.NET Micro Framework for Beginners

April 24, 2015 Getting Started

*** Draft, in-progress document ***

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1. About the Book

1.1. Intended Audience

This book is for beginners wanting to get started on .NET Micro Framework. No prior knowledge is necessary. The book covers the basics of .NET Micro Framework, Visual Studio and even C#! If you're a hobbyist or an engineer, you will find a good deal of info in this book. This book makes no assumption about what you, the reader, knows so everything is explained extensively.

1.2. Disclaimer

This is a free book use it for your own knowledge and at your own risk. GHI Electronics is not responsible for any damage or loss caused by the use of this free book or by any information provided. There is no guarantee any information in this book is valid.

2. Introduction

Have you ever thought of a great idea for a product but you couldn't bring it to life because technology wasn't on your side? Or maybe thought, “there's got to be an easier way!” Maybe you are a programmer that wanted to make a security system but then thought using a PC is too expensive to run a simple system? The answer is Microsoft's .NET Micro Framework (NETMF).

Here is a scenario, you want to make a pocket-GPS-data-logger that saves positions, acceleration, and temperatures on a memory card and displays them on a small display. If you make this project using classic microcontrollers, like AVR, or PIC micro, all this can be done but then you need a compiler for the microcontroller you chose, a week to learn the processor, a week to write a serial driver, a month or more to figure out the FAT file system and more time for memory cards...etc. In short, most of the time will be spent learning things that should otherwise be trivial. .NET Micro Framework is encapsulate all the low level drivers allowing the developer to concentrate on their own application.

Throughout this document, I will refer to .NET Micro Framework as NETMF.

2.1. Advantages

Using .NET Micro Framework has many advantages:

1. It runs on Microsoft's Visual C# Express, free and and high-end IDE.
2. .NET Micro Framework is open-source and free.
3. Your same code will run any NETMF device with almost no changes.
4. Full debugging capabilities. (Breakpoints, stepping in code, variables...etc.)
5. Has been tested in many commercial products, with assured quality.
6. Includes many bus drivers.(SPI, UART , I2C...etc.)
7. Eliminates the need to use complicated and long processors' datasheets.
8. If you are already a PC C# programmer then you already know NETMF.

2.2. What is .NET?

The .NET Framework was developed to standardize programming. (Note how I am talking about the full .NET Framework and not the Micro Framework.) Once you program in .NET, you are no longer concerned of the underlying operating system. It offers a set of libraries that developers can use from many programming languages.

The .NET Framework runs on PCs and not on smaller devices, because it is a very large framework. Also, the full framework has many things (methods) that wouldn't be very useful on smaller devices. This is how .NET Compact Framework was born. The compact framework removed unneeded libraries to shrink down the size of the framework. This smaller version runs on Windows CE and smart phones. The compact framework is smaller than the full framework but it is still too large for mini devices because of its size and because it requires an operating system to run.

.NET Micro Framework is the smallest version of those frameworks. It removed more libraries and it became OS independent. Because of the similarity among these three frameworks, almost the same code can now run on PCs and small devices, with little or no modifications. For example, using the serial port on a PC, a mobile device or .NET Micro Framework works the same way, when using .NET.

3. .NET Gadgeteer

.NET Gadgeteer platform definitions take NETMF's flexibility to the next level. It is a set of rules on how hardware sensor and control modules can interact with a the processor's mainboard. The complete specifications and software are open-source. GHI Electronics is proud to the first to offer a .NET Gadgeteer platform. More details are found at http://www.ghielectronics.com/products/dotnet-gadgeteer

.NET Gadgeteer users will find this book useful to understand the underlying .NET Micro Framework, the heart and soul of .NET Gadgeteer.

Tip: You can always run raw NETMF code on any .NET Gadgeteer device. However, you will need the schematics and a little amount of work to determine what pins are connected to what sockets.

4. Getting Started

I am sure you can't wait to run your first project, maybe blink an LED. I will promise to get you there as fast as possible!

4.1. System Setup

Before anything, we want to make sure the PC is setup with needed software. First download and install all software components as explained here

https://www.ghielectronics.com/support/netmf

By the way, you may want to bookmark this page as it has about everything you need to use NETMF.

4.2. The Emulator

NETMF includes an emulator that allows NETMF applications to run right on the PC. Lets create a project and run it on the emulator.

Open visual Studio and from the top menu select file -> New Project. If the installation and setup was done properly a Micro Framework option should show under Visual C# and also under Visual Basic.

IMPORTANT: Make sure to name the project exactly NETMFBook, case sensitive. I will explain why later when we talk about namespaces.

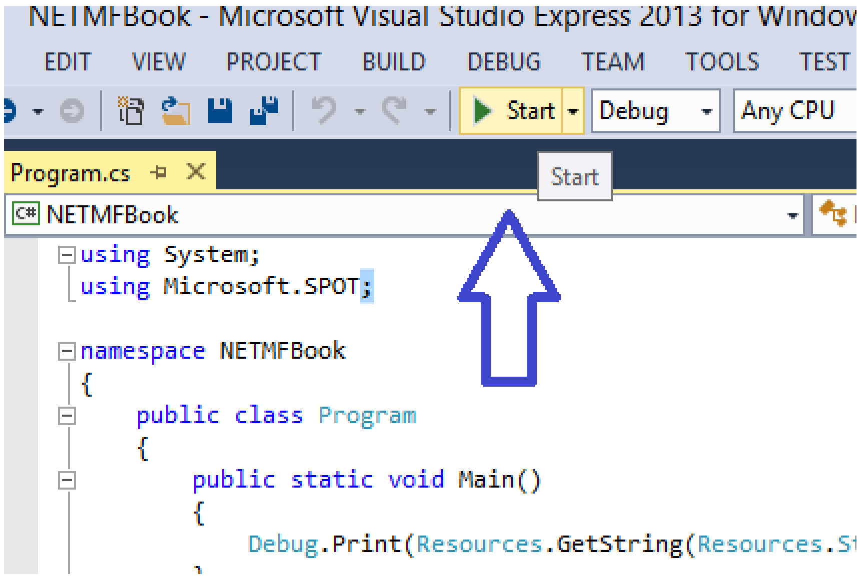
Tip: We will use C# throughout this book but Visual Basic can be used very similarly. There are many websites that translate C# code to Visual Basic code!

The code will look like this. Note the namespace, NETMFBook.

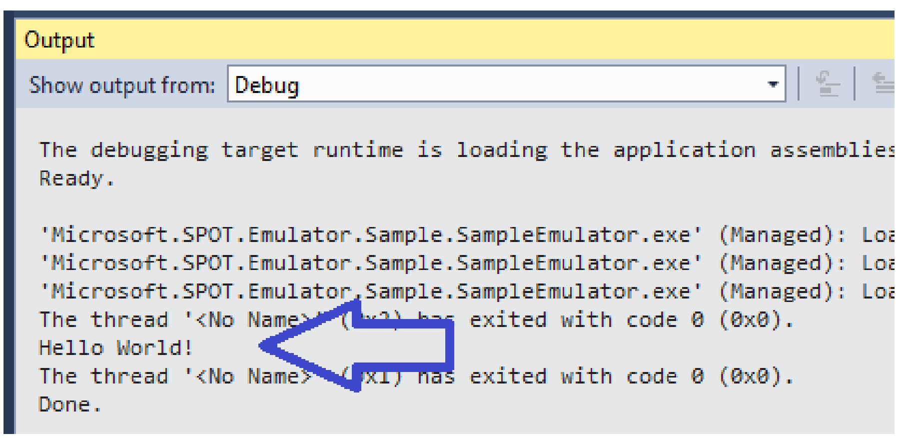
```
using System;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            Debug.Print(Resources.GetString(Resources.StringResources.String1));
        }
    }
}
```

If the code is not visible, click Program.CS file found under the Solution Explorer window.

Go ahead and run the program, by clicking on the start button or pressing the F5 key.



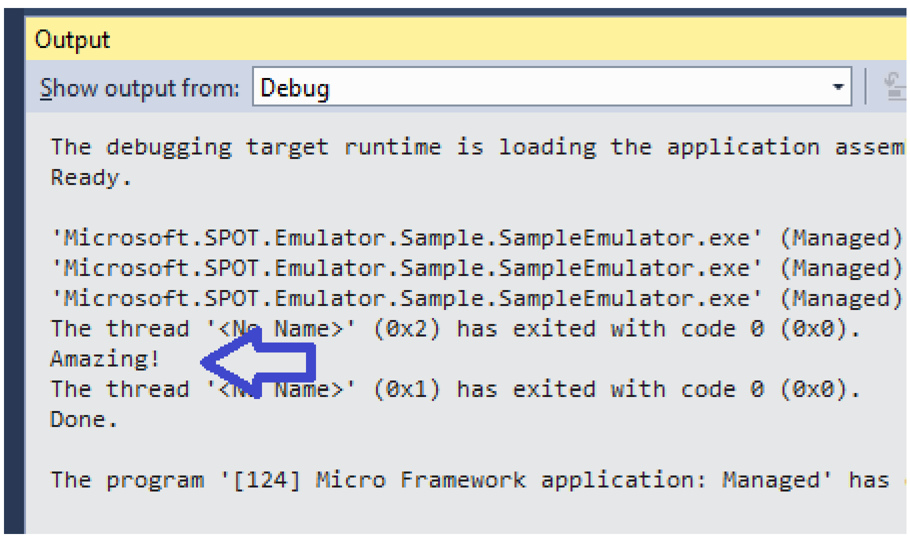
Visual Studio will compile and run the program. This program prints a string from resource and then it ends. This means the emulator will open up and close back real quick. It will look like not much happened but take a look inside the output window.



