging as a starting point. You can use this sample .NET application code as a guide to write your own application.

### Use .NET SDK Command Line API to Build Application

If you are using Microsoft Visual Studio, see “Use Microsoft Visual Studio to Build Application (Windows only)” on page 10-7.

- 1 Open the command prompt in Windows and navigate to the `work` folder.

- 2 At the command line, enter:

```
dotnet new console --framework net5.0 --name MakeSquareApp
```

This command creates a folder named `MakeSquareApp` that contains the following:

- `obj` folder
  - `MakeSquareApp.csproj` project file
  - `Program.cs` C# source file
- 3 Copy the `makesquare.ctf` file generated by `compiler.build.dotNETAssembly` to the `MakeSquareApp` folder.
  - 4 Edit the project to add assembly dependencies and the `makesquare.ctf` archive file.
    - a Open the project file in a text editor and add the following assembly dependencies to the project using the `<ItemGroup>` tag:
      - `MathWorks.MATLAB.Runtime.dll`
      - `MathWorks.MATLAB.Types.dll`

### Windows Paths

If MATLAB is installed on your system	<ul style="list-style-type: none"> <li>• <code>matlabroot\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll</code></li> <li>• <code>matlabroot\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll</code></li> </ul>
If MATLAB Runtime is installed on your system	<ul style="list-style-type: none"> <li>• <code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll</code></li> <li>• <code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll</code></li> </ul>

### Linux and macOS Paths

If MATLAB is installed on your system	<ul style="list-style-type: none"> <li>• <code>matlabroot/extern/dotnet/netstandard2.0/MathWorks.MATLAB.Runtime.dll</code></li> <li>• <code>matlabroot/extern/dotnet/netstandard2.0/MathWorks.MATLAB.Types.dll</code></li> </ul>
If MATLAB Runtime is installed on your system	<ul style="list-style-type: none"> <li>• <code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;/extern/dotnet/netstandard2.0/MathWorks.MATLAB.Runtime.dll</code></li> <li>• <code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;/extern/dotnet/netstandard2.0/MathWorks.MATLAB.Types.dll</code></li> </ul>

- b Include the `makesquare.ctf` archive file as a content file to the project.
  - Add the `makesquare.ctf` archive file as a content file within the `<ItemGroup>` tag.
  - Add the tag `CopyToOutputDirectory` and set it to `Always`. This step ensures that the `makesquare.ctf` file is copied to the output folder and can be used for debugging.
  - Add the tag `CopyToPublishDirectory` and set it to `Always`. This step ensures that the `makesquare.ctf` file is copied to the cross-platform folder to which this project is published.

Once you add the assembly dependencies and include `makesquare.ctf` as a content file, your project file looks like the following:

## Windows

```
<Project Sdk="Microsoft.NET.Sdk">
  <PropertyGroup>
    <OutputType>Exe</OutputType>
    <TargetFramework>net5.0</TargetFramework>
  </PropertyGroup>

  <ItemGroup>
    <Reference Include="MathWorks.MATLAB.Runtime">
      <HintPath>C:\Program Files\MATLAB\MATLAB_Runtime\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll</HintPath>
    </Reference>
    <Reference Include="MathWorks.MATLAB.Types">
      <HintPath>C:\Program Files\MATLAB\MATLAB_Runtime\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll</HintPath>
    </Reference>

    <Content Include="makesquare.ctf">
      <HintPath>C:\work\MakeSquareApp\makesquare.ctf</HintPath>
      <CopyToOutputDirectory>Always</CopyToOutputDirectory>
      <CopyToPublishDirectory>Always</CopyToPublishDirectory>
    </Content>
  </ItemGroup>
</Project>
```

## Linux

```
<Project Sdk="Microsoft.NET.Sdk">
  <PropertyGroup>
    <OutputType>Exe</OutputType>
    <TargetFramework>net5.0</TargetFramework>
  </PropertyGroup>

  <ItemGroup>
    <Reference Include="MathWorks.MATLAB.Runtime">
      <HintPath>/usr/local/MATLAB/MATLAB_Runtime/R2023a/extern/dotnet/netstandard2.0/MathWorks.MATLAB.Runtime.dll</HintPath>
    </Reference>
    <Reference Include="MathWorks.MATLAB.Types">
      <HintPath>/usr/local/MATLAB/MATLAB_Runtime/R2023a/extern/dotnet/netstandard2.0/MathWorks.MATLAB.Types.dll</HintPath>
    </Reference>

    <Content Include="makesquare.ctf">
      <HintPath>~/work/MakeSquareApp/makesquare.ctf</HintPath>
      <CopyToOutputDirectory>Always</CopyToOutputDirectory>
      <CopyToPublishDirectory>Always</CopyToPublishDirectory>
    </Content>
  </ItemGroup>
</Project>
```

## macOS

```
<Project Sdk="Microsoft.NET.Sdk">
  <PropertyGroup>
    <OutputType>Exe</OutputType>
    <TargetFramework>net5.0</TargetFramework>
  </PropertyGroup>

  <ItemGroup>
    <Reference Include="MathWorks.MATLAB.Runtime">
      <HintPath>/Applications/MATLAB/MATLAB_Runtime/R2023a/extern/dotnet/netstandard2.0/MathWorks.MATLAB.Runtime.dll</HintPath>
    </Reference>
    <Reference Include="MathWorks.MATLAB.Types">
      <HintPath>/Applications/MATLAB/MATLAB_Runtime/R2023a/extern/dotnet/netstandard2.0/MathWorks.MATLAB.Types.dll</HintPath>
    </Reference>

    <Content Include="makesquare.ctf">
      <HintPath>~/work/MakeSquareApp/makesquare.ctf</HintPath>
      <CopyToOutputDirectory>Always</CopyToOutputDirectory>
      <CopyToPublishDirectory>Always</CopyToPublishDirectory>
    </Content>
  </ItemGroup>
</Project>
```

- 5 Replace the C# source file `Program.cs` with the sample file `makesquareSample1_mda.cs`:

**makesquareSample1\_mda.cs**

```

using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;

class makesquareSample1 {
    public static void makesquareSample() {
        string ctfPath = @"makesquare.ctf";
        using (dynamic matlab = MATLABRuntime.StartMATLAB(ctfPath)) {
            double xIn = 5.0;
            double [,] results = matlab.makesquare(new RunOptions(nargout: 1), xIn);
            for (int i = 0; i < results.GetLength(0); i++)
            {
                for (int j = 0; j < results.GetLength(1); j++)
                {
                    Console.WriteLine("{0} ", results[i, j]);
                }
                Console.WriteLine();
            }
        }
    }
    // The main entry point for the application.
    static void Main(string[] args) {
        try {
            makesquareSample();
        } catch (Exception e) {
            Console.WriteLine(e);
            Environment.Exit(1);
        }
    }
}

```

The generated sample code has been edited by replacing the data type for the `results` variable from `dynamic` to `double [,]`. Also, a nested `for` loop to print the data in the `results` variable has been inserted.

- 6 At the command line, build your .NET 5.0 project by entering:

```
dotnet build MakeSquareApp.csproj
```

- 7 At the command line, run your application by entering:

```
dotnet run
```

The application displays a 5-by-5 magic square.

```

17    24     1     8    15
23     5     7    14    16
 4     6    13    20    22
10    12    19    21     3
11    18    25     2     9

```

---

**Note** On Linux and macOS systems, you must set the `LD_LIBRARY_PATH` and `DYLD_LIBRARY_PATH` runtime paths respectively, prior to running your application. For details, see “Set MATLAB Runtime Path for Deployment”.

---



## Use Microsoft Visual Studio to Build Application (Windows only)

- 1 Open Microsoft Visual Studio and create a C# **Console App** named MakeSquareApp.
- 2 Choose .NET 5.0 (Current) as the framework.
- 3 Remove any source code (.cs) files that were created within your project.
- 4 Add the makesquareSample1\_mda.cs sample application code file generated by compiler.build.dotNETAssembly from the samples folder to the project. Right-click your project in **Solution Explorer** and select **Add > Existing Item**. In the dialog box, browse for the file and add the file.
- 5 Add the following assembly dependencies:
  - MathWorks.MATLAB.Runtime.dll
  - MathWorks.MATLAB.Types.dll

### Location of Assembly Dependencies

If MATLAB is installed on your system	<ul style="list-style-type: none"> <li>• matlabroot\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll</li> <li>• matlabroot\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll</li> </ul>
If MATLAB Runtime is installed on your system	<ul style="list-style-type: none"> <li>• &lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll</li> <li>• &lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll</li> </ul>

- 6 Add the makesquare.ctf archive file as a content file to the project. Right-click your project in **Solution Explorer** and select **Add > Existing Item**. In the dialog box, browse for the file and add the file.
- 7 Right-click the makesquare.ctf file in **Solution Explorer** and select **Properties**. In the **Properties** window, set **Build Action** to **Content** and **Copy to Output Directory** to **Copy always**.
- 8 Right-click your project in **Solution Explorer** and select **Edit Project File**. The MakeSquareApp.csproj project file opens in the editor. Add the <CopyToPublishDirectory> tag right below the <CopyToOutputDirectory> tag and set it to Always. The edited portion of the MakeSquareApp.csproj project file looks like the following:

```

...
<ItemGroup>
  <Content Include="makesquare.ctf">
    <CopyToOutputDirectory>Always</CopyToOutputDirectory>
    <CopyToPublishDirectory>Always</CopyToPublishDirectory>
  </Content>
</ItemGroup>

```

- 9 On the menu bar, choose **Build** and choose **Build Solution** to build the application within Visual Studio.

The build process generates an executable named MakeSquareApp.exe.

- 10 Run the application from Visual Studio by pressing **Ctrl+F5**. Alternatively, you can execute the generated executable from a system terminal:

```

> cd C:\work\MakeSquareApp\MakeSquareApp\bin\Debug\net5.0
> MakeSquareApp.exe

```

The application returns the same output as the sample MATLAB code.

```
17    24     1     8    15
23     5     7    14    16
 4     6    13    20    22
10    12    19    21     3
11    18    25     2     9
```

---

**Tip** If you are unable to run your application from Visual Studio, open the **Developer Command Prompt for Visual Studio** and start Visual Studio by entering `devenv /useenv`. Then, open your project and run your application.

---

## Publish to Linux and macOS

---

**Note** Applications can only be published from Windows to Linux and macOS.

---

- To publish the application to Linux, enter the following command on a single line at the system command prompt:

```
dotnet publish --configuration Release --framework net5.0
--runtime linux-x64 --self-contained true MakeSquareApp.csproj
```

- To publish application to macOS, enter the following command on a single line:

```
dotnet publish --configuration Release --framework net5.0
--runtime osx.12-x64 --self-contained true MakeSquareApp.csproj
```

To publish to a specific platform, use the appropriate Runtime Identifier (RID). For details, see <https://docs.microsoft.com/en-us/dotnet/core/rid-catalog>.

### Publish from Visual Studio

For details on how to set up publishing from Visual Studio, see the .NET documentation. Once setup is complete, edit your publish profile to contain the following settings:

- Set **Configuration** to **Release | Any CPU**.
- Set **Target framework** to **net5.0**.
- Set **Deployment mode** to **Self-contained**.
- Set **Target runtime** to **linux-x64** or **osx-x64**.
- Leave **Target location** unchanged or set it to a location of your choice.

## Run Published Application on Linux

- 1 Copy the Release folder from `C:\work\MakeSquareApp\bin` on Windows to `~/work` on a Linux machine. Create a `work` folder on Linux if one does not already exist.
- 2 On the Linux machine, verify that you have installed MATLAB Runtime and set up your `LD_LIBRARY_PATH` environment variable. For details, see “Install and Configure MATLAB Runtime” and “Set MATLAB Runtime Path for Deployment”.
- 3 Open a Linux console and navigate to:

```
~/work/Release/net5.0/linux-x64/publish
```

- 4 Add execute permissions to the Linux executable:

```
chmod +x MakeSquareApp
```

- 5 Run the application by entering:

```
./MakeSquareApp
```

```
17 24 1 8 15
23 5 7 14 16
4 6 13 20 22
10 12 19 21 3
11 18 25 2 9
```

Follow similar steps to run the application on macOS.