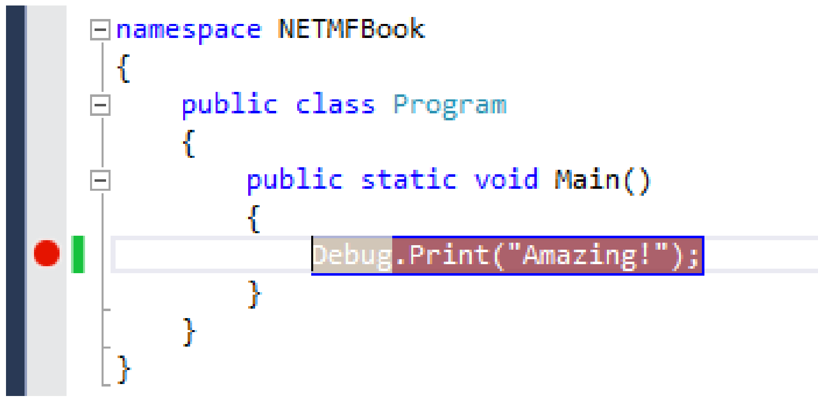
The text “Hello World!” was actually printed from the program we just ran. However, the text is from a resource, which is why it is not very clear. Lets modify the code slightly.

```
using System;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            Debug.Print("Amazing!");
        }
    }
}
```

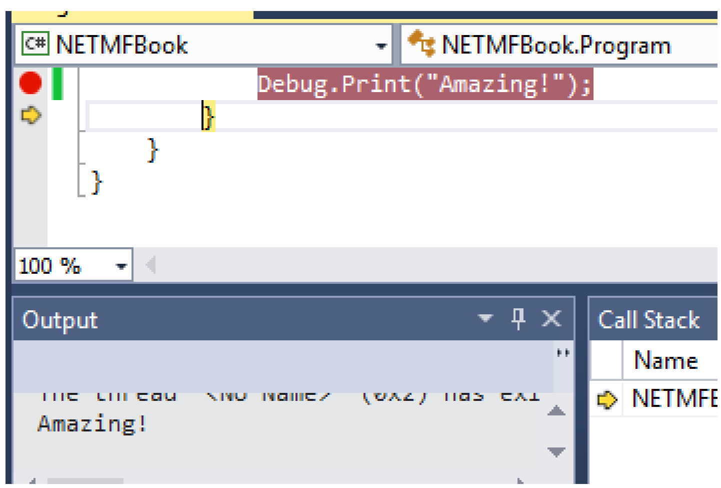
This is the output window.



Lets try the debugging feature and step through the code this time. Set the cursor on the debug print line and press the F9 key.



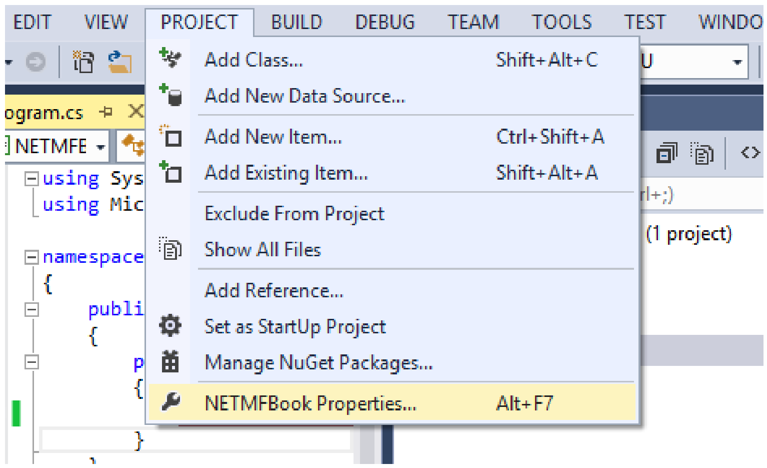
The red line is a breakpoint, meaning the interpreter will stop and wait when it reaches this line. Try to run the program, just like before. Everything will start the same except the program will pause at that line. The word “Amazing!” won't be in the output window as it hasn't executed yet. Press F10 and watch the output window at the same time.



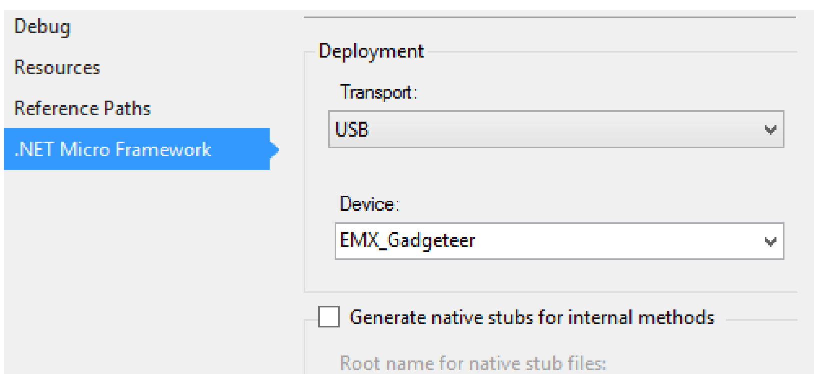
Note how the yellow arrow now points to the next line and the output window shows the text. You can now press F5 to let the program continue, or press shift+F5 to terminate.

4.3. Using the Hardware

Switching from the emulator to the actual hardware is very simple. First, connect your hardware to the PC, this is mostly though USB but sometimes serial or Networking can be used. The next step is to go to the project properties



Then click on the .NET Micro Framework tab

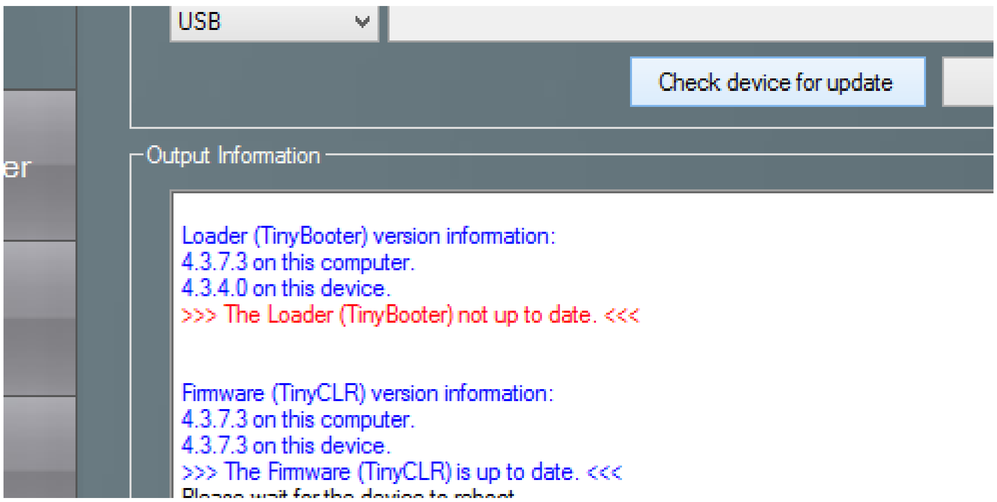


We can now change the transport to USB, to whatever appropriate to the hardware you maybe using. If the device is using USB and is connected properly, it should show under the device list. If it is not showing, open the Device Manager in Windows and make sure the USB drivers are properly installed. The GHI SDK includes them and installs them automatically.

Once the correct transport is selected, press F5 just like before. You will notice that the emulator did not open this time. The code is now actually deployed and running inside the device. Yes you are now programming electronics, that easy!

5. FEZ Config

FEZ Config is a software inspired by Microsoft MFDeploy but has a lot more to offer. One of its important tasks is to update the firmware that resides on the board. Before we proceed, we must check the firmware on the device. Open FEZ Config and click the button “Check device for update”



If the version matched, nothing needs to be done; otherwise, click on the Firmware Updater tab and follow the instructions. Your device may have specific instructions for firmware update, so consult the device's specific documentation.

Tip: FEZ Stands for Fast and Easy but in the past, it was Freakin Easy! See the history here

https://www.ghielectronics.com/technologies/fez

6. The Basics of C#

This book is not meant to cover C# in details but I will cover most of basics to help you get started quickly. If you are familiar with C#, Visual Studio and how to add assemblies to a project, you can completely skip this chapter.

6.1. What is C#?

C and C++ are the most popular programming languages. C# is an updated and modernized version of C and C++. It includes everything you would expect from a modern language, like garbage collector and run-time validation. It is also object-oriented which makes programs more portable and easier to debug and port. Although C# puts a lot of rules on programming to shrink down the bug-possibilities, it still offers most of the powerful features C/C++ have.

6.2. The Starting Point

If you have noticed, programs always start at a method called Main. A method is a little chunk of code that does a certain task. Methods start and finish with open/close curly brackets. In our first program, we only had one line of code between our curly brackets.

The line was `Debug.Print("Amazing!");`

You can see how the line/command always ends with a semicolon. In this example, this line calls the Print method that exists in the Debug object. It calls it while also passing the string “Amazing!” to it.

Confused? Let's try to clear it out a bit. Let's say a dog is an object. You have multiple methods to control this dog, the object. One method can be “Sit” and another can be “Run”. Methods sometimes take arguments. For example, the “Run”method can accept how many steps to run. This hypothetical code will make a dog run for 100 steps!

Dog.Run(100);

6.3. Comments

It is important to add comments/notes/warnings in code. Those comments will help you and others understand what the code means. There are 2 ways to create comments, line comments and block comments. Comments (Ignored text) are shown in green by default in Visual Studio. C# completely ignores these comments.

To comment a line, or part of a line, add // before the comment text. The color of the text will change to green indicating that the text is now comment and is ignored by C#.

```
using System;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            Debug.Print("Amazing!");// A comment!
        }
        // Another comments!
    }
}
```

Whole blocks can be commented as well. Start the comment with /* and then end it with */ symbols.

```
using System;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            Debug.Print("Amazing!");// A comment!
        }
        /* Another comments!
         This can be multi line comment!
         */
    }
}
```

Run the above program and step through the code. The compiler will completely ignore the comment lines.

6.4. while-loop

It is time for our first keyword, “while”. The while-loop starts and ends with curly brackets to contain some looping code. Everything inside will repeatedly run while a statement is true. For example, I can ask you to keep reading this book “while” you are awake! In this case, awake can be true if you are up or false if you are asleep. Before we dig into variables, lets just run the loop while true! Meaning run infinitely.

```
using System;
using System.Threading;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            while (true)
            {
                Debug.Print("Amazing!");
                Thread.Sleep(1000);
            }
        }
    }
}
```

Run the Program, press F5, then pause/break it using ctrl+alt+break. You can also add a breakpoint in the loop and step in the code. Note the yellow arrow and how the program progresses when pressing F10.

Tip: We added a sleep for 1000 milliseconds so we are not printing the text too fast and flooding the system with messages. Using events and giving the system a plety amount of free time to do its own internal tasks is important. NETMF does a lot of tasks internally to manage the entire system. More on this later.

Note that this program will never end so you will need to force stop using shift+F5.

6.5. Variables

Variables are places in memory reserved for your use. The amount of memory reserved for you depends on the type of the variable. I will not cover every single type here but any C# book will explain this in details.

We will be using an int variable. This type of variable is used to hold integer numbers, no fractions.

Simply saying:

int MyVar;

will tell the system that you want some memory reserved for you. This memory will be referenced to as MyVar. You can give it any name you'd like, as long as the name doesn't contain spaces, or start with a number. Now, you can put any integer number into this memory/variable.

MyVar = 1234;

You can also use mathematical operations to calculate numbers:

MyVar = 123 + 456;

or you can increment the number by one:

MyVar++;

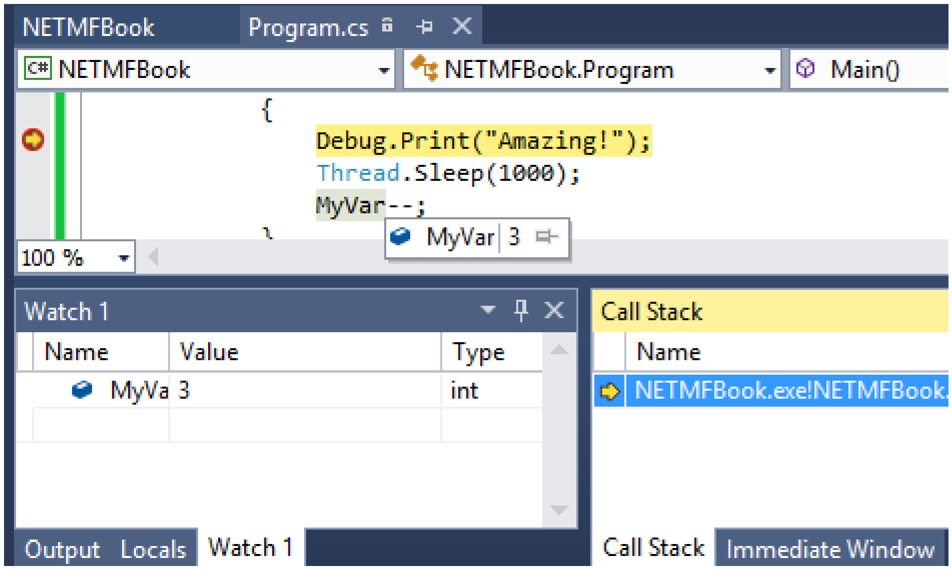
or decrement it by one:

MyVar- -;

With all that, can we make a program that prints the word 'Amazing!' three times? Here is the code.

```
using System;
using System.Threading;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            int MyVar = 3;
            while (MyVar > 0)
            {
                Debug.Print("Amazing!");
                Thread.Sleep(1000);
                MyVar--;
            }
        }
    }
}
```

Add a breakpoint in the loop and when the program pauses place the mouse cursor over the variable MyVar. This will show the value that is currently in stored in it. You can also right-click the mouse and from the menu click on Add Watch. This will place the variable in a watch window so you can see its value while stepping through the code.



We said in the last section that the while loop accepts true and false. But where is the true and false? The result from what we have entered for the while loop results in either true and false. In other words, is the value inside MyVar larger than zero? The answer is either yes or no, that is true and false.

There are other variable types, like double and float. Those can carry a fractional number, like 123.964.

6.6. String

We have already used strings in many places. In a way, they are just variables, but they do not hold a number, but hold a string of characters. Strings are always contained in double quotes so the compiler can recognize them.

Now to the confusing part!What is the difference between the following two lines?

```
int MyVar = 3;
```

```
string MyString = "3";
```

To us, they contain the same thing, number 3. This is very wrong in the computer world. The number 3 is three things, the count three, hat is Tres in Spanish! Even though the language maybe different, three apples are three apples, mathematically speaking. The string three is different. This is not a mathematical representation. It is a variable that is holding the symbol “3”.

Lets try this code that adds integers and also adds strings.

```
using System;
using System.Threading;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            int MyVar1 = 3;
            int MyVar2 = 3;
            string MyString1 = "3";
            string MyString2 = "3";

            Debug.Print("Using int =>" + (MyVar1 + MyVar2).ToString());
            Debug.Print("Using strings =>" + MyString1 + MyString2);
        }
    }
}
```

3+3 results in 6 as we know, but string 3 plus string 3 is not 6, but it is 33. You are adding a symbol to another symbol.

```
Using int =>6
Using strings =>33
```

Since strings are very useful, almost everything has a ToString method attached to it. For an integer variable, this converts the mathematical value of the variable to a string with matching symbols. So when using something that requires a string, like the debug print method, just remember to convert whatever you are trying to print to a string.

Can you guess what this program is going to do?

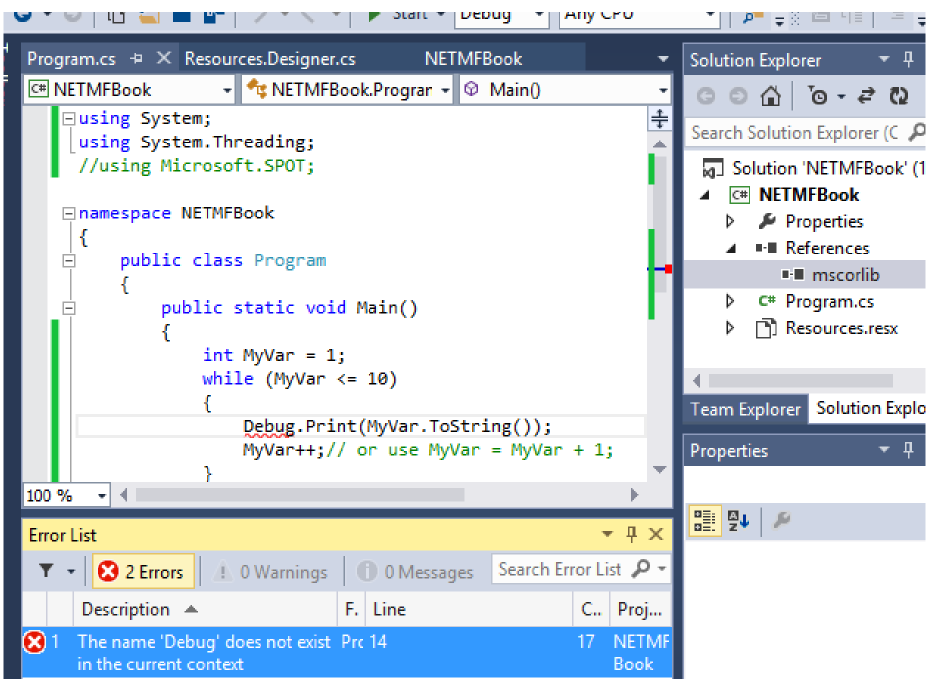
```
using System;
using System.Threading;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            int MyVar = 1;
```

```
            while (MyVar <= 10)
            {
                Debug.Print(MyVar.ToString());
                MyVar++;// or use MyVar = MyVar + 1;
            }
        }
    }
}
```

6.7. Assemblies

Assemblies are files containing compiled (assembled) code. This allows developers to use the code but they don't have access to the assemblies source code. We have already used Debug.Print. Who made the Debug class/object and who made the Print method that is in it? Those are made by the NETMF team at Microsoft. They compile the code and give you an assembly to use it. This way, users are not messing with the internal code but they can still use it.