---

**Note** You can use .NET Framework version 4.6.1 or higher to implement this example. However, you cannot deploy the example across platforms. Also, .NET Framework has no command-line interface.

---

## See Also

`compiler.build.dotNETAssembly` | `compiler.build.DotNETAssemblyOptions` | `MathWorks.MATLAB.Types.RunOptions`

## More About

- “MATLAB Compiler SDK .NET Target Requirements” on page 1-2
- “Install and Configure MATLAB Runtime”
- “Pass .NET Data Types to MATLAB Functions”
- “Handle MATLAB Data in .NET Applications”

## External Websites

- <https://dotnet.microsoft.com/download>

## .NET Development Environment

To deploy MATLAB code within .NET applications you need to setup your development environment.

- Use the MATLAB desktop to author MATLAB code and MATLAB Compiler SDK to generate .NET components from MATLAB code.
- Use the .NET 5.0 SDK command-line interface (CLI) along with a code editor or Microsoft Visual Studio to integrate MATLAB code within .NET applications. Verify that you have .NET 5.0 SDK or Microsoft Visual Studio 2019 or higher installed. If you have version 16.8.0 of Visual Studio 2019 installed, then you do not need to install .NET 5.0 or higher separately. You can verify whether .NET 5.0 is installed by typing `dotnet --info` at a system command prompt. For details, see .NET CLI Overview.
- Add the following assembly dependencies to your project:
  - `MathWorks.MATLAB.Runtime.dll`
  - `MathWorks.MATLAB.Types.dll`

If MATLAB is installed on your system	<ul style="list-style-type: none"> <li>• <code>matlabroot\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll</code></li> <li>• <code>matlabroot\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll</code></li> </ul>
If MATLAB Runtime is installed on your system	<ul style="list-style-type: none"> <li>• <code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll</code></li> <li>• <code>&lt;MATLAB_RUNTIME_INSTALL_DIR&gt;\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll</code></li> </ul>

You can test your .NET application against the installed version of MATLAB that was used to generate the .NET artifacts or against an installation of MATLAB Runtime. However, during deployment you must use MATLAB Runtime.

If you are using the .NET 5.0 SDK along with a code editor for development, edit the project file (.csproj) and add the above references using the `<ItemGroup>` tag. For example:

```
<Project Sdk="Microsoft.NET.Sdk">
  <PropertyGroup>
    <OutputType>Exe</OutputType>
    <TargetFramework>net5.0</TargetFramework>
  </PropertyGroup>

  <ItemGroup>
    <Reference Include="MathWorks.MATLAB.Runtime">
      <HintPath>C:\Program Files\MATLAB\MATLAB Runtime\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll</HintPath>
    </Reference>
    <Reference Include="MathWorks.MATLAB.Types">
      <HintPath>C:\Program Files\MATLAB\MATLAB Runtime\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll</HintPath>
    </Reference>
  </ItemGroup>
</Project>
```

If you are using Microsoft Visual Studio for development, you can add the above dependencies from the **Solution Explorer**:

- In **Solution Explorer**, right-click on the **Dependencies** node and choose **Add Project Reference**.
- Browse for the assembly dependencies in the **Reference Manager** and add them.

## See Also

### More About

- “MATLAB Compiler SDK .NET Target Requirements” on page 1-2
- “Deploy MATLAB Code Within .NET Application Using MATLAB Data API for .NET” on page 10-2

### External Websites

- <https://dotnet.microsoft.com/download>



# **MATLAB Compiler SDK .NET API Based on MATLAB Data API for .NET**

---

# MathWorks.MATLAB.Runtime.MATLABRuntime

.NET class that represents a MATLAB Runtime instance

## Description

The `MATLABRuntime` class represents a MATLAB Runtime instance. You can call MATLAB functions as methods of a `MATLABRuntime` object using dot notation because the functions are dynamically invoked when you call them.

## Assemblies

C:\Program Files\MATLAB\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll

C:\Program Files\MATLAB\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll

## Class Details

Namespace: `MathWorks.MATLAB.Runtime`  
 Superclass: `System.Dynamic.DynamicObject`  
 Interface: `System.IDisposable`

## Method Summary

### Static Methods

"StartMATLAB" on page 11-2	Start MATLAB Runtime instance synchronously
"StartMATLABAsync" on page 11-3	Start MATLAB Runtime instance asynchronously
"TerminateApplication" on page 11-5	Terminate MATLAB application
"SetupMacRunLoopAndRun" on page 11-5	Set up Core Foundation <code>CFRunLoop</code> for an application running on macOS.

### Instance Methods

"WaitForFiguresToClose" on page 11-6	Pause until all figures in an assembly have been closed
"Dispose" on page 11-7	Terminate MATLAB Runtime instance explicitly

## Method Details

### StartMATLAB

```
static MATLABRuntime StartMATLAB(string ctfArchiveName);
```

#### Description

Start MATLAB Runtime instance synchronously in a separate process and connect to it.



**Parameters**

string                      Name of deployable archive (.ctf file).  
ctfArchiveName

**Returns**

Instance of MATLABRuntime.

**Throws**

MathWorks.MATLAB.Exc   MATLAB fails to start.  
ptions.MATLABNotAva  
ilableException  
System.ArgumentNullE   Null string is not a valid argument.  
xception

**C# Example**

Start a new MATLAB Runtime instance with a deployable archive (.ctf file).

```
using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;

namespace MyConsoleApp
{
    class Program
    {
        static void Main(string[] args)
        {
            string ctfPath = @"P:\MATLAB\work\mylinspace.ctf ";
            using (dynamic matlab = MATLABRuntime.StartMATLAB(ctfPath))
            {
                double[] vec = matlab.mylinspace(1.0, 100.0);
                foreach (double i in vec)
                {
                    Console.WriteLine("{0} ", i);
                }
            }
            Console.ReadLine();
        }
    }
}
```

**StartMATLABAsync**

```
static Task<MATLABRuntime> StartMATLABAsync(string ctfArchiveName);

static Task<MATLABRuntime> StartMATLABAsync(string ctfArchiveName,
System.Threading.CancellationToken token);
```

**Description**

Start a MATLAB Runtime instance asynchronously in a separate process and connect to it.

**Parameters**

string ctfArchiveName	Name of deployable archive (.ctf file).
CancellationToken token	Cancellation token used to cancel asynchronous tasks. The default is System.Threading.CancellationToken.None.

**Returns**

Task that completes when the MATLABRuntime instance is instantiated or an exception occurs.

**Throws**

MathWorks.MATLAB.Exc MATLAB fails to start.  
 eptions.MATLABNotAva  
 ilableException  
 System.ArgumentNullE Null string is not a valid argument.  
 xception

**C# Example**

Start two MATLAB Runtime instances asynchronously.

```
using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;

static async void CallDisp(Task<MATLABRuntime> matlabTask)
{
    dynamic matlab = await matlabTask;
    using (matlab)
    {
        matlab.mydisp(new RunOptions(nargout: 0), "Hello, Call MATLAB!");
    }
}
try
{
    // First MATLAB Runtime instance creation, specify the callback function
    Task workflowTask1 = MATLABRuntime.StartMATLABAsync("mydisp.ctf").ContinueWith(CallDisp);

    // Second MATLAB Runtime instance creation, specify the callback function
    Task workflowTask2 = MATLABRuntime.StartMATLABAsync("mydisp.ctf").ContinueWith(CallDisp);

    // Each of the above tasks is currently executing in the background
    // Wait for all of those tasks to start, execute, and terminate
    Task.WhenAll(workflowTask1, workflowTask2).Wait();
    Console.WriteLine("Done!");

    // Handle exceptions thrown from within the task
} catch (AggregateException ae) {
    // Rethrow any other exceptions
    throw ae.InnerException;
}
```

Start a MATLAB Runtime instance asynchronously, but cancel if the operation takes more than 10 seconds.

```
using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;

static async Task CallMATLAB(Task<MATLABRuntime> matlabTask) {
    using (dynamic matlab = await matlabTask) {
        matlab.mydisp(new RunOptions(nargout: 0), "Hello, CallMATLAB!");
    }
}
```

```
// Create a cancel token source, and kickoff the task
CancellationTokenSource src = new CancellationTokenSource();
Task workflowTask = MATLABRuntime
    .StartMATLABAsync("mydisp.ctf",src.Token)
    .ContinueWith(CallMATLAB);

// Cancel the above task after 10 seconds. This method is non-blocking.
src.CancelAfter(TimeSpan.FromSeconds(10));
try {
    // Wait for the task to complete
    workflowTask.Wait();
    Console.WriteLine("Task completed successfully!");
} catch (AggregateException ae) {
    if (ae.InnerException is OperationCancelledException)
        Console.Error.WriteLine("Task was cancelled before completion.");
    else // Rethrow any other exceptions
        throw ae.InnerException;
} finally {
    src.Dispose();
}
```

### TerminateApplication

```
static void TerminateApplication();
```

#### Description

Terminate the MATLAB application and tear-down MATLAB Runtime instances.

#### C# Example

```
using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;

namespace MyConsoleApp
{
    class Program
    {
        static void Main(string[] args)
        {
            string ctfPath = @"P:\MATLAB\work\mylinspace.ctf ";
            dynamic matlab = MATLABRuntime.StartMATLAB(ctfPath);
            double[] dbls = matlab.mylinspace(1.0, 100.0);
            foreach (double i in dbls)
            {
                Console.Write("{0} ", i);
            }
            Console.ReadLine();
            MATLABRuntime.TerminateApplication();
        }
    }
}
```

### SetupMacRunLoopAndRun

```
static void SetupMacRunLoopAndRun(Func<Object, int> userFunc, Object args);
```

**Description**

Set up Core Foundation CFRunLoop for an application running on macOS. Use this method if `NoJVM` or `OutOfProcess` attribute is not specified.

**Parameters**

<code>Func&lt;Object, int&gt; userFunc</code>	User specified function or method that runs MATLAB code with <code>Object</code> as the parameter and <code>int</code> as the output.
<code>Object args</code>	Arguments passed to the user specified function or method.

**C# Example**

```
using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;
using MathWorks.MATLAB.Exceptions;
using System.Threading.Tasks;
using System.IO;
using System.Threading;
using System.Diagnostics;
using System.Dynamic;
[assembly: RuntimeOption("-softwareopenglmesa")]

namespace MyConsoleApp
{
    public class Program
    {
        static void Main(string[] args)
        {
            MATLABRuntime.SetupMacRunLoopAndRun(MainFunc, null);
        }
        static int MainFunc(Object args)
        {
            try
            {
                string ctfPath = @"P:\MATLAB\work\matlabfunccomp.ctf ";
                using (dynamic matlab = MATLABRuntime.StartMATLAB(ctfPath))
                {
                    matlab.myFun(new RunOptions(nargout: 0), "all");
                }
            }
            catch (Exception ex)
            {
                Console.WriteLine(ex.Message + DateTime.Now.ToLongTimeString());
            }
            Thread.Sleep(100);
            Console.WriteLine("Terminating Application");
            MATLABRuntime.TerminateApplication();
            return 0;
        }
    }
}
```

**WaitForFiguresToClose**

```
void WaitForFiguresToClose();
```

**Description**

Wait for all visible figures created from the MATLAB Runtime instance to close before proceeding.