Go back to the last piece of code from the previous section. Go under References in your project's Solution Explorer and delete Microsoft.SPOT.Native the comment the line using Microsoft.SPOT. Try to compile the code, by pressing F7.



The compiler no longer recognizes the debug library any longer. Now, right click on

References and add the Microsoft.SPOT.Native assembly back and make sure the code compiles and runs before proceeding. We will be adding assemblies in the coming chapters.

Tip: SPOT is the old name of NETMF. It was never changed in code for backward compatibility reasons.

Namespaces are way to group tings under one name to easily pull or not pull parts of libraries. For example, we just aded the library Microsoft.SPOT.Native but then we pulled the namespace Microsoft.SPOT. This was done with the “using” statement. It is important to remember that when using specific library, we need to add its assembly, or source code, to our project and then also add the appropriate namespace.

IMPORTANT: Earlier in the book I explained how when you a create a project to follow along with this book it must be named NETMFBook. This is because the code examples all have this name space and this may cause problems if you have multiple files or when using resources. I still highly recommend you use the same project name but if you didn't you can copy the code example and then change the namespace to whatever you project uses.

6.8. if-statement

An important part of programming is checking some state and taking action accordingly. For example, “if” the temperature is over 80, turn on the fan. Since I am trying to keep all examples emulator-friendly, this code will use the center button on the emulator, also called the select button. To use this code you will need to add the Microsoft.SPOT.Hardware assembly to References. If you want to run this code on a real hardware, just change the pin number to whatever the pin is connected to on your hardware.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            InputPort SelectButton = new InputPort(
                Cpu.Pin.GPIO_Pin3, false, Port.ResistorMode.PullUp);
            while (true)
            {
                if(SelectButton.Read() == false)
                {
                    Debug.Print("Pressed");
                }
```

```
                Thread.Sleep(100);
            }
        }
    }
}
```

The code will simply check a pin 10 times every second. If the button is pressed, it will print pressed in every loop. Note from the code that the button is false when it is pressed. This maybe the opposite from logic but there is a reason for this. More on InputPorts later.

If-statements can optionally have an else-statement. The else is the code that will run if the event was false instead of true. This code will show the button state, pressed or unpressed.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            InputPort SelectButton = new InputPort(
                Cpu.Pin.GPIO_Pin3, false, Port.ResistorMode.PullUp);
            while (true)
            {
                if (SelectButton.Read() == false)
                {
                    Debug.Print("Pressed");
                }
                else
                {
                    Debug.Print("Unpressed");
                }
                Thread.Sleep(100);
            }
        }
    }
}
```

6.9. Classes

All objects we talked about so far are actually “classes” in C#. In modern object oriented programming languages, everything is an object and methods always belong to one object. This allows for having methods of the same name but they can be for completely different objects. A “human” can “walk” and a “cat” can also “walk” but do they walk the same way? When you call the “walk” method in C# it is not clear if the cat or the human will walk but using human.walk or cat.walk makes it more clear.

Creating classes is beyond the scope of this book. Here is a very simple class to get you started

```
class MyClass
{
    int Add(int a, int b)
    {
        return a + b;
    }
}
```

6.10. Static vs. non-static

Some objects in life have multiple instances but others only exist once. The objects with multiple instances are non-static. For example, an object representing a human doesn't mean much. You will need an “instance” of this object to represent a one human. So this will be something like

Human Mike;

We now have a “reference” called Mike of type Human. It is important to note this reference at this point is not referencing any object (no instance assigned) just yet, so it is referencing NULL.

To create the “new” object instance and reference it from Mike

Mike = new Human();

For short, also use

Human Mike = new Human();

We now can use any of the Human methods on our “instance” of Mike

Mike.Run(distance);

Mike.Eat();

bool hungry = Mike.IsHungry();

We have used those non-static methods already when we were reading an input pin, the select button on the emulator. You cant or example use InputPort.Read because we do not know which pin are we talking about. Go back to the example and check how it is constructed with the appropriate pin number.

Static methods are easier to handle because there is only one object that is used directly without creating instances. The easiest example is our Debug object. There is only one debug object in the NETMF system so using one of its methods, like Print, is used directly. Debug.Print("string"); I may not have used the exact definitions of static and instances but I wanted to describe it in the simplest way.

6.11. For-Loop

Using the while-loop is enough to serve all our loop needs but for-loop can be clearer in some cases. We had a program using a while loop that counted 1 to 10. Here is the equivalent program but using a for loop.

```
using System;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            for (int MyVar = 1; MyVar <= 10; MyVar++)
            {
                Debug.Print(MyVar.ToString());
            }
        }
    }
}
```

The easiest way to understand for loops is by actually stepping in the code and seeing how the code flows and how the variable changes. Try to step in the coe anibserve the variable value and the program flows.

6.12. Switch Statement

You probably won't use the switch statement for beginner applications but you will find it very useful when making large programs, especially when handling state-machines. A switch-statement will compare a variable to a list of constants (only constants) and make an appropriate jump accordingly. In this example, we will read the current "DayOfWeek" value and then from its value we will print the day as a string. We can do all this using few if-statements but, in this case, it is much easier and cleaner to use a switch-statement.

```
using System;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            DateTime currentTime = DateTime.Now;
            int day = (int)currentTime.DayOfWeek;

            switch (day)
            {
                case 0: Debug.Print("Sunday"); break;
                case 1: Debug.Print("Monday"); break;
                case 2: Debug.Print("Tuesday"); break;
                case 3: Debug.Print("Wednsday"); break;
                case 4: Debug.Print("Thursday"); break;
                case 5: Debug.Print("Friday"); break;
                case 6: Debug.Print("Saturday"); break;
                default: Debug.Print("We should never see this"); break;
            }
        }
    }
}
```

For simplicity, I used numbers in the previous example but this is the proper way of writing the earlier code

```
using System;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            DateTime currentTime = DateTime.Now;

            switch (currentTime.DayOfWeek)
            {
                case DayOfWeek.Sunday: Debug.Print("Sunday"); break;
                case DayOfWeek.Monday: Debug.Print("Monday"); break;
                case DayOfWeek.Tuesday: Debug.Print("Tuesday"); break;
```

```
                case DayOfWeek.Wednesday: Debug.Print("Wednsday"); break;
                case DayOfWeek.Thursday: Debug.Print("Thursday"); break;
                case DayOfWeek.Friday: Debug.Print("Friday"); break;
                case DayOfWeek.Saturday: Debug.Print("Saturday"); break;
                default: Debug.Print("We should never see this"); break;
            }
        }
    }
}
```

6.13. Array

If we are reading an analog input 100 times and we want to pass all 100 values to a method, it would not be practical to pass 100 variables in 100 arguments. Instead, we create an “array” of our variable type. You can create an array of any object. We will mainly be using byte arrays. When you start interfacing to devices or accessing files, you will always be using byte arrays.

Arrays are declared similar to objects.

byte[] MyArray;

The code above creates a “reference” of an object of type “byte array”. This is a reference but it doesn't have an object yet, it is null.

To create the object we use the “new” keyword and then we need to tell it the size of our array. This size is the count of how many elements of the type we will have in an array. Our type is a byte, so the number is how many bytes we are allocating in memory.

byte[] MyArray; MyArray = new byte[10];

We have created a byte array with 10 elements in it. The array object is referenced from “MyArray”.

We now can store/read any of the 10 values in the array by indicating which “index“ we want to access.

```
byte[] MyArray;
MyArray = new byte[10];
MyArray[0] = 123;// first index
MyArray[9] = 99;// last index
MyArray[10] = 1;// This is BAD...ERROR!!
```

A very important note here is that indexes start from zero. So, if we have an array of size 10, then we have indexes from 0 to 9. Accessing index 10 will NOT work and will raise an exception.

We can assign values to elements in an array at the time of initialization. This example will store the numbers 1 to 10 in indexes 0 to 9.

```
byte[] MyArray = new byte[10] { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
```

To copy an array, use the Array class as follows

```
byte[] MyArray1 = new byte[10] { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
byte[] MyArray2 = new byte[10];
Array.Copy(MyArray1, MyArray2, 5);//copy 5 elements only
```

One important and useful property of an array is the Length property. We can use it to determine the length of an array.

```
byte[] MyArray1 = new byte[10] { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
byte[] MyArray2 = new byte[10];
Array.Copy(MyArray1, MyArray2, MyArray1.Length);//copy the whole array 10.4.
```

6.14. Threading

This can be a very advanced topic, but thanks to NETMF, beginners can enjoy this advanced features. Processors/programs only run one instruction at a time. Remember how we stepped in the code? Only one instruction got executed and then the flow went on to the next instruction. Then how is it possible that your PC can run multiple programs at the same time? Actually, your PC is never running them a once! What it is doing is running every program for a short time, stops it and goes on to run the next program.

Generally, threading is not recommended for beginners but there are things that can be done much easier using threads. For example, you want to blink an LED. It would be nice to blink an LED in a separate thread and never have to worry about it in the main program.

Tip: LED stands for Light Emitting Diodes.