**C# Example**

```
using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;

namespace MyConsoleApp
{
    class Program
    {
        static void Main(string[] args)
        {
            string ctfPath = @"P:\MATLAB\work\myPlot.ctf ";
            using (dynamic matlab = MATLABRuntime.StartMATLAB(ctfPath))
            {
                matlab.myPlot(new RunOptions(nargout: 0), 10.0);
                matlab.WaitForFiguresToClose();
            }
        }
    }
}
```

**Dispose**

```
void Dispose();
```

**Description**

Terminate MATLAB Runtime instance explicitly. If not called, the MATLAB Runtime instance will be terminated by the “TerminateApplication” on page 11-5 method.

**Throws**

MathWorks.MATLAB.Exc MATLAB fails to terminate.  
ptions.MATLABExecut  
ionException

**C# Example**

```
using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;

namespace MyConsoleApp
{
    class Program
    {
        static void Main(string[] args)
        {
            string ctfPath = @"P:\MATLAB\work\dotnetnew\output\mylinspace.ctf ";
            dynamic matlab = MATLABRuntime.StartMATLAB(ctfPath);
            double[] vec = matlab.mylinspace(1.0, 100.0);
            foreach (double i in vec)
            {
                Console.WriteLine("{0} ", i);
            }
        }
    }
}
```

```
        }  
        matlab.Dispose();  
    }  
}
```

## Version History

Introduced in R2022b

### See Also

[MathWorks.MATLAB.Runtime.NojvmAttribute](#) |  
[MathWorks.MATLAB.Runtime.OutOfProcessAttribute](#) |  
[MathWorks.MATLAB.Runtime.RuntimeOptionAttribute](#)

# MathWorks.MATLAB.Runtime.NojvmAttribute

.NET attribute class that launches MATLAB Runtime without Java Virtual Machine (JVM) support

## Description

The Nojvm attribute lets you launch MATLAB Runtime without Java Virtual Machine (JVM) support.

## Assemblies

C:\Program Files\MATLAB\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll

C:\Program Files\MATLAB\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll

## Class Details

Namespace: MathWorks.MATLAB.Runtime  
Superclass: System.Attribute

## Construction

[assembly: Nojvm(tf)] launches MATLAB Runtime without Java Virtual Machine (JVM) support if tf is set to true. If tf is set to false, MATLAB Runtime is launched with JVM support.

## Parameters

tf	Boolean true or false.
----	------------------------

## C# Example

```
using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;
[assembly: Nojvm(true)]

namespace MyConsoleApp
{
    class Program
    {
        static void Main(string[] args)
        {
            try
            {
                string ctfPath = @"P:\MATLAB\work\mylinspace.ctf ";
                using (dynamic matlab = MATLABRuntime.StartMATLAB(ctfPath))
                {
                    double[] vec = matlab.mylinspace(1.0, 100.0);
                    foreach (double i in vec)
                    {
```

```
        Console.WriteLine("{0} ", i);
    }
}
catch (MathWorks.MATLAB.Exceptions.MATLABNotAvailableException)
{
    Console.Error.WriteLine("Could not start MATLAB Runtime.");
}
MATLABRuntime.TerminateApplication();
}
}
```

## Version History

Introduced in R2022b

### See Also

[MathWorks.MATLAB.Runtime.MATLABRuntime](#) |  
[MathWorks.MATLAB.Runtime.OutOfProcessAttribute](#) |  
[MathWorks.MATLAB.Runtime.RuntimeOptionAttribute](#)



# MathWorks.MATLAB.Runtime.OutOfProcessAttribute

.NET attribute class to start a separate process to run a .NET assembly

## Description

The `OutOfProcess` attribute lets you start a separate process to run a .NET assembly.

## Assemblies

C:\Program Files\MATLAB\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll

C:\Program Files\MATLAB\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll

## Class Details

Namespace: MathWorks.MATLAB.Runtime  
Superclass: System.Attribute

## Construction

`[assembly: OutOfProcess(tf)]` launches a separate process to run .NET assembly if `tf` is set to true. If `tf` is set to false the .NET assembly runs in the same process.

## Parameters

<code>tf</code>	Boolean true or false.
-----------------	------------------------

## C# Example

```
using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;
[assembly: Nojvm(true), OutOfProcess(true)]

namespace MyConsoleApp
{
    class Program
    {
        static void Main(string[] args)
        {
            try
            {
                string ctfPath = @"P:\MATLAB\work\mylinspace.ctf ";
                using (dynamic matlab = MATLABRuntime.StartMATLAB(ctfPath))
                {
                    double[] vec = matlab.mylinspace(1.0, 100.0);
                }
            }
        }
    }
}
```

```
        foreach (double i in vec)
        {
            Console.WriteLine("{0} ", i);
        }
    }
}
catch (MathWorks.MATLAB.Exceptions.MATLABNotAvailableException)
{
    Console.Error.WriteLine("Could not start MATLAB Runtime.");
}
MATLABRuntime.TerminateApplication();
}
}
```

## Version History

Introduced in R2022b

### See Also

[MathWorks.MATLAB.Runtime.MATLABRuntime](#) |  
[MathWorks.MATLAB.Runtime.NojvmAttribute](#) |  
[MathWorks.MATLAB.Runtime.RuntimeOptionAttribute](#)

# MathWorks.MATLAB.Runtime.RuntimeOptionAttribute

.NET attribute class for specifying MATLAB Runtime options that are passed to the application at initialization time

## Description

The RuntimeOption attribute lets you specify MATLAB Runtime options that are passed to the application at initialization time.

### Assemblies

C:\Program Files\MATLAB\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Runtime.dll

C:\Program Files\MATLAB\R2023a\extern\dotnet\netstandard2.0\MathWorks.MATLAB.Types.dll

### Class Details

Namespace: MathWorks.MATLAB.Runtime

Superclass: System.Attribute

## Construction

[assembly: RuntimeOption("option")] passes "option" to the application at initialization time.

## Parameters

option	Description
-nodisplay	Suppress the MATLAB nodisplay run-time warning. On Linux, open MATLAB Runtime without display functionality.
-singleCompThread	Limit MATLAB to a single computational thread.
-softwareopengl	Use Mesa Software OpenGL <sup>®</sup> for rendering.

## C# Example

```
using System;
using MathWorks.MATLAB.Runtime;
using MathWorks.MATLAB.Types;
[assembly: RuntimeOption("-singleCompThread")]
```

```
namespace MyConsoleApp
```

```
{
  class Program
  {
    static void Main(string[] args)
    {
      try
      {
        string ctfPath = @"P:\MATLAB\work\mylinspace.ctf ";
        using (dynamic matlab = MATLABRuntime.StartMATLAB(ctfPath))
        {
          double[] vec = matlab.mylinspace(1.0, 100.0);
          foreach (double i in vec)
          {
            Console.WriteLine("{0} ", i);
          }
        }
      }
      catch (MathWorks.MATLAB.Exceptions.MATLABNotAvailableException)
      {
        Console.Error.WriteLine("Could not start MATLAB Runtime.");
      }
      MATLABRuntime.TerminateApplication();
    }
  }
}
```

## Version History

Introduced in R2022b

### See Also

[MathWorks.MATLAB.Runtime.MATLABRuntime](#) |  
[MathWorks.MATLAB.Runtime.NojvmAttribute](#)

# Troubleshooting

---

- “Failure to Find MATLAB Runtime Files” on page 12-2
- “Failure to Find MATLAB Classes” on page 12-3
- “Diagnostic Messages” on page 12-4

## Failure to Find MATLAB Runtime Files

If your application generates a diagnostic message indicating that a module cannot be found, it could be that MATLAB Runtime is not properly located on your path. You fix this problem by ensuring that the MATLAB Runtime files are on your application path.

On a system with MATLAB installed, *matlabroot*\runtime\*arch* must be on your system path ahead of any other MATLAB installations.

- *matlabroot* is your root MATLAB folder.
- *arch* is the architecture of your computer such as win64 for a 64-bit Windows computer.

On a system with MATLAB Runtime installed, *mcr\_root*\*ver*\runtime\*arch* is on your system path.

- *mcr\_root* is your root MATLAB Runtime folder. *ver* is the version number of MATLAB Runtime.
- *arch* is the architecture of your computer such as win64 for a 64-bit Windows computer.

## Failure to Find MATLAB Classes

If your application generates a diagnostic message indicating that `Mathworks.MATLAB.NET.name` cannot be found, it could be that you need to reference the `MWArray.dll` assembly in your Visual Studio project.

The `MWArray.dll` assembly is located at `matlabroot\toolbox\dotnetbuilder\bin\arch\v4.0`.

- `matlabroot` is your root MATLAB or MATLAB Runtime folder.
- `arch` is the architecture of your computer, such as `win64` for a 64-bit Windows computer.

## **Diagnostic Messages**

The following table shows diagnostic messages you might encounter, probable causes for the message, and suggested solutions.

See the following table for information about some diagnostic messages.



## Diagnostic Messages and Suggested Solutions

Message	Probable Cause	Suggested Solution
LoadLibrary("component_name_1_0.dll") failed - The specified module could not be found.	You may get this error message while registering the project DLL from the DOS prompt. This can occur if the MATLAB Runtime is not on the system path.	See "Failure to Find MATLAB Runtime Files" on page 12-2.
Error in component_name.class_name.x: Error getting data conversion options.	This is often caused by mwcomutil.dll not being registered.	<ol style="list-style-type: none"> <li>1 Open a DOS window.</li> <li>2 Change folders to <i>matlabroot</i> \bin\win64.</li> <li>3 Run the following command: mwregsvr mwcomutil.dll</li> </ol> <p>(<i>matlabroot</i> is your root MATLAB folder.)</p>
Error in VBAProject: ActiveX component can't create object.	<ul style="list-style-type: none"> <li>• Project DLL is not registered.</li> <li>• An incompatible MATLAB DLL exists somewhere on the system path.</li> </ul>	<p>If the DLL is not registered,</p> <ol style="list-style-type: none"> <li>1 Open a DOS window.</li> <li>2 Change folders to <i>projectdir</i> \distrib.</li> <li>3 Run the following command: mwregsvr <i>projectdll.dll</i></li> </ol> <p>(<i>projectdir</i> represents the location of your project files).</p>
object ref not set to instance of an object	This occurs when an object that has not been instantiated is called	Instantiate the object.
Error in VBAProject: Automation error The specified module could not be found.	This usually occurs if MATLAB is not on the system path.	See "Failure to Find MATLAB Runtime Files" on page 12-2.
Showing a modal dialog box or form when the application is not running in UserInteractive mode is not a valid operation. Specify the ServiceNotification or DefaultDesktopOnly style to display a notification from a service application.	<p>This warning occurs when ASP.NET code tries to bring up a dialog box.</p> <p>If occurs because getframe() makes the figure window visible before performing the capture and thus fails when running in IIS. msgbox() calls in MATLAB code cause the warning to appear also.</p>	<p>Work around this problem by doing the following:</p> <ol style="list-style-type: none"> <li>1 Open the Windows Control Panel.</li> <li>2 Open Services.</li> <li>3 From the list of services, select and open the <b>IIS Admin</b> service.</li> <li>4 In the Properties dialog, on the <b>Log On</b> tab, select <b>Local System Account</b>.</li> <li>5 Select the option <b>Allow Service to Interact with Desktop</b>.</li> </ol>

## Enhanced Error Diagnostics Using mstack Trace

Use this enhanced diagnostic feature to troubleshoot problems that occur specifically during MATLAB code execution.

To implement this feature, use .NET exception handling to invoke the MATLAB function inside of the .NET application, as demonstrated in this try-catch code block:

```
try
{
Magic magic = new Magic();
magic.callmakeerror();
}
catch(Exception ex)
{
Console.WriteLine("Error: {0}", exception);
}
```

When an error occurs, the MATLAB code stack trace is printed before the Microsoft .NET application stack trace, as follows:

```
... MATLAB code Stack Trace ...
    at
file C:\work\MagicDemoCSharpApp\bin\Debug\
CallldmakeerrComp_mcr\compiler\g388611\ca
thy\MagicDemoComp\dmakeerror.m,name
dmakeerror_error2,line at 14.
    at
file C:\work\MagicDemoCSharpApp\bin\Debug\
CallldmakeerrComp_mcr\compiler\work\MagicDemoComp\dmakeerror.m,name
dmakeerror_error1,line at 11.
    at
file C:\work\MagicDemoCSharpApp\bin\Debug\
CallldmakeerrComp_mcr\compiler\work\MagicDemoComp\dmakeerror.m,name dmakeerror,line at 4.
    at
file C:\work\MagicDemoCSharpApp\bin\Debug\
CallldmakeerrComp_mcr\compiler\work\MagicDemoComp\callldmakeerror.m,name
callldmakeerror,line at 2.

... .Application Stack Trace ...
    at MathWorks.MATLAB.NET.Utility.MWMCR.EvaluateFunction
(String functionName, Int32 numArgsOut, Int
32 numArgsIn, MWArray[] argsIn)
    at MathWorks.MATLAB.NET.Utility.MWMCR.EvaluateFunction
(Int32 numArgsOut, String functionName, MWA
rray[] argsIn)
    at CallldmakeerrComp.Callldmakeerr.callldmakeerror() in
C:\work\MagicDemoComp\src\
Callldmakeerr.cs:line 140
    at MathWorks.Demo.MagicSquareApp.MagicDemoApp.Main(String[]
args) in C:\work\Ma
gicDemoCSharpApp\MagicDemoApp.cs:line 52
```

# Reference Information

---

- “Rules for Data Conversion Between .NET and MATLAB” on page 13-2
- “Interfaces Generated by MATLAB Compiler SDK” on page 13-9

## Rules for Data Conversion Between .NET and MATLAB

### In this section...

“Managed .NET Types to MATLAB Arrays” on page 13-2

“MATLAB Arrays to Managed .NET Types” on page 13-2

“.NET Types to MATLAB Types” on page 13-3

“Character and String Conversion” on page 13-7

“Unsupported MATLAB Array Types” on page 13-7

**Note** The conversion rules listed in the following tables apply to scalars, vectors, matrices, and multidimensional arrays of the native types listed.

### Managed .NET Types to MATLAB Arrays

The following table lists the data conversion rules used when converting native .NET types to MATLAB arrays.

#### Conversion Rules: Managed Types to MATLAB Arrays

Native .NET Type	MATLAB Array	Comments
System.Double	double	—
System.Single	single	Available only when the <code>makeDouble</code> constructor argument is set to <code>false</code> . The default is <code>true</code> , which creates a MATLAB double type.
System.Int64	int64	
System.Int32	int32	
System.Int16	int16	
System.Byte	int8	
System.String	char	None
System.Boolean	logical	None

### MATLAB Arrays to Managed .NET Types

The following table lists the data conversion rules used when converting MATLAB arrays to native .NET types.

**Conversion Rules: MATLAB Arrays to Managed Types**

<b>MATLAB Type</b>	<b>.NET Type (Primitive)</b>	<b>.NET Type (Class)</b>	<b>Comments</b>
cell	N/A	MWCellArray	Cell and struct arrays have no corresponding .NET type.
structure	N/A	MWStructArray	
char	System.String	MWCharArray	
double	System.Double	MWNumericArray	Default is type double.
single	System.Single	MWNumericArray	
uint64	System.Int64	MWNumericArray	Conversion to the equivalent unsigned type is not supported
uint32	System.Int32	MWNumericArray	Conversion to the equivalent unsigned type is not supported
uint16	System.Int16	MWNumericArray	Conversion to the equivalent unsigned type is not supported
uint8	System.Byte	MWNumericArray	None
logical	System.Boolean	MWLogicalArray	None
Function handle	N/A	N/A	None
Object	N/A	N/A	None

**.NET Types to MATLAB Types**

In order to create .NET interfaces that describe the type-safe API of a MATLAB Compiler SDK generated component, you must decide on the .NET types used for input and output parameters.

When choosing input types, consider how .NET inputs become MATLAB types. When choosing output types, consider the inverse conversion

The following tables list the data conversion results and rules used to convert .NET types to MATLAB arrays and MATLAB arrays to .NET types.

---

**Note** Invalid conversions result in a thrown `ArgumentException`

---

**Conversion Results: .NET Types to MATLAB Types**

<b>.NET Type</b>	<b>Converts to MATLAB Type</b>
NumericType <ul style="list-style-type: none"> <li>• System.Double</li> <li>• System.Single</li> <li>• System.Byte</li> <li>• System.Int16</li> <li>• System.Int32</li> <li>• System.Int64</li> <li>• System.Int64</li> </ul>	numeric
System.Boolean	logical
System.Char	char
System.String	
NumericType[N]	NumericType[1,N]
NumericType[P <sub>n</sub> ,...,P <sub>1</sub> ,M,N]	NumericType[M,N,P <sub>1</sub> ,...,P <sub>n</sub> ]
System.Boolean[N]	logical [1,N]
System.Boolean[P <sub>n</sub> ,...,P <sub>1</sub> ,M,N]	logical [M,N,P <sub>1</sub> ,...,P <sub>n</sub> ]
System.Char[N]	char [1,N]
System.Char[P <sub>n</sub> ,...,P <sub>1</sub> ,M,N]	char [M,N,P <sub>1</sub> ,...,P <sub>n</sub> ]
System.String[N]	char [N,max_string_length]
System.String[P <sub>n</sub> ,...,P <sub>1</sub> ,N]	char [N,max_string_length, P <sub>1</sub> ,...,P <sub>n</sub> ]
Scalar .NET struct	MATLAB struct constructed from public instance fields of the .NET struct
.NET struct [ N ]	MATLAB struct [ 1,N ] where each element is constructed from public instance fields of the .NET struct
.NET struct [ M,N ]	MATLAB struct [ M,N ] where each element is constructed from public instance fields of the .NET struct
native.MWStructArray	struct
native.MWCellArray	cell
Hashtable	struct
Dictionary <K,V>Where K = string and V = scalar or array of [Numeric, boolean, Char, String]	struct
ArrayList	cell
Any other .NET type in the default application domain	.NET object
Any other serializable .NET type in a non-default application domain	.NET object

**Conversion Rules: MATLAB Numeric Types to .NET Types**

To Convert This MATLAB Type:	To this:	Follow these rules:
numeric	Scalar	The type must be scalar in MATLAB. For example, a 1 X 1 int in MATLAB.
	Vector	The type must be a vector in MATLAB. For example, a 1 X $N$ or $N$ X 1 int array in MATLAB.
	$N$ -dimensional array	The $N$ -dimensional array type specified by the user must match the rank of the MATLAB numeric array.

**Tip** When converting MATLAB numeric arrays, widening conversions are allowed. For example, an int can be converted to a double. The type specified must be a numeric type that is equal or wider. Narrowing conversions throw an ArgumentException.

**Caution** .NET types are not as flexible as MATLAB types. Take care and test appropriately with .NET outputs before integrating data into your applications.

**Conversion Rules: MATLAB Char Arrays to .NET Types**

To Convert This MATLAB Type:	To this:	Follow these rules:
char	Char	The char must be scalar.
	Char array	The $N$ -dimensional Char type must match the rank of the MATLAB char array.
	String	MATLAB char array must be [1, $N$ ]
	String array	The $N$ -dimensional MATLAB char array can be converted to $(N-1)$ -dimensional array of type String.

**Conversion Rules: MATLAB Logical Arrays to .NET Types**

To Convert This MATLAB Type:	To this:	Follow these rules:
logical	Boolean	The logical must be scalar.
	Boolean[]	The MATLAB logical array must be [1, <i>N</i> ] or [ <i>N</i> ,1].
	Boolean array	The <i>N</i> -dimensional Boolean array must match the rank of the MATLAB logical array.

**Conversion Rules: Cell Array to .NET Types**

To Convert This MATLAB Type:	To this:	Follow these rules:
cell	System.Array	The <i>N</i> -dimensional MATLAB cell array is converted to an <i>N</i> -dimensional System.Array of type object.
	ArrayList	The MATLAB cell array must be a vector.

---

**Caution** If the MATLAB cell array contains a struct, it is left unchanged. All other types are converted to native types. Any nested cell array is converted to a System.Array matching the dimension of the cell array, as illustrated in this code snippet:

```
Let C = {[1,2,3], {[1,2,3]}, 'Hello world'}
% be a cell
```

C can be converted to an object[1,3] where object[1,1] contains int[, ], object[1,2] contains an object[1,1] whose first element is an int[, ], and object[1,3] contains char[, ].

---

**Note** Any nested cell array is converted to a System.Array that matches the dimension of the cell array

---



**Conversion Rules: Struct to .NET Types**

To Convert This MATLAB Type:	To this:	Follow these rules:
struct	.NET struct	The name and number of public fields in the specified .NET struct must match the name and number of fields in the MATLAB struct.
	Hashtable	A scalar struct can be converted to a Hashtable. Any nested struct will also be converted to a Hashtable. If the nested struct is not a scalar, then an ArgumentException is thrown. The dictionary key must be of type String.

**Conversion Rules: .NET Objects in MATLAB to .NET Native Objects**

To Convert this MATLAB Type:	To this:	Follow these rules:
.NET object	Type or super-type of the containing object	A .NET object in MATLAB can only be converted to a type or a super-type.

**Character and String Conversion**

A native .NET string is converted to a 1-by- $N$  MATLAB character array, with  $N$  equal to the length of the .NET string.

An array of .NET strings (`string[]`) is converted to an  $M$ -by- $N$  character array, with  $M$  equal to the number of elements in the string (`[]`) array and  $N$  equal to the maximum string length in the array.

Higher dimensional arrays of `String` are similarly converted.

In general, an  $N$ -dimensional array of `String` is converted to an  $N+1$  dimensional MATLAB character array with appropriate zero padding where supplied strings have different lengths.

**Unsupported MATLAB Array Types**

The MATLAB Compiler SDK product does not support returning the following MATLAB array types because they are not CLS-compliant:

- `int8`
- `uint16`
- `uint32`
- `uint64`

However, it is permissible to pass these types as arguments to a MATLAB Compiler SDK component.

## Interfaces Generated by MATLAB Compiler SDK

### In this section...

“Single Output API” on page 13-9

“Standard API” on page 13-10

“feval API” on page 13-11

MATLAB Compiler SDK generates one or more APIs for each MATLAB function in the .NET assembly based on the MATLAB function signature.

- A single output on page 13-9 signature that assumes that only a single output is required and returns the result in a single `MWArray` rather than an array of `MWArray`.
- A standard on page 13-10 signature that specifies inputs of type `MWArray` and returns values as an array of `MWArray`.
- A feval on page 13-11 signature that includes both input and output arguments in the argument list rather than returning outputs as a return value. Output arguments are specified first, followed by the input arguments.

### Single Output API

For each MATLAB function in the .NET assembly, MATLAB Compiler SDK generates a wrapper class that has overloaded methods to implement the various forms of the generic MATLAB function call. The single output API for a MATLAB function returns a single `MWArray`.

Typically, you use the single output interface for MATLAB functions that return a single argument. You can also use the single output interface when you want to use the output of a function as the input to another function.

The following table shows a generic function `foo` along with the single output API that the compiler generates for its several forms.

Generic MATLAB function	<code>function [Out1, Out2, ..., varargout] = foo(In1, In2, ..., InN, varargin)</code>
API if there are no input arguments	<code>public MWArray foo()</code>
API if there are one or more input arguments	<code>public MWArray foo(MWArray In1, MWArray In2...MWArray inN)</code>
API if there are optional input arguments	<code>public MWArray foo(MWArray In1, MWArray In2, ..., MWArray inN params MWArray[] varargin)</code>

In the example, the input arguments `In1`, `In2`, and `inN` are of type `MWArray`.