To use threading, add “using System.Threading” to the top of your code. Done! That is all you need.

Tip: Your program, even if you didn't add any thready is a thread itself that is automatically created. If you remember, we added Thread.Sleep to add delays in our main loop, which is a thread.

This program will print NETMF once every two seconds in the the main loop, which is a thread that is automatically created. We are also printing Hello once a second from a thread we created.

```
using System;
using System.Threading;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            Thread MyThread = new Thread(HelloThreadLoop);
            MyThread.Start();
            while(true)
            {
                Debug.Print("NETMF");
                Thread.Sleep(2000);// Wait 2 seonds
            }

        }
        static void HelloThreadLoop()
        {
            while (true)
            {
                Debug.Print("Hello");
                Thread.Sleep(1000);// Wait a second
            }
        }
    }
}
```

Congratulations, you now know enough about C# to create some amazing projects with .NET Micro Framework. Lets get started!

7. Digital Input & Output

Microcontrollers (tiny processors) always have many “digital” pins that can be used as inputs or outputs. By “digital” pins we mean the pin can be “one” or “zero”, that is voltage high for one and voltage low for zero. The low state has a near zero volts, where the high state has voltage that is near the processor's IO's voltage. The IO's voltage was 5V in the 8-bit days but modern processors run on 3.3V, or lower in rare cases.

Note: Static discharge from a human body may damage the processor. Professionals use special equipment and take precautions handling the static charges in their body. You may not have such equipment so just try to stay away from touching the circuit if you don't have to.

NETMF supports digital input and output pins through the “Microsoft.SPOT.Hardware” assembly and namespace. Go ahead and add the assembly and namespace like we learned before. We are now ready to use the digital pins.

7.1. Digital Inputs

Digital inputs sense if the state of a pin is high or low. There is a voltage limitation on these input pins. For example, the minimum voltage on the pin is 0 volts. A negative voltage may damage the microcontroller. Also, the maximum voltage you can apply to a pin must not exceed the the processor's power source voltage, typically 3.3V. Since 5V is still commonly used from the old days, many microcontrollers running at 3.3V have digital input pins that tolerate 5V. Check the product's manual to determine if some or all pins are 5V tolerant.

IMPORTANT: 5V-tolerant doesn't mean the processor can be powered off of 5V. Always power it with 3.3V. Only the input pins can tolerate 5V.

Are unconnected input pins high or low? The answer is neither! The right answer would the pin is floating. Any surrounding electrical noise the environment will push the pin one way or another, or even worse, toggle the pin at a high rate. Input pins should never be left floating. Thankfully, most microcontrollers have a built in weak pull up or pull down resistors on the pins. Think of these resistors as rubber bands that are pulling the pin high (or low). This pull will make the pin high but then an external low state will force the pin low, like if the pin is connected to ground through a button. When the button is not pressed, no connection to ground, and the pin is pulled high by the internal resistor, the rubber band!

As for programming, the InputPort object is used to handle digital input pins. Typically, any GPIO (General Purpose Input Output) pin on the microcontroller can be be switched between input or an output.

There are many uses for input ports but the most common is to connect it to a button or a switch. This example, we used earlier, runs on the emulator and checks if the center button is pressed.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            InputPort SelectButton = new InputPort(
                Cpu.Pin.GPIO_Pin3, false, Port.ResistorMode.PullUp);
            while (true)
            {
                if(SelectButton.Read() == false)
                {
                    Debug.Print("Pressed");
                }
                Thread.Sleep(100);
            }
        }
    }
}
```

The code can run on hardware as well but you will need to change the GPIO pin number. Typically, boards come with a class that list all the board/chip pin numbers. For example, all GHI Electronics' boards pins are grouped into one assembly called GHI.Pins. Lets assume a board is designed with the G120 System on Module at its heart. And also assume there is a button connected to pin P0.26. The code will now looks like this.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            InputPort SelectButton = new InputPort(
                GHI.Pins.G80.Gpio.PE3, true, Port.ResistorMode.PullUp);
            int count = 0;
```

```
            while (true)
            {
                if (SelectButton.Read() == false)
                {
                    Debug.Print("Pressed " + count++);
                }
                Thread.Sleep(100);
            }
        }
    }
}
```

Note that the input is setup with a pull up resistor enabled. This assumes the button is connected between the pin and ground. Button pressed will set the pin low (false) and an unpressed pin will be pulled high by the internal resistor, as explained earlier.

There is also another argument about the glitch filter, but what is that? Typically, when a button is pressed, two metal contacts close on each other quickly. This will cause the contacts to bounce once or more. This bounce is very small and short in time but computers are very fast and they will see the one button press as multiple presses! Of course this is a glitch and solve this we have a glitch filter that only register a pin change if it didn't bounce few times in a very short time. Always enable glitch filters when an input is used with buttons or switches.

7.2. Interrupt Port

In the previous example, we had to loop infinitely checking if the button was pressed. This wastes the microcontroller's energy. You will be checking the pin repeatedly, maybe a million times, before it is pressed! Interrupt ports execute a method automatically when a button is pressed (when pin's state changes to low for example).

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            InterruptPort SelectButton = new InterruptPort(
                GHI.Pins.G80.Gpio.PE3, true, Port.ResistorMode.PullUp,
                Port.InterruptMode.InterruptEdgeLow);
            SelectButton.OnInterrupt += SelectButton_OnInterrupt;
```

```
            // Do other things ...
            // or just sleep!
            Thread.Sleep(Timeout.Infinite);
        }

        static void SelectButton_OnInterrupt(uint pin, uint state, DateTime time)
        {
            Debug.Print("Pressed");
        }
    }
}
```

Note that event handlers can be assigned to more than one source. This is where the first argument “Pin” come in handy, to check which pin actually fired the event.

Another important useful feature is the “time” argument. NETMF is not real time. This means the event will fire up after the button is pressed but when the system is free. IF the system is busy, this can take some time. Now, for button this is not a problem as a human will not notice if actions triggered by the button happened immediately or after 50 milliseconds! However, in cases when we need to know when did the trigger actually fire, the time is saved aside and when the event is fired the time is passed to the handler. Not to worry, we are talking about short milliseconds on a busy system.

This code measures the time between when the event fired and when the event was executed.

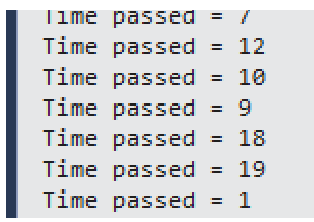
```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            InterruptPort SelectButton = new InterruptPort(
                Cpu.Pin.GPIO_Pin3, false,
Port.ResistorMode.PullUp,Port.InterruptMode.InterruptEdgeLow);
            SelectButton.OnInterrupt += SelectButton_OnInterrupt;
            // Do other things ...
            // or just sleep!
            Thread.Sleep(Timeout.Infinite);
        }

        static void SelectButton_OnInterrupt(uint Pin, uint State, DateTime time)
        {
```

```
            TimeSpan LapsedTime = (DateTime.Now - time);
            Debug.Print("Time passed = " + LapsedTime.Milliseconds);
        }
    }
}
```

The time passed is going to be zero since the system is not busy at all. Lets do something wrong! Replace the sleep with an infinite loop. This loop is not doing much but it will greatly stress the system making it loop there constantly.

```
while (true){ }
//Thread.Sleep(Timeout.Infinite);
```

We can see now how it is taking about 12 milliseconds to respond. Still, that is only 0.012 seconds !



Tip: Most but not all pins on all microcontrollers support interrupts.

7.3. Digital Outputs

Digital output pin can be set to true or false, one or zero. Note that one doesn't mean it is 1 Volt but it means that the pin is supplying voltage. If the processor is powered off of 3.3V source then state 1 on a pin means that there is near 3.3V on the output pin. When the pin is set to zero then it's voltage is very close to zero volts.

Tip: Digital pins are very weak! They can't be used to drive devices. For example, a motor may run on 3.3V but you can not connect it directly to the processor's digital pin. That is because the processor's output is 3.3V but can supply very little current. The best you can do is drive a small LED, or “signal” 1 or 0 to another input pin.

This example will not run on the emulator since there are no output pins there. The example is a simple blink LED demo.

```
using System;
using System.Threading;
```

```
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            OutputPort LED = new OutputPort(
                GHI.Pins.G80.Gpio.PE14, true);

            while (true)
            {
                LED.Write(!LED.Read()); // Invert the LED
                Thread.Sleep(200); // Wait a bit!
            }
        }
    }
}
```

Try to change the code to make the LED blink faster or slower, maybe on for a short time and off for a longer time, a strobe effect.

Important note: Never connect two output pins together. If they are connected and one is set to high and the other is set to low, you will damage the processor. Always connect an output pin to an input, or to a simple load, like a LED.

7.4. Tristate Port

In rare cases a pin maybe needed as an input and output. One way is to "Dispose" the OutputPort pin then create a new InputPort on the same pin. NETMF supports better options for this, through a Tristate port. Tristate means three states; that is input, output low and output high. One minor issue about tristate pins is; if a pin is set to output and then you set it to output again, we will receive an exception. One way to get around this is by checking the direction of the pin before changing it. The direction of the pin is its "Active" property, where false means input and true is output.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
```

```
        public static void Main()
        {
            TristatePort Pin = new TristatePort(
                GHI.Pins.G80.Gpio.PE14, true,true,Port.ResistorMode.PullUp);

            Pin.Active = true; // Make it Input
            bool state = Pin.Read();

            Pin.Active = false; // Make it Output
            Pin.Write(true); // Set
            Pin.Write(false); // Clear

            // ...
            // ...
        }
    }
}
```

Note: TristatePort will only work with interrupt capable digital pins.