Similarly, in the case of optional arguments, the `params` arguments are of type `MWArray`. (The `varargin` argument is similar to the `varargin` function in MATLAB — it allows the user to pass a variable number of arguments.)

**Note** When you call a class method in your .NET application, specify all required inputs first, followed by any optional arguments.

Functions having a single integer input require an explicit cast to type `MWNumericArray` to distinguish the method signature from a standard interface signature that has no input arguments.

## Standard API

Typically, you use the standard interface for MATLAB functions that return multiple output values.

The standard calling interface returns an array of `MWArray` rather than a single array object.

The following table shows the standard API for a generic function with none, one, more than one, or a variable number of arguments.

Generic MATLAB function	<code>function [Out1, Out2, ..., varargout] = foo(In1, In2, ..., InN, varargin)</code>
API if there are no input arguments	<code>public MWArray[] foo(int numArgsOut)</code>
API if there is one input argument	<code>public MWArray [] foo(int numArgsOut, MWArray In1)</code>
API if there are two to <i>N</i> input arguments	<code>public MWArray[] foo(int numArgsOut, MWArray In1, MWArray In2, \dots MWArray InN)</code>
API if there are optional arguments, represented by the <code>varargin</code> argument	<code>public MWArray[] foo(int numArgsOut, MWArray in1, MWArray in2, MWArray InN, params MWArray[] varargin)</code>

Details about the arguments for these samples of standard signatures are shown in the following table.

Argument	Description	Details
<code>numArgsOut</code>	Number of outputs	An integer indicating the number of outputs you want the method to return.  The <code>numArgsOut</code> argument must always be the first argument in the list.
<code>In1, In2, ... InN</code>	Required input arguments	All arguments that follow <code>numArgsOut</code> in the argument list are inputs to the method being called.  Specify all required inputs first. Each required input must be of type <code>MWArray</code> or one of its derived types.
<code>varargin</code>	Optional inputs	You can also specify optional inputs if your MATLAB code uses the <code>varargin</code> input: list the optional inputs, or put them in an <code>MWArray[]</code> argument, placing the array last in the argument list.
<code>Out1, Out2, ... OutN</code>	Output arguments	With the standard calling interface, all output arguments are returned as an array of <code>MWArray</code> .

## feval API

In addition to the methods in the single API and the standard API, in most cases, the MATLAB Compiler SDK product produces an additional overloaded method. If the original MATLAB code contains no output arguments, then the compiler will not generate the `feval` method interface.

Consider a function with the following structure:

```
function [Out1, Out2, ..., varargout] = foo(In1, In2, ..., InN,
varargin)
```

The compiler generates the following API, known as the `feval` interface.

```
public void foo
    (int numArgsOut,
     ref MArray [] ArgsOut,
     MArray[] ArgsIn)
```

The interface accepts the following arguments:

<code>numArgsOut</code>	Number of outputs	An integer indicating the number of outputs you want to return.  This number generally matches the number of output arguments that follow. The <code>varargout</code> array counts as just one argument, if present.
<code>ref MArray [] ArgsOut</code>	Output arguments	Following <code>numArgsOut</code> are all the outputs of the original MATLAB code, each listed in the same order as they appear on the left side of the original MATLAB code.  A <code>ref</code> attribute prefaces all output arguments, indicating that these arrays are passed by reference.
<code>MArray[] ArgsIn</code>	Input arguments	<code>MArray</code> types or supported .NET primitive types.  When you pass an instance of an <code>MArray</code> type, the underlying MATLAB array is passed directly to the called function. Native types are first converted to <code>MArray</code> types.



# Functions

---

## compiler.build.dotNETAssembly

Create .NET assembly for deployment outside MATLAB

### Syntax

```
compiler.build.dotNETAssembly(Files)
compiler.build.dotNETAssembly(Files,Name,Value)
compiler.build.dotNETAssembly(ClassMap)
compiler.build.dotNETAssembly(ClassMap,Name,Value)
compiler.build.dotNETAssembly(opts)
results = compiler.build.dotNETAssembly( ___ )
```

### Description

`compiler.build.dotNETAssembly(Files)` creates a .NET assembly using the MATLAB functions specified by `Files`.

`compiler.build.dotNETAssembly(Files,Name,Value)` creates a .NET assembly with additional options specified using one or more name-value arguments. Options include the class name, output directory, and additional files to include.

`compiler.build.dotNETAssembly(ClassMap)` creates a .NET assembly with a class mapping specified using a container `.Map` object `ClassMap`.

`compiler.build.dotNETAssembly(ClassMap,Name,Value)` creates a .NET assembly using `ClassMap` and additional options specified using one or more name-value arguments. Options include the assembly name, output directory, and additional files to include.

`compiler.build.dotNETAssembly(opts)` creates a .NET assembly with options specified using a `compiler.build.DotNetAssemblyOptions` object `opts`. You cannot specify any other options using name-value arguments.

`results = compiler.build.dotNETAssembly( ___ )` returns build information as a `compiler.build.Results` object using any of the input argument combinations in previous syntaxes. The build information consists of the build type, paths to the compiled files, and build options.

### Examples

#### Create .NET Assembly Using File

Create a .NET assembly on a Windows system using a function file that generates a magic square.

In MATLAB, locate the MATLAB function that you want to deploy as a .NET assembly. For this example, use the file `magicsquare.m` located in `matlabroot\extern\examples\compiler`.

```
appFile = fullfile(matlabroot,'extern','examples','compiler','magicsquare.m');
```

Build a .NET assembly using the `compiler.build.dotNETAssembly` command.



```
compiler.build.dotNETAssembly(appFile);
```

The build function generates the following files within a folder named `magicsquaredotNETAssembly` in your current working directory:

- `GettingStarted.html` — HTML file that contains information on integrating your assembly.
- `includedSupportPackages.txt` — Text file that lists all support files included in the assembly.
- `magicsquare.dll` — Dynamic-link library file that can be accessed using the `mwArray` API.
- `magicsquare.xml` — XML file that contains documentation for the `mwArray` assembly.
- `magicsquare_overview.html` — HTML file that contains requirements for accessing the component and for generating arguments using the `mwArray` class hierarchy.
- `magicsquareNative.dll` — Dynamic-link library file that can be accessed using the native API.
- `magicsquareNative.xml` — XML file that contains documentation for the native assembly.
- `magicsquareVersion.cs` — C# file that contains version information.
- `mccExcludedFiles.log` — Log file that contains a list of any toolbox functions that were not included in the application. For information on non-supported functions, see *MATLAB Compiler Limitations*.
- `readme.txt` — Text file that contains packaging and interface information.
- `requiredMCRProducts.txt` — Text file that contains product IDs of products required by MATLAB Runtime to run the application.
- `unresolvedSymbols.txt` — Text file that contains information on unresolved symbols.

## Customize .NET Assembly

Create a .NET assembly on a Windows system and customize it using name-value arguments.

For this example, use the files `flames.m` and `flames.mat` located in `matlabroot\extern\examples\compiler`.

```
appFile = fullfile(matlabroot,'extern','examples','compiler','flames.m');
MATFile = fullfile(matlabroot,'extern','examples','compiler','flames.mat');
```

Build a .NET assembly using the `compiler.build.dotNETAssembly` command. Use name-value arguments to specify the assembly name and version, add a MAT-file, and enable verbose output.

```
compiler.build.dotNETAssembly(appFile, 'AssemblyName', 'FlamesComp', ...
    'AssemblyVersion', '2.0', ...
    'AdditionalFiles', MATFile, ...
    'Verbose', 'on');
```

## Create .NET Assembly Using Class Map Input

Create a .NET assembly on a Windows system using a class map and multiple function files.

Create a `containers.Map` object whose keys are class names and whose values are the locations of function files.

```
cmap = containers.Map;
cmap('Class1') = {'exampleFcn1.m', 'exampleFcn2.m'};
cmap('Class2') = {'exampleFcn3.m', 'exampleFcn4.m'};
```

Build a .NET assembly using the `compiler.build.dotNETAssembly` command.

```
compiler.build.dotNETAssembly(cmap);
```

Alternatively, you can specify additional options using name-value arguments when you build the .NET assembly.

```
compiler.build.dotNETAssembly(cmap, ...
    'AssemblyName', 'MyExampleComp', ...
    'AssemblyVersion', '2.0', ...
    'Verbose', 'on');
```

## Create Multiple Assemblies Using Options Object

Create multiple .NET assemblies on a Windows system using a `compiler.build.DotNETAssemblyOptions` object.

For this example, use the file `magicsquare.m` located in `matlabroot\extern\examples\compiler`.

```
appFile = fullfile(matlabroot, 'extern', 'examples', 'compiler', 'magicsquare.m');
```

Create a `DotNETAssemblyOptions` object using `appFile`. Use name-value arguments to specify a common output directory, generate the assembly archive separately, and enable verbose output.

```
opts = compiler.build.DotNETAssemblyOptions(appFile, ...
    'OutputDir', 'D:\Documents\MATLAB\work\dotNETBatch', ...
    'EmbedArchive', 'off', ...
    'Verbose', 'on')
```

```
opts =
```

```
DotNETAssemblyOptions with properties:
```

```

    AssemblyName: 'example.magicsquare'
      ClassMap: [1x1 containers.Map]
    DebugBuild: off
    EmbedArchive: off
    EnableRemoting: off
    FrameworkVersion: '4.0'
    SampleGenerationFiles: {}
    StrongNameKeyFile: ''
    AssemblyVersion: '1.0.0.0'
      Interface: 'mwwarray'
    AdditionalFiles: {}s+ AutoDetectDataFiles: ons+ ObfuscateArchive: offs+ SupportPackages:
      Verbose: on
      OutputDir: 'D:\Documents\MATLAB\work\dotNETBatch'
```

```
Class Map Information
```

```
magicsquareClass: {'C:\Program Files\MATLAB\R2023a\extern\examples\compiler\magicsquare
```

Build the .NET Assembly using the `DotNETAssemblyOptions` object.

```
compiler.build.dotNETAssembly(opts);
```

To compile using the function file `hello.m` with the same options, use dot notation to modify the `ClassMap` of the existing `COMComponentOptions` object before running the build function again.

```
remove(opts.ClassMap, keys(opts.ClassMap));
opts.ClassMap('helloClass') = fullfile(matlabroot, 'extern', 'examples', 'compiler', 'hello.m');
compiler.build.dotNETAssembly(opts);
```

By modifying the `ClassMap` argument and recompiling, you can compile multiple components using the same options object.

## Get Build Information from .NET Assembly

Create a .NET assembly on a Windows system and save information about the build type, generated files, included support packages, and build options to a `compiler.build.Results` object.

Compile using the file `magicsquare.m`.

```
results = compiler.build.dotNETAssembly('magicsquare.m')

results =

    Results with properties:
        BuildType: 'dotNETAssembly'
        Files: {4x1 cell}
    IncludedSupportPackages: {}
        Options: [1x1 compiler.build.DotNETAssemblyOptions]
```

The `Files` property contains the paths to the following compiled files:

- `magicsquare.dll`
- `magicsquareNative.dll`
- `magicsquare_overview.dll`
- `GettingStarted.html`

## Input Arguments

### Files — Files implementing MATLAB functions

character vector | string scalar | cell array of character vectors | string array

Files implementing MATLAB functions, specified as a character vector, a string scalar, a string array, or a cell array of character vectors. File paths can be relative to the current working directory or absolute. Files must have a `.m` extension.

Example: `["myfunc1.m", "myfunc2.m"]`

Data Types: `char` | `string` | `cell`

### ClassMap — Class map

`containers.Map` object

Class map, specified as a `containers.Map` object. Map keys are class names and each value is the set of files mapped to the corresponding class. Files must have a `.m` extension.