8. Analog Pins

8.1. Analog Inputs

Where digital pins only read a state of true and false, analog inputs can read the voltage on a pin. To digitize the analog value, analog digital converters (ADC) have few bits to set the analog value. The more the bits there are the more precision the ADC is. Let's assume an ADC is 8-bit. This means it has 256 levels, that is 2 (2 states per bit) to the power of 8. Let's also assume that we are reading a voltage range of 0 to 256 that is properly scaled to the input voltage range, 0 to 3.3V. This means that every “step” in the ADC equals exactly one volt. Reading 4 in the ADC means there is 4V coming in. But what happens if the voltage is 4.5V? Since each step is 1V, this will be the minimum the ADC can see. Going to a 10-bit ADC will give us 1024 steps, that is 4 times as much as 8-bit 256 steps. We can now read, in this example, 0.25V changes.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            AnalogInput Ain = new AnalogInput(GHI.Pins.G80.AnalogInput.PB1);

            while (true)
            {
                Debug.Print("Ain = " + Ain.Read().ToString("F3"));
                Thread.Sleep(500);
            }
        }
    }
}
```

Tip: Scaling is built into the AnalogInput class, just change the scale and offset in the constructor.

The channel number and the digital pin number are not related. This applies to everything, not just analog. A pin maybe P0.25 but then it is Analog channel 6 and PWM channel 2. The Pin assembly simplifies this but if needed, the user manual will reveal the actual channel number. For example, the following 2 lines do the exact same thing on G80 because pin PB1 is Analog channel 9.

```
AnalogInput Ain = new AnalogInput(GHI.Pins.G80.AnalogInput.PB1);
AnalogInput Ain = new AnalogInput((Cpu.AnalogChannel) 9);
```

8.2. Analog Outputs

Analog outputs allow a pin's voltage level to be controlled by software. The first thing that may come to mind is to dim an LED or slow down a motor. This is not what Analog Outputs are used for. Analog outputs are rarely used but here is an example on how to set an analog output. If you own an oscilloscope, this example will output a sign wave.

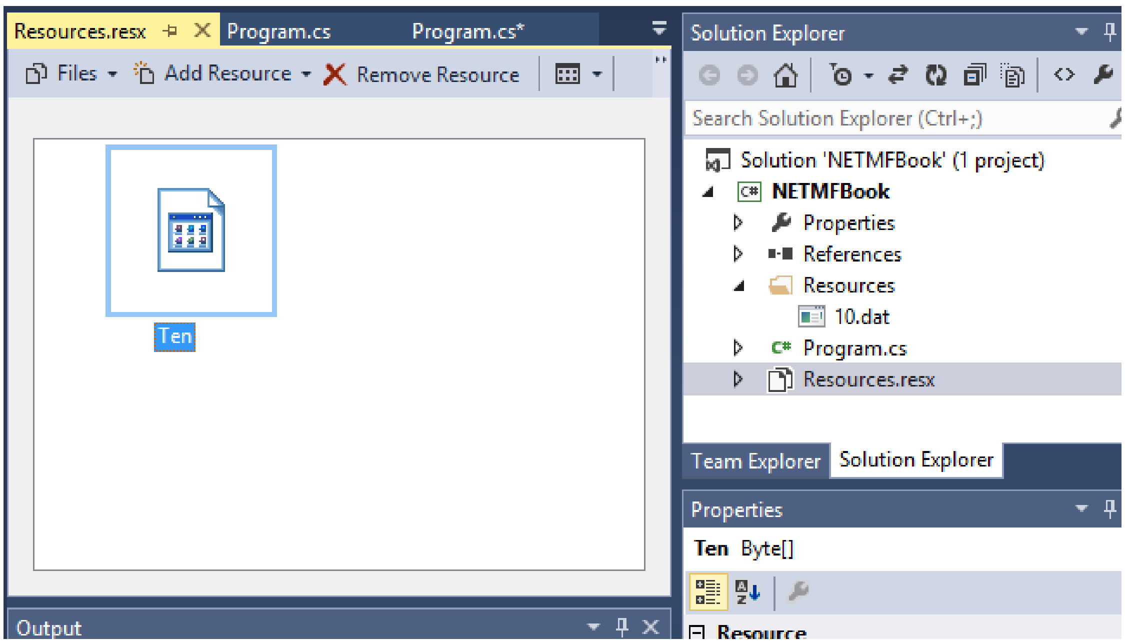
```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            AnalogOutput Ain = new AnalogOutput(GHI.Pins.G80.AnalogOutput.PA4);
            double i = 0;
            while (true)
            {
                // Sin returns -1 to 1 but analog out needs 0 to 1
                // Scale by slashing in half and moving up 0.5
                Ain.Write((System.Math.Sin(i) / 2) + 0.5);
                i = i + 0.1;
                Thread.Sleep(5);
            }
        }
    }
}
```

Playing WAV Audio

While NETMF interpreter is not fast enough to play audio file, GHI Electronics libraries extend the system with a native PCM player. If raw PCM samples are available, they can be simply sent to the method to playback. If a WAV file is used, a simple code is needed to extract the PCM data from the file. Note that the file has to be 8-bit PCM, mono, no compression to work.

The best way to play WAV files is to load from a storage device, like an SD cards. They are large in size and using an SD card will allow us to load chunks at once. For the sake of simplicity, this example loads the file from a resource. Just make sure the file is really small, like 10KB.

Before adding the file to the project resources, the project extension need to be changed from WAV to DAT. Visual Studio tries to handle audio file differently and we do to want that. We want this file to be a simple raw data. Now, open the Resources.resx file in the Solution Explorer then drag and drop your audio file.



We can now load this resource in memory, which is why we want to keep the file small.

To hear the sound, you need to wire an amplified speaker to the analog input pin, like speakers used with desktop PCs. A headphone may work as well. On the 3.5mm plug, connect the very tip of the plug to the analog output pin and also connect ground (GND) from the board to the upper sleeve on the plug.

Tip: The example requires the GHI.Hardware assembly.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;
```

```
namespace NETMFBook
{
    public class Program
    {
        public class WAVE
        {
            int index;
            int dataSize;
            int sampleRate;

            /// <summary>
            /// Loads a WAV file. ONLY PCM 8-bit Mono.
            /// </summary>
            /// <param name="wav">WAV file bytes.</param>
            public WAVE(byte[] wav)
            {
                // see https://ccrma.stanford.edu/courses/422/projects/WaveFormat/

                index = 0;
                if (wav[index + 0] != 'R' || wav[index + 1] != 'I' || wav[index + 2] != 'F' ||
wav[index + 3] != 'F')
                {
                    throw new Exception("File is not RIFF");
                }
                index += 4;
                // ChunkSize
                uint ChunkSize = Utility.ExtractValueFromArray(wav, index, 4);
                index += 4;
                //format
                if (wav[index + 0] != 'W' || wav[index + 1] != 'A' || wav[index + 2] != 'V' ||
wav[index + 3] != 'E')
                {
                    throw new Exception("File is not WAVE format");
                }
                index += 4;
                ////////////////////////////////////

                // fmt sub chunk //////////////////////
                //subchunk ID
                if (wav[index + 0] != 'f' || wav[index + 1] != 'm' || wav[index + 2] != 't' ||
wav[index + 3] != ' ')
                {
                    throw new Exception("Unexpected fmt subchunk!");
                }
                index += 4;
                bool BitVarSampleRate16;

                uint Subchunk1Size = Utility.ExtractValueFromArray(wav, index, 4);
                index += 4;
                if (Subchunk1Size == 16)
                {
```

```
                    BitVarSampleRate16 = true;
                }
                else if (Subchunk1Size == 18)
                {
                    BitVarSampleRate16 = false;
                }
                else
                {
                    throw new Exception("Invalid Subchunk1Size.");
                }

                ushort AudioFormat = (ushort)Utility.ExtractValueFromArray(wav, index, 2);
                index += 2;
                if (AudioFormat != 1)
                {
                    throw new Exception("AudioFormat invalid.");
                }

                ushort NumChannels = (ushort)Utility.ExtractValueFromArray(wav, index, 2);
                index += 2;
                if (NumChannels != 1)
                {
                    throw new Exception("Must be mono.");
                }

                sampleRate = (int)Utility.ExtractValueFromArray(wav, index, 4);
                index += 4;
                if (sampleRate != 8000)
                {
                    throw new Exception("Sample rate must be 8000KHz.");
                }

                ushort ByteRate = (ushort)Utility.ExtractValueFromArray(wav, index, 4);
                index += 4;

                ushort BlockAlign = (ushort)Utility.ExtractValueFromArray(wav, index, 2);
                index += 2;

                if (BitVarSampleRate16)
                {
                    ushort BitsPerSample = (ushort)Utility.ExtractValueFromArray(wav, index,
2);

                    index += 2;
                    if (BitsPerSample != 8)
                    {
                        throw new Exception("Must be 8 bit.");
                    }
                }
                else
                {
                    uint BitsPerSample = Utility.ExtractValueFromArray(wav, index, 4);
```

```
                    index += 4;
                    if (BitsPerSample != 8)
                    {
                        throw new Exception("Must be 8 bit.");
                    }
                }

                ///////////////////////////////////////////

                //// data sub-chunk ///////////////////////////////////////
                if (wav[index + 0] != 'd' || wav[index + 1] != 'a' || wav[index + 2] != 't' ||
wav[index + 3] != 'a')
                {
                    throw new Exception("Unexpected data subchunk!");
                }
                index += 4;

                uint Subchunk2Size = (ushort)Utility.ExtractValueFromArray(wav, index, 4);
                index += 4;

                dataSize = (int)Subchunk2Size;
                ////////////////////////////////////////////
            }

            public int GetDataIndex()
            {
                return index;
            }

            public int GetDataSize()
            {
                return dataSize;
            }

            public int GetSampleRate()
            {
                return sampleRate;
            }
        }
        public static void Main()
        {
            byte [] rawData = Resources.GetBytes(Resources.BinaryResources.scream);
            WAVE wav = new WAVE(rawData);

            while (true)
            {
                GHI.IO.Audio.PlayPcm(GHI.Pins.G80.AnalogOutput.PA4,
                    rawData, wav.GetDataIndex(), wav.GetDataSize(), wav.GetSampleRate());
                Thread.Sleep(1000);// Scream once a second!
            }
        }
```

```
    }
}
```

If you are not sure where to get a suitable audio files, search GHI Electronics codeshare for wav.

Tip: This feature is excellent to play notifications, like saying words such as STOP and ALARM. Playing music compressed files, like MP3, is possible by adding an MP3 decoder chip.

9. PWM

Pulse Width Modulation (PWM) is very important part of most embedded systems. It is used for dimming LEDs and lights and also in controlling the speed on motors. It can also be used to generate frequencies for making sounds and generating pulses that control devices like servo motors. We will cover these individually.

Tip: The use of PWM requires adding the Microsoft.SPOT.Hardware.PWM assembly.

9.1. Dimming LEDs and Lights

To dim an small LED we do not reduce the voltage going to it, instead, we turn the LED on and off very quickly and control the ratio of its being on to its being off. If the LED is on half the time and off the other half then the LED is only receiving half the energy. Change that to on quarter of the time and off three quarter and the LED is now dimmer. We change this ratio by something called duty cycle. In NETMF, this is a value between 1 and 0. Setting it to 0.5 is basically half the energy. This demo will start with the LED at full power and then it dims it down till it is completely off and then it goes back to completely lit.

Tip: The example requires the Microsoft.SPOT.Hardware.PWM assembly.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            PWM MyFader = new PWM(GHI.Pins.G80.PwmOutput.PE13, 10000, 0.1, false);
            double level = 0.5;
            double step = 0.01;
            while (true)
            {
                MyFader.DutyCycle = level;
                /* DutyCycle is not dynamic so make a call to
                 * Start() to refresh the object */
                MyFader.Start();

                level += step;
                if ((level >= 0.9) || (level <= 0.1))
```

```
                {
                    step *= -1; // Invert the step
                }

                Thread.Sleep(10);
            }
        }
    }
}
```

Dimming a light work exactly the same way, except the pin on the processor is not capable of driving a light. A transistor must be added to control the light, or the large/high-power LED.

A good example of how the circuit is implemented is by checking the schematic's of GHI's Load module. The transistor basically work like a digitally controlled switch. The pin on the processor will only control the transistor and then the light will be controlled by the transistor and its own power source.

Tip: The pin number and the channel number are two different things, as explained before.

9.2. Controlling DC Motors

This work very similar to controlling lights, where a transistor is being used. However, the motors are picky to what frequency is being used to control them. The easiest way would be in experimenting with different frequencies to see what works best or consult the motor manufacture. This is a good example on the use of analog inputs. An analog input can be used to change the frequency on a motor for quick experimentation.

9.3. Servo Motors

Servo motors set the position or an arm between 0 degrees and 180 degrees by changing the controlling pulse from 1.25ms to 1.75ms. These pulses need to be generates every 20 milliseconds.

In Earlier examples, we used the frequency and duty cycles. With servos, we need better control over the pulses so we will use the the period and the duration instead. The code below will move the position of the servo to very one second.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
```

```
    {
        public static void Main()
        {
            PWM MyServo = new PWM(Cpu.PWMChannel.PWM_3, 2175, 175,
PWM.ScaleFactor.Microseconds, false);

            while (true)
            {
                // 0 degrees. 20ms period and 1.25ms high pulse
                MyServo.Duration = 1250;
                MyServo.Period = 20000;
                MyServo.Start();
                Thread.Sleep(1000);

                // 90 degrees. 20ms period and 1.50ms high pulse
                MyServo.Duration = 1500;
                MyServo.Period = 20000;
                MyServo.Start();
                Thread.Sleep(1000);

                // 180 degrees. 20ms period and 1.75ms high pulse
                MyServo.Duration = 1750;
                MyServo.Period = 20000;
                MyServo.Start();
                Thread.Sleep(1000);
            }

        }
    }
}
```

9.4. Generating Sounds

Music notes have specific frequencies, C for example is about 261Hz. Plugging these numbers into an array and knowing the length of each tone is all that is needed to play some simple music. You can connect a simple peizo to a pin but we recommend adding a transistor for better results.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        const int NOTE_C = 261;
```

```
        const int NOTE_D = 294;
        const int NOTE_E = 330;
        const int NOTE_F = 349;
        const int NOTE_G = 392;

        const int WHOLE_DURATION = 1000;
        const int EIGHTH = WHOLE_DURATION / 8;
        const int QUARTER = WHOLE_DURATION / 4;
        const int QUARTERDOT = WHOLE_DURATION / 3;
        const int HALF = WHOLE_DURATION / 2;
        const int WHOLE = WHOLE_DURATION;

        public static void Main()
        {
            //make sure the two below arrays match in length. each duration element
corresponds to
            //one note element.
            int[] note = { NOTE_E, NOTE_E, NOTE_F, NOTE_G, NOTE_G, NOTE_F, NOTE_E,
                          NOTE_D, NOTE_C, NOTE_C, NOTE_D, NOTE_E, NOTE_E, NOTE_D,
                          NOTE_D, NOTE_E, NOTE_E, NOTE_F, NOTE_G, NOTE_G, NOTE_F,
                          NOTE_E, NOTE_D, NOTE_C, NOTE_C, NOTE_D, NOTE_E, NOTE_D,
                          NOTE_C, NOTE_C};

            int[] duration = { QUARTER, QUARTER, QUARTER, QUARTER, QUARTER, QUARTER,
QUARTER,
                              QUARTER, QUARTER, QUARTER, QUARTER, QUARTER, QUARTERDOT, EIGHTH,
                              HALF,    QUARTER, QUARTER, QUARTER, QUARTER, QUARTER,
QUARTER,
                              QUARTER, QUARTER, QUARTER, QUARTER, QUARTER, QUARTER,
QUARTERDOT,
                              EIGHTH,  WHOLE};
            PWM MyPWM = new PWM(GHI.Pins.G80.PwmOutput.PA15, 261, 0.50, false);
            while (true)
            {
                for (int i = 0; i < note.Length; i++)
                {
                    MyPWM.Stop();
                    MyPWM.Frequency = note[i];
                    MyPWM.Start();
                    Thread.Sleep(duration[i]);
                }
                Thread.Sleep(100);
            }
        }
    }
}
```

10. Time and Timers

The NETMF runtime system includes time and timer services. This example sets the date and time to a fixed value.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            //Set the time to 07/25/2012 at 11:46:11
            DateTime time = new DateTime(2012, 07, 25, 11, 46, 11);

            // lost after power cycle or reset:
            Utility.SetLocalTime(time);
            while (true)
            {
                Debug.Print(DateTime.Now.ToString());
                Thread.Sleep(1000);
            }
        }

    }
}
```

10.1. RTC

Any System needs power to keep track of time. When power is lost, the time stops or resets to some internal default value. Fortunately, most microcontrollers include a separate Real Time Clock (RTC) circuitry that keeps track of time and runs off a small battery. The system can read this RTC to set the local time or can fetch the correct time over the network.

This example checks if the RTC has a resonate value, meaning it did not reset. It then copies that value to the NETMF's internal clock. Note how we use try-catch when reading the time as the time maybe corrupt and would cause an exception.

The example also prints both, the RTC time and the system time. They will match at the beginning but run this for a while and the time will drift apart eventually.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;
using GHI.Processor;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            DateTime DT;
            try
            {
                // Read the RTC
                DT = RealTimeClock.GetDateTime();
                Debug.Print("Current Real-time Clock " + DT.ToString());
            }
            catch // If the time is not invalid, like day of the month is 40!
            {
                Debug.Print("Bad time exception");
                // Set to something!
                DT = new DateTime(2000, 1, 1, 1, 1, 1);
            }
            if (DT.Year < 2015)
            {
                Debug.Print("Bad time value");
                // Date is wrong! We need to set
                // .. get time from user or network ands set RTC
                // Set the time to 07/25/2015 at 11:46:11 in this example
                DT = new DateTime(2015, 07, 25, 11, 46, 11);
                RealTimeClock.SetDateTime(DT);
            }
            // lost after power cycle or reset:
            Utility.SetLocalTime(DT);
            while (true)
            {
                Debug.Print("System Time: " + DateTime.Now.ToString());
                Debug.Print("   RTC Time: " + RealTimeClock.GetDateTime());
                Thread.Sleep(1000);
            }
        }

    }
}
```

Tip: It is useful to set the time when creating files as the files created will carry the current time and date.

10.2. Timer

Timers are used to let the system know that we need something to happen at a certain time. NETMF includes two timer classes, Timer and ExtendedTimes. Timer class is the same one included in full framework where ExtendedTimer is specific to NETMF with extra functionality.

This example creates a timer that will run after five seconds and then it will keep firing every second.

Tip: the time parameters expects milliseconds.