Example: `cmap`

### opts — .NET assembly build options

`compiler.build.DotNetAssemblyOptions` object

.NET assembly build options, specified as a `compiler.build.DotNETAssemblyOptions` object.

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1, . . . , NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

*Before R2021a, use commas to separate each name and value, and enclose `Name` in quotes.*

Example: `'Verbose', 'on'`

### AdditionalFiles — Additional files

character vector | string scalar | cell array of character vectors | string array

Additional files and folders to include in the .NET assembly, specified as a character vector, a string scalar, a string array, or a cell array of character vectors. Paths can be relative to the current working directory or absolute.

Example: `'AdditionalFiles', ["myvars.mat", "data.txt"]`

Data Types: `char` | `string` | `cell`

### AssemblyName — Name of .NET assembly

character vector | string scalar

Name of the .NET assembly, specified as a character vector or a string scalar. Specify `'AssemblyName'` as a namespace, which is a period-separated list, such as `companyname.groupname.component`. The name of the generated library is set to the last entry of the period-separated list. The name must begin with a letter and contain only alphabetic characters and periods.

Example: `'AssemblyName', 'mathworks.dotnet.mymagic'`

Data Types: `char` | `string`

### AssemblyVersion — Assembly version

`'1.0.0.0'` (default) | character vector | string scalar

Assembly version, specified as a character vector or a string scalar. For information on versioning using MATLAB Compiler SDK, see “Versioning”.

Example: `'AssemblyVersion', '4.0'`

Data Types: `char` | `string`

### AutoDetectDataFiles — Flag to automatically include data files

`'on'` (default) | on/off logical value

Flag to automatically include data files, specified as `'on'` or `'off'`, or as numeric or logical 1 (`true`) or 0 (`false`). A value of `'on'` is equivalent to `true`, and `'off'` is equivalent to `false`. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to `'on'`, then data files that you provide as inputs to certain functions (such as `load` and `fopen`) are automatically included in the .NET assembly.
- If you set this property to `'off'`, then you must add data files to the assembly using the `AdditionalFiles` option.

Example: `'AutoDetectDataFiles', 'off'`

Data Types: `logical`

### **ClassName — Name of .NET class**

character vector | string scalar

Name of the .NET class, specified as a character vector or a string scalar. You cannot specify this option if you use a `ClassMap` input. Class names must meet the .NET class name requirements.

The default value is the name of the first file listed in the `Files` argument appended with `Class`.

Example: `'ClassName', 'magicsquareClass'`

Data Types: `char` | `string`

### **DebugBuild — Flag to enable debug symbols**

'off' (default) | on/off logical value

Flag to enable debug symbols, specified as 'on' or 'off', or as numeric or logical 1 (true) or 0 (false). A value of 'on' is equivalent to true, and 'off' is equivalent to false. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to 'on', then the compiled assembly contains debug symbols.
- If you set this property to 'off', then the compiled assembly does not contain debug symbols.

Example: `'DebugBuild', 'on'`

Data Types: `logical`

### **EmbedArchive — Flag to embed deployable archive**

'on' (default) | on/off logical value

Flag to embed the deployable archive, specified as 'on' or 'off', or as numeric or logical 1 (true) or 0 (false). A value of 'on' is equivalent to true, and 'off' is equivalent to false. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to 'on', then the function embeds the deployable archive in the .NET assembly.
- If you set this property to 'off', then the function generates the deployable archive as a separate file.

Example: `'EmbedArchive', 'off'`

Data Types: `logical`

### **EnableRemoting — Flag to control remoting type**

'off' (default) | on/off logical value

Flag to control the remoting type of the assembly, specified as 'on' or 'off', or as numeric or logical 1 (true) or 0 (false). A value of 'on' is equivalent to true, and 'off' is equivalent to false. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to 'on', then the function builds a remotable assembly.

- If you set this property to 'off', then the function builds an assembly that is not remotable.

Example: 'EnableRemoting', 'on'

Data Types: logical

### **FrameworkVersion — Framework version**

'4.0' (default) | character vector | string scalar

Version of the Microsoft .NET Framework used to compile the assembly.

Example: 'AssemblyVersion', '5.0'

Data Types: char | string

### **Interface — Data API**

'marray' | 'matlab-data' | character vector | string scalar

Data API used for handling data exchange between a .NET application and deployed MATLAB code.

- `marray` — `MArray` API. This API works with .NET Framework. This is the default interface on Windows.
- `matlab-data` — MATLAB Data API for .NET. This API requires .NET 5.0 or higher. This is the default interface on macOS.

MathWorks recommends using the MATLAB Data API for .NET.

Example: 'Interface', 'matlab-data'

Data Types: char | string

### **ObfuscateArchive — Flag to obfuscate deployable archive**

'off' (default) | on/off logical value

Flag to obfuscate the deployable archive, specified as 'on' or 'off', or as numeric or logical 1 (true) or 0 (false). A value of 'on' is equivalent to true, and 'off' is equivalent to false. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to 'on', then folder structures and file names in the deployable archive are obfuscated from the end user, and user code and data contained in MATLAB files are placed into a user package within the archive. Additionally, all .m files are converted to P-files before packaging. This option is equivalent to using `mcc` with `-j` and `-s` specified.
- If you set this property to 'off', then the deployable archive is not obfuscated. This is the default behavior.

Example: 'ObfuscateArchive', 'on'

Data Types: logical

### **OutputDir — Path to output directory**

character vector | string scalar

Path to the output directory where the build files are saved, specified as a character vector or a string scalar. The path can be relative to the current working directory or absolute.

The default name of the build folder is the assembly name appended with `dotNETAssembly`.

Example: 'OutputDir', 'D:\Documents\MATLAB\work\mymagicdotNETAssembly'

Data Types: char | string

### SampleGenerationFiles — MATLAB sample files

character vector | string scalar | cell array of character vectors | string array

MATLAB sample files used to generate sample .NET driver files for functions included within the assembly, specified as a character vector, a string scalar, a string array, or a cell array of character vectors. Paths can be relative to the current working directory or absolute. Files must have a .m extension. For more information and limitations, see “Sample Driver File Creation”.

Example: 'SampleGenerationFiles', ["sample1.m", "sample2.m"]

Data Types: char | string | cell

### StrongNameKeyFile — Path to encryption key

character vector | string scalar

Path to the encryption key file used to sign the shared assembly, specified as a character vector or a string scalar. If the value is empty, the function creates a private assembly. The file path can be relative to the current working directory or absolute.

Example: 'StrongNameKeyFile', 'sgKey.snk'

Data Types: char | string

### SupportPackages — Support packages

'autodetect' (default) | 'none' | string scalar | cell array of character vectors | string array

Support packages to include, specified as one of the following options:

- 'autodetect' (default) — The dependency analysis process detects and includes the required support packages automatically.
- 'none' — No support packages are included. Using this option can cause runtime errors.
- A string scalar, character vector, or cell array of character vectors — Only the specified support packages are included. To list installed support packages or those used by a specific file, see `compiler.codetools.deployableSupportPackages`.

Example: 'SupportPackages', {'Deep Learning Toolbox Converter for TensorFlow Models', 'Deep Learning Toolbox Model for Places365-GoogLeNet Network'}

Data Types: char | string | cell

### Verbose — Flag to control build verbosity

'off' (default) | on/off logical value

Flag to control build verbosity, specified as 'on' or 'off', or as numeric or logical 1 (true) or 0 (false). A value of 'on' is equivalent to true, and 'off' is equivalent to false. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to 'on', then the MATLAB command window displays progress information indicating compiler output during the build process.
- If you set this property to 'off', then the command window does not display progress information.

Example: 'Verbose', 'on'

Data Types: logical

## Output Arguments

### **results** – Build results

`compiler.build.Results` object

Build results, returned as a `compiler.build.Results` object. The `Results` object consists of:

- The build type, which is 'dotNETAssembly'
- Paths to the following compiled files:
  - *AssemblyName.dll*
  - *AssemblyNameNative.dll*
  - *AssemblyName\_overview.dll*
  - *GettingStarted.html*
- A list of included support packages
- Build options, specified as a `DotNETAssemblyOptions` object

## Limitations

- In addition to Windows, this function is supported on Linux and macOS operating systems.

## Version History

Introduced in R2021a

## See Also

`compiler.build.DotNETAssemblyOptions`



# compiler.build.DotNETAssemblyOptions

Options for building .NET assemblies

## Syntax

```
opts = compiler.build.DotNETAssemblyOptions(Files)
opts = compiler.build.DotNETAssemblyOptions(Files,Name,Value)
opts = compiler.build.DotNETAssemblyOptions(ClassMap)
opts = compiler.build.DotNETAssemblyOptions(ClassMap,Name,Value)
```

## Description

`opts = compiler.build.DotNETAssemblyOptions(Files)` creates a `DotNETAssemblyOptions` object using MATLAB functions specified by `Files`. Use the `DotNETAssemblyOptions` object as an input to the `compiler.build.dotNETAssembly` function.

`opts = compiler.build.DotNETAssemblyOptions(Files,Name,Value)` creates a `DotNETAssemblyOptions` object with options specified using one or more name-value arguments. Options include the class name, output directory, and additional files to include.

`opts = compiler.build.DotNETAssemblyOptions(ClassMap)` creates a `DotNETAssemblyOptions` object with a class mapping specified using a container.Map object `ClassMap`.

`opts = compiler.build.DotNETAssemblyOptions(ClassMap,Name,Value)` creates a `DotNETAssemblyOptions` object with a class mapping specified using `ClassMap` and options specified using one or more name-value arguments. Options include the assembly name, output directory, and additional files to include.

## Examples

### Create .NET Assembly Options Object Using File

Create a `DotNETAssemblyOptions` object using file input.

For this example, use the file `magicsquare.m` located in `matlabroot\extern\examples\compiler`.

```
appFile = fullfile(matlabroot,'extern','examples','compiler','magicsquare.m');
opts = compiler.build.DotNETAssemblyOptions(appFile)
```

`opts =`

`DotNETAssemblyOptions` with properties:

```
AssemblyName: 'example.magicsquare'
AssemblyVersion: '1.0.0.0'
ClassMap: [1x1 containers.Map]
DebugBuild: off
EmbedArchive: on
```

```

        EnableRemoting: off
        FrameworkVersion: '4.0'
    SampleGenerationFiles: {}
    StrongNameKeyFile: ''
        AdditionalFiles: {}s+ AutoDetectDataFiles: ons+ ObfuscateArchive: offs+ SupportPackages:
        Verbose: off
        OutputDir: '.\magicsquaredotNETAssembly'

    Class Map Information
        magicsquareClass: {'C:\Program Files\MATLAB\R2023a\extern\examples\compiler\magicsquare

```

You can modify property values of an existing `DotNETAssemblyOptions` object using dot notation.

```
opts.Verbose = 'on'
```

```
opts =
```

DotNETAssemblyOptions with properties:

```

        AssemblyName: 'example.magicsquare'
        AssemblyVersion: '1.0.0.0'
        ClassMap: [1x1 containers.Map]
        DebugBuild: off
        EmbedArchive: on
        EnableRemoting: off
        FrameworkVersion: '4.0'
    SampleGenerationFiles: {}
    StrongNameKeyFile: ''
        AdditionalFiles: {}s+ AutoDetectDataFiles: ons+ ObfuscateArchive: offs+ SupportPackages:
        Verbose: on
        OutputDir: '.\magicsquaredotNETAssembly'

    Class Map Information
        magicsquareClass: {'C:\Program Files\MATLAB\R2023a\extern\examples\compiler\magicsquare

```

Use the `DotNETAssemblyOptions` object as an input to the `compiler.build.dotNETAssembly` function to build a .NET assembly.

```
buildResults = compiler.build.dotNETAssembly(opts);
```

### Customize .NET Assembly Options Object

Create a `DotNETAssemblyOptions` object and customize it using name-value arguments.

For this example, use the file `magicsquare.m` located in `matlabroot\extern\examples\compiler`. Use name-value arguments to specify the output directory and disable automatic detection of data files.

```
opts = compiler.build.DotNETAssemblyOptions('magicsquare.m', ...
    'OutputDir', 'D:\Documents\MATLAB\work\MagicDotNET', ...
    'AutoDetectDataFiles', 'off')
```

```
opts =
```

DotNETAssemblyOptions with properties:

```
AssemblyName: 'example.magicsquare'
```

```

    AssemblyVersion: '1.0.0.0'
      ClassMap: [1x1 containers.Map]
      DebugBuild: off
      EmbedArchive: on
      EnableRemoting: off
      FrameworkVersion: '4.0'
SampleGenerationFiles: {}
  StrongNameKeyFile: ''
    AdditionalFiles: {}
  AutoDetectDataFiles: off
    SupportPackages: {'autodetect'}
      Verbose: off
      OutputDir: 'D:\Documents\MATLAB\work\MagicDotNET'

```

Class Map Information

```

  magicsquareClass: {'C:\Program Files\MATLAB\R2023a\extern\examples\compiler\magicsquare

```

You can modify the property values of an existing `DotNETAssemblyOptions` object using dot notation. For example, enable verbose output.

```

opts.Verbose = 'on'

```

```

opts =

```

DotNETAssemblyOptions with properties:

```

    AssemblyName: 'example.magicsquare'
    AssemblyVersion: '1.0.0.0'
      ClassMap: [1x1 containers.Map]
      DebugBuild: off
      EmbedArchive: on
      EnableRemoting: off
      FrameworkVersion: '4.0'
SampleGenerationFiles: {}
  StrongNameKeyFile: ''
    AdditionalFiles: {}
  AutoDetectDataFiles: off
    SupportPackages: {'autodetect'}
      Verbose: on
      OutputDir: 'D:\Documents\MATLAB\work\MagicDotNET'

```

Class Map Information

```

  magicsquareClass: {'C:\Program Files\MATLAB\R2023a\extern\examples\compiler\magicsquare

```

Use the `DotNETAssemblyOptions` object as an input to the `compiler.build.dotNETAssembly` function to build a .NET assembly.

```

buildResults = compiler.build.dotNETAssembly(opts);

```

### Create .NET Assembly Options Object Using Class Map

Create a `DotNETAssemblyOptions` object using a class map.

Create a `containers.Map` object whose keys are class names and whose values are MATLAB function files.

```

cmap = containers.Map;
cmap('Class1') = {'exampleFcn1.m','exampleFcn2.m'};
cmap('Class2') = {'exampleFcn3.m','exampleFcn4.m'};

```

Create the `DotNETAssemblyOptions` object using the class map `cmap`.

```
opts = compiler.build.DotNETAssemblyOptions(cmap)
```

```
opts =
```

DotNETAssemblyOptions with properties:

```

    AssemblyName: 'example.exampleFcn1'
    AssemblyVersion: '1.0.0.0'
    ClassMap: [2x1 containers.Map]
    DebugBuild: off
    EmbedArchive: on
    EnableRemoting: off
    FrameworkVersion: '4.0'
    SampleGenerationFiles: {}
    StrongNameKeyFile: ''
    AdditionalFiles: {}s+ AutoDetectDataFiles: ons+ ObfuscateArchive: offs+ SupportPackages:
    Verbose: off
    OutputDir: '.\exampleFcn1dotNETAssembly'
```

Class Map Information

```

    Class1: {2x1 cell}
    Class2: {2x1 cell}
```

You can also create a `DotNETAssemblyOptions` object using name-value arguments or modify an existing object using dot notation. For this example, specify an output directory, enable verbose output, and disable automatic detection of data files.

```
opts = compiler.build.DotNETAssemblyOptions(cmap,...
    'OutputDir','D:\Documents\MATLAB\work\MagicDotNET',...
    'Verbose','On');
```

```
opts.AutoDetectDataFiles = 'off'
```

```
opts =
```

DotNETAssemblyOptions with properties:

```

    AssemblyName: 'example.exampleFcn1'
    AssemblyVersion: '1.0.0.0'
    ClassMap: [2x1 containers.Map]
    DebugBuild: off
    EmbedArchive: on
    EnableRemoting: off
    FrameworkVersion: '4.0'
    SampleGenerationFiles: {}
    StrongNameKeyFile: ''
    AdditionalFiles: {}
    AutoDetectDataFiles: off
    SupportPackages: {'autodetect'}
    Verbose: on
    OutputDir: 'D:\Documents\MATLAB\work\MagicDotNET'
```

Class Map Information

```

    Class1: {2x1 cell}
    Class2: {2x1 cell}
```

Use the `DotNETAssemblyOptions` object as an input to the `compiler.build.dotNETAssembly` function to build a .NET assembly.

```
buildResults = compiler.build.dotNETAssembly(opts);
```

## Input Arguments

### Files — Files implementing MATLAB functions

character vector | string scalar | cell array of character vectors | string array

Files implementing MATLAB functions, specified as a character vector, a string scalar, a string array, or a cell array of character vectors. File paths can be relative to the current working directory or absolute. Files must have a `.m` extension.

Example: `["myfunc1.m", "myfunc2.m"]`

Data Types: `char` | `string` | `cell`

### ClassMap — Class map

`containers.Map` object

Class map, specified as a `containers.Map` object. Map keys are class names and each value is the set of files mapped to the corresponding class. Files must have a `.m` extension.

Example: `cmap`

### Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1, ..., NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

*Before R2021a, use commas to separate each name and value, and enclose `Name` in quotes.*

Example: `'Verbose', 'on'`

### AdditionalFiles — Additional files

character vector | string scalar | cell array of character vectors | string array

Additional files and folders to include in the .NET assembly, specified as a character vector, a string scalar, a string array, or a cell array of character vectors. Paths can be relative to the current working directory or absolute.

Example: `'AdditionalFiles', ["myvars.mat", "data.txt"]`

Data Types: `char` | `string` | `cell`

### AssemblyName — Name of .NET assembly

character vector | string scalar

Name of the .NET assembly, specified as a character vector or a string scalar. Specify `'AssemblyName'` as a namespace, which is a period-separated list, such as `companyname.groupname.component`. The name of the generated library is set to the last entry of the period-separated list. The name must begin with a letter and contain only alphabetic characters and periods.

Example: `'AssemblyName', 'mathworks.dotnet.mymagic'`

Data Types: `char` | `string`

**AssemblyVersion — Assembly version**`'1.0.0.0'` (default) | character vector | string scalar

Assembly version, specified as a character vector or a string scalar. For information on versioning using MATLAB Compiler SDK, see “Versioning”.

Example: `'AssemblyVersion', '4.0'`

Data Types: `char` | `string`

**AutoDetectDataFiles — Flag to automatically include data files**`'on'` (default) | on/off logical value

Flag to automatically include data files, specified as `'on'` or `'off'`, or as numeric or logical 1 (`true`) or 0 (`false`). A value of `'on'` is equivalent to `true`, and `'off'` is equivalent to `false`. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to `'on'`, then data files that you provide as inputs to certain functions (such as `load` and `fopen`) are automatically included in the .NET assembly.
- If you set this property to `'off'`, then you must add data files to the assembly using the `AdditionalFiles` option.

Example: `'AutoDetectDataFiles', 'off'`

Data Types: `logical`

**ClassName — Name of .NET class**

character vector | string scalar

Name of the .NET class, specified as a character vector or a string scalar. You cannot specify this option if you use a `ClassMap` input. Class names must meet the .NET class name requirements.

The default value is the name of the first file listed in the `Files` argument appended with `Class`.

Example: `'ClassName', 'magicsquareClass'`

Data Types: `char` | `string`

**DebugBuild — Flag to enable debug symbols**`'off'` (default) | on/off logical value

Flag to enable debug symbols, specified as `'on'` or `'off'`, or as numeric or logical 1 (`true`) or 0 (`false`). A value of `'on'` is equivalent to `true`, and `'off'` is equivalent to `false`. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to `'on'`, then the compiled assembly contains debug symbols.
- If you set this property to `'off'`, then the compiled assembly does not contain debug symbols.

Example: `'DebugBuild', 'on'`

Data Types: `logical`

**EmbedArchive — Flag to embed deployable archive**`'on'` (default) | on/off logical value

Flag to embed the deployable archive, specified as 'on' or 'off', or as numeric or logical 1 (true) or 0 (false). A value of 'on' is equivalent to true, and 'off' is equivalent to false. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to 'on', then the function embeds the deployable archive in the .NET assembly.
- If you set this property to 'off', then the function generates the deployable archive as a separate file.

Example: 'EmbedArchive', 'off'

Data Types: logical

### **EnableRemoting — Flag to control remoting type**

'off' (default) | on/off logical value

Flag to control the remoting type of the assembly, specified as 'on' or 'off', or as numeric or logical 1 (true) or 0 (false). A value of 'on' is equivalent to true, and 'off' is equivalent to false. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to 'on', then the function builds a remutable assembly.
- If you set this property to 'off', then the function builds an assembly that is not remutable.

Example: 'EnableRemoting', 'on'

Data Types: logical

### **FrameworkVersion — Framework version**

'4.0' (default) | character vector | string scalar

Version of the Microsoft .NET Framework used to compile the assembly.

Example: 'AssemblyVersion', '5.0'

Data Types: char | string

### **Interface — Data API**

'marray' | 'matlab-data' | character vector | string scalar

Data API used for handling data exchange between a .NET application and deployed MATLAB code.

- `marray` — `MWArray` API. This API works with .NET Framework. This is the default interface on Windows.
- `matlab-data` — MATLAB Data API for .NET. This API requires .NET 5.0 or higher. This is the default interface on macOS.

MathWorks recommends using the MATLAB Data API for .NET.

Example: 'Interface', 'matlab-data'

Data Types: char | string

### **ObfuscateArchive — Flag to obfuscate deployable archive**

'off' (default) | on/off logical value

Flag to obfuscate the deployable archive, specified as 'on' or 'off', or as numeric or logical 1 (true) or 0 (false). A value of 'on' is equivalent to true, and 'off' is equivalent to false. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to 'on', then folder structures and file names in the deployable archive are obfuscated from the end user, and user code and data contained in MATLAB files are placed into a user package within the archive. Additionally, all .m files are converted to P-files before packaging. This option is equivalent to using `mcc` with `-j` and `-s` specified.
- If you set this property to 'off', then the deployable archive is not obfuscated. This is the default behavior.

Example: 'ObfuscateArchive', 'on'

Data Types: logical

### **OutputDir — Path to output directory**

character vector | string scalar

Path to the output directory where the build files are saved, specified as a character vector or a string scalar. The path can be relative to the current working directory or absolute.

The default name of the build folder is the assembly name appended with `dotNETAssembly`.

Example: 'OutputDir', 'D:\Documents\MATLAB\work\mymagicdotNETAssembly'

Data Types: char | string

### **SampleGenerationFiles — MATLAB sample files**

character vector | string scalar | cell array of character vectors | string array

MATLAB sample files used to generate sample .NET driver files for functions included within the assembly, specified as a character vector, a string scalar, a string array, or a cell array of character vectors. Paths can be relative to the current working directory or absolute. Files must have a .m extension. For more information and limitations, see "Sample Driver File Creation".

Example: 'SampleGenerationFiles', ["sample1.m", "sample2.m"]

Data Types: char | string | cell

### **StrongNameKeyFile — Path to encryption key**

character vector | string scalar

Path to the encryption key file used to sign the shared assembly, specified as a character vector or a string scalar. If the value is empty, the function creates a private assembly. The file path can be relative to the current working directory or absolute.

Example: 'StrongNameKeyFile', 'sgKey.snk'

Data Types: char | string

### **SupportPackages — Support packages**

'autodetect' (default) | 'none' | string scalar | cell array of character vectors | string array

Support packages to include, specified as one of the following options:

- 'autodetect' (default) — The dependency analysis process detects and includes the required support packages automatically.



- 'none' — No support packages are included. Using this option can cause runtime errors.
- A string scalar, character vector, or cell array of character vectors — Only the specified support packages are included. To list installed support packages or those used by a specific file, see `compiler.codetools.deployableSupportPackages`.

Example: `'SupportPackages',{ 'Deep Learning Toolbox Converter for TensorFlow Models', 'Deep Learning Toolbox Model for Places365-GoogLeNet Network'}`

Data Types: `char` | `string` | `cell`

### **Verbose — Flag to control build verbosity**

'off' (default) | on/off logical value

Flag to control build verbosity, specified as 'on' or 'off', or as numeric or logical 1 (true) or 0 (false). A value of 'on' is equivalent to true, and 'off' is equivalent to false. Thus, you can use the value of this property as a logical value. The value is stored as an on/off logical value of type `matlab.lang.OnOffSwitchState`.

- If you set this property to 'on', then the MATLAB command window displays progress information indicating compiler output during the build process.
- If you set this property to 'off', then the command window does not display progress information.

Example: `'Verbose','on'`

Data Types: `logical`

## **Output Arguments**

### **opts — .NET assembly build options**

`DotNETAssemblyOptions` object

.NET assembly build options, returned as a `DotNETAssemblyOptions` object.

## **Version History**

**Introduced in R2021a**

### **See Also**

`compiler.build.dotNETAssembly`

## **enableTSUtilsfromNetworkDrive**

Set trust setting to load .NET assemblies from network drive

### **Syntax**

```
enableTSUtilsfromNetworkDrive
```

### **Description**

`enableTSUtilsfromNetworkDrive` sets the trust setting so that the MATLAB Compiler SDK module can load .NET assemblies from remote drives.

---

**Note** This is only required when using .NET 2.0 or 3.5.

---

### **Examples**

#### **Enable Load from Remote Drives**

Enable MATLAB Compiler SDK to use network drives on a system.

Enter the following on the MATLAB command line after logging in with Administrator privileges:

```
enableTSUtilsfromNetworkDrive
```

### **Tips**

- Administrator privileges are required to run this command.
- The setting is permanent and only needs to be executed once per machine.

## **Version History**

**Introduced in R2013a**

# ntswrap

Generate type-safe API

## Syntax

```
ntswrap('-a','interfaceAssemblyFile','-c','componentName.className','-i','interfaceName')
ntswrap('-a','interfaceAssemblyFile','-c','componentName.className','-i','interfaceName','-s','-k')
ntswrap(___,'-b','assemblyFile','-d','-n','Namespace.Class','-o','outputDir','-v','version','-w','assemblyName')
```

## Description

`ntswrap('-a','interfaceAssemblyFile','-c','componentName.className','-i','interfaceName')` generates an assembly that contains the type-safe API for the MATLAB Compiler SDK .NET assembly *componentName* wrapped in the class *className*.

`ntswrap('-a','interfaceAssemblyFile','-c','componentName.className','-i','interfaceName','-s','-k')` generates the source code for the type-safe API instead of an assembly.

`ntswrap(___,'-b','assemblyFile','-d','-n','Namespace.Class','-o','outputDir','-v','version','-w','assemblyName')` generates the type-safe API with additional options specified using one or more of the listed arguments. Options include the Microsoft .NET Framework version, assembly and class names, and output directory.

## Examples

### Generate Type-Safe Assembly

Generate an assembly that contains a type-safe API using a .NET assembly and a type-safe interface DLL.

Create the type-safe interface `IMultiply.dll` and .NET assembly `Multiply.dll` using the procedure outlined in “Implement Type-Safe Interface and Integrate into .NET Application” on page 7-8.

Generate the type-safe API using `ntswrap`.

```
ntswrap('-c','Multiply.Arithmetic', ...
        '-a','IMultiply.dll', ...
        '-i','IMultiply');
```

This syntax generates the .NET binary `ArithmeticIMultiply.dll` that contains a type-safe API for the MATLAB Compiler SDK class `Arithmetic` in the namespace `Multiply`.

## Generate Source Code for Type-Safe Assembly

Generate source code for a type-safe API using a .NET assembly and a type-safe interface DLL.

Create the type-safe interface `IMultiply.dll` and .NET assembly `Multiply.dll` using the procedure outlined in “Implement Type-Safe Interface and Integrate into .NET Application” on page 7-8.

Generate the type-safe API using `ntswrap`. Use the additional arguments `-s` and `-k` to generate source code instead of an assembly.

```
ntswrap('-c','Multiply.Arithmetic', ...
        '-a','IMultiply.dll', ...
        '-i','IMultiply', ...
        '-s','-k');
```

This syntax generates the source code file `ArithmeticIMultiply.cs` for the type-safe API.

## Input Arguments

### -a — Assembly that contains statically typed interface

character vector | string scalar

Assembly that contains the statically typed interface referenced by the `-i` argument, specified as a character vector or string vector that contains the relative or absolute path to the assembly.

Example: `'-a','IMyInterface.dll'`

Data Types: `char` | `string`

### -b — .NET assembly

character vector | string scalar

The .NET assembly that defines the component referenced by the `-c` argument, specified as a character vector that contains the relative or absolute path to the assembly. Use this option if `ntswrap` cannot find the specified .NET assembly.

Example: `'-b','MATLAB_NET_assembly.dll'`

Data Types: `char` | `string`

### -c — Component class namespace

character vector | string scalar

Component class namespace of the .NET assembly, specified as a period-separated list that consists of the component name followed by the class name. If the assembly is scoped to a namespace, specify the full namespace-qualified name.

Example: `'-c','MydotNETComp.MyClass'`

Data Types: `char` | `string`

### -d — Enable debugging

Enable debugging of the type-safe API assembly. This option is incompatible with `-s`.

### -f — Specify strong name key file

Specify the strong name key file to sign the generated type safe assembly. This option is incompatible with `-s`.

Example: `'-f', 'keyfile.snk'`

**-i — Interface name**

character vector | string scalar

Interface name, specified by a character vector or string scalar. The interface name is usually prefixed by an `I` and correlates to the interface assembly identified by the `-a` option.

Example: `'-i', 'IMyInterface'`

Data Types: `char` | `string`

**-k — Keep source code**

Keep the generated type-safe API source code. If this argument is omitted, the source code is deleted after processing. This argument is optional.

**-n — Namespace containing type-safe class**

character vector | string scalar

Namespace containing the type-safe API class, specified as a character vector or string scalar. Use this option to override the namespace specified by the `-c` argument. This argument is optional.

Example: `'-n', 'Sample.Sample'`

Data Types: `char` | `string`

**-o — Path to output folder**

character vector | string scalar

Path to the output folder where the build files are saved, specified as a character vector or a string scalar that contains the relative or absolute path. This argument is optional.

Example: `'-o', 'D:\Documents\MATLAB\work\TypeSafeProject'`

Data Types: `char` | `string`

**-s — Generate source code**

Generate source code only; do not compile type-safe API source into an assembly. This argument is optional.

**-v — Microsoft .NET Framework version**

character vector | string scalar

Microsoft .NET Framework version (CSC compiler) used to generate the type-safe API assembly, specified as a character vector or string scalar. This argument is optional and is incompatible with `-s`.

Example: `'-v', 'v4.0'`

Data Types: `char` | `string`

**-w — Name of type-safe API**

character vector | string scalar

Name of the generated type-safe API class and assembly, specified as a character vector or string scalar. Use this option to override the default name. This argument is optional.

Example: '-w', 'TypeSafeMultiply'

Data Types: char | string

## Tips

- To use `ntswrap` from the Windows command prompt, use the following syntax:  
`ntswrap.exe -a interfaceAssembly -c className -i interfaceName`  
`ntswrap.exe` is located in `matlabroot\toolbox\dotnetbuilder\bin\<arch>`.

## Version History

Introduced in R2011a

## See Also

### Topics

“Type-Safe Interfaces” on page 7-2

“Implement Type-Safe Interface and Integrate into .NET Application” on page 7-8

# Deploying .NET Components With the F# Programming Language

## Integrate .NET Assembly into F# Application

The F# programming language offers the opportunity to implement the same solutions you usually implement using C#, but with less code. This can be helpful when scaling a deployment solution across an enterprise-wide installation, or in any situation where code efficiency is valued. The brevity of F# programs can also make them easier to maintain.

The following example shows you how to integrate the deployable MATLAB magic function into an F# application.

### Prerequisites

You must be running Microsoft Visual Studio 2010 or higher to use this example.

If you build this example on a system running 64-bit Microsoft Visual Studio, you must add a reference to the 32-bit MWArray DLL due to a current imitation of Microsoft's F# compiler.

### Step 1: Build the Component

Build the MagicSquareComp component using the instructions in “Generate .NET Assembly and Build .NET Application”.

### Step 2: Integrate Component Into F# Application

- 1 Using Microsoft Visual Studio 2010 or higher, create an F# project.
- 2 Add references to your .NET component and MWArray in Visual Studio.
- 3 Make the .NET namespaces available for your component and MWArray libraries:

```
open MagicSquareComp
open MathWorks.MATLAB.NET.Arrays
```

- 4 Define the Magic Square function with an initial `let` statement, as follows:

```
let magic n =
```

Then, add the following statements to complete the function definition.

- a Instantiate the Magic Square component:

```
use magicComp = new MagicSquareComp.MagicSquareClass()
```

- b Define the input argument:

```
use inarg = new MWNumericArray((int) n)
```

- c Call MATLAB, get the output argument cell array, and extract the first element as a two-dimensional float array:

```
(magicComp.makesquare(1, inarg).[0].ToArray() :> float[,])
```

The complete function definition looks like this:

```
let magic n =
    // Instantiate the magic square component
    use magicComp = new MagicSquareComp.MagicSquareClass()
```



```
// Define the input argument
use inarg = new MWNumericArray((int) n)
// Call MATLAB, get the output argument cell array,
// extract the first element as a 2D float array
(magicComp.makesquare(1, inarg).[0].ToArray()
 :?> float[,])
```

- 5 Add another let statement to define the output display logic:

```
let printMagic n =
    let numArray = magic n
    // Display the output
    printfn "Number of [rows,cols]: [%d,%d]"
        (numArray.GetLength(0)) (numArray.GetLength(1))
    printfn ""
    for i in 0 .. numArray.GetLength(0)-1 do
        for j in 0 .. numArray.GetLength(1)-1 do
            printf "%3.0f " numArray.[i,j]
        printfn ""
    printfn "=====\n"

ignore(List.iter printMagic [1..19])
// Pause until keypress
ignore(System.Console.ReadKey())
```

The complete program listing follows:

### The F# Magic Square Program

```
open MagicSquareComp
open MathWorks.MATLAB.NET.Arrays
let magic n =
    // Instantiate the magic square component
    use magicComp = new MagicSquareComp.MagicSquareClass()
    // Define the input argument
    use inarg = new MWNumericArray((int) n)
    // Call MATLAB, get the output argument cell array,
    // extract the first element as a 2D float array
    (magicComp.makesquare(1, inarg).[0].ToArray() :?> float[,])

let printMagic n =
    let numArray = magic n
    // Display the output
    printfn "Number of [rows,cols]: [%d,%d]"
        (numArray.GetLength(0)) (numArray.GetLength(1))
    printfn ""
    for i in 0 .. numArray.GetLength(0)-1 do
        for j in 0 .. numArray.GetLength(1)-1 do
            printf "%3.0f " numArray.[i,j]
        printfn ""
    printfn "=====\n"

ignore(List.iter printMagic [1..19])
// Pause until keypress
ignore(System.Console.ReadKey())
```

### **Step 3: Deploy the Component**

For information about deploying your component to end users, see “MATLAB Runtime” on page 6-3.