```
using System;
using System.Threading;
using Microsoft.SPOT;

namespace NETMFBook
{
    public class Program
    {
        static void RunMe(object o)
        {
            Debug.Print("It is time!");
        }

        public static void Main()
        {
            Timer MyTimer =
               new Timer(new TimerCallback(RunMe), null, 5000, 1000);
            Debug.Print(
                   "The timer will fire in 5 seconds and then " +
                   "fire periodically every 1 second");
            Thread.Sleep(Timeout.Infinite);
        }
    }
}
```

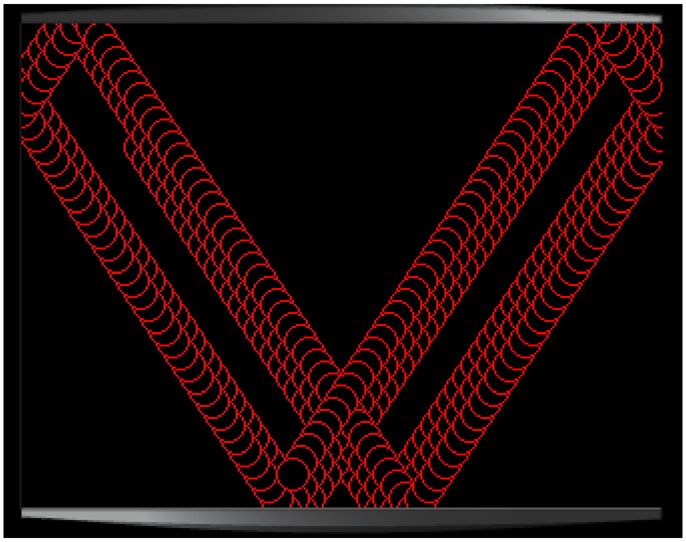
11. Graphics

NETMF shines when it comes to its graphics. It is simple for small system, yet powerful when compared to other embedded system graphics options. We will start by using the emulator for a start and then explain how to configure the system to use an actual display.

Tip: The assembly Microsoft.SPOT.Graphics is required to be added to list of references.

11.1. Simple Shapes

This example will bounce a circle on the screen.

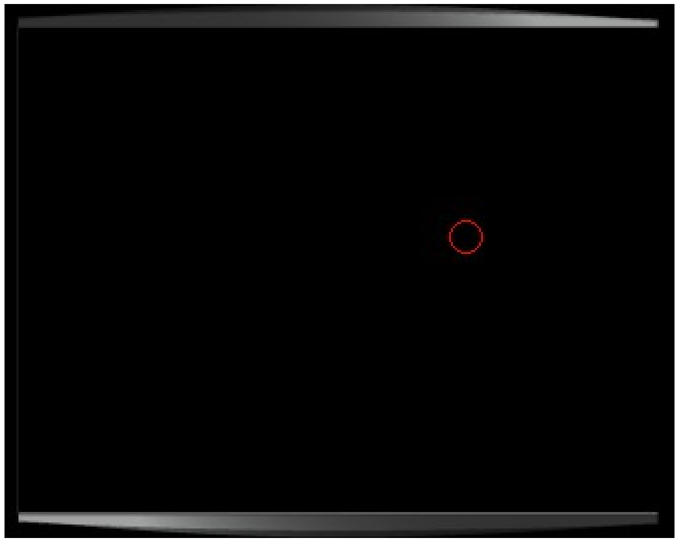


```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Presentation;
using Microsoft.SPOT.Presentation.Media;

namespace NETMFBook
{
    public class Program
    {
```

```
        public static void Main()
        {
            int x = 55, y = 55; // position
            int dx = 4, dy = 6; // speed and direction

            Bitmap LCD = new Bitmap(320, 240);
            while (true)// Infinite loop
            {
                // Move
                x += dx;
                y += dy;
                // Bounce back!
                if (x < 0 || x > LCD.Width)
                    dx *= -1;
                if (y < 0 || y > LCD.Height)
                    dy *= -1;

                LCD.DrawEllipse(ColorUtility.ColorFromRGB(250, 0, 0), x, y, 8, 8);
                LCD.Flush();

                Thread.Sleep(30);// Sleep for few milliseconds
            }
        }
    }
}
```

To draw on the screen, we first need to create a bitmap that is exactly the same size as the screen. We then draw what we wish on the bitmap. When done drawing, call Flush to transfer the bitmap onto the screen.

To make once circle bounce on the screen, we need to clear the bitmap before drawing the new circle.



```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Presentation;
using Microsoft.SPOT.Presentation.Media;

namespace NETMFBook
{
    public class Program
    {

        public static void Main()
        {
            int x = 55, y = 55; // position
            int dx = 4, dy = 6; // speed and direction

            Bitmap LCD = new Bitmap(320, 240);
            while (true)// Infinite loop
            {
                // Move
                x += dx;
                y += dy;
                // Bounce back!
                if (x < 0 || x > LCD.Width)
                    dx *= -1;
                if (y < 0 || y > LCD.Height)
                    dy *= -1;
```

```
                LCD.Clear();
                LCD.DrawEllipse(ColorUtility.ColorFromRGB(250, 0, 0), x, y, 8, 8);
                LCD.Flush();

                Thread.Sleep(30);// Sleep for few milliseconds
            }
        }
    }
}
```

There are other methods for drawing simple shapes, test them out.

11.2. Fonts

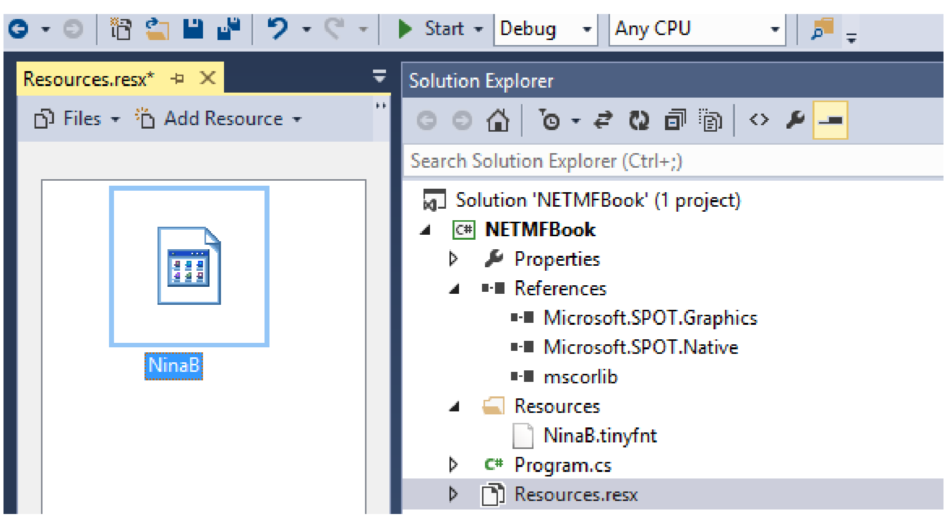
Fonts is something typically very difficult to handle on an embedded system. Thanks to NETMF, we can convert about any true type font to TinyFont and use with NETMF.

This is a useful tool for converting fonts
http://informatix.miloush.net/microframework/Utilities/TinyFontTool.aspx

Once you have a font file, include it in the system as a resource. There are also font files that are incuded in the NETMF installation

C:\Program Files (x86)\Microsoft .NET Micro Framework\v4.3\Fonts

To add a font to a resource, double click Resources.resx in the Solution Explorer to open the resource manager. Now drag NinaB.tinyfnt file to the resource window.

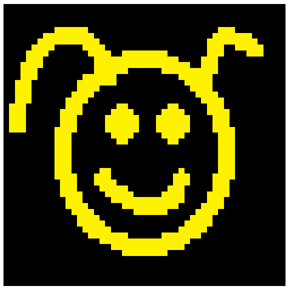


We can now use this font in code. If the code below did not compile right, you have accidentally changed the namespace. Create a project called exactly NETMFBook and you should be okay. We will use the same code as before but this time we are bouncing the text.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Presentation;
using Microsoft.SPOT.Presentation.Media;

namespace NETMFBook
{
    public class Program
    {

        public static void Main()
        {
            int x = 55, y = 55; // position
            int dx = 4, dy = 6; // speed and direction

            Bitmap LCD = new Bitmap(320, 240);
            Font MyFont = Resources.GetFont(Resources.FontResources.NinaB);

            while (true)// Infinite loop
            {
                // Move
                x += dx; y += dy;
                // Bounce back!
                if (x < 0 || x > LCD.Width)
                    dx *= -1;
                if (y < 0 || y > LCD.Height)
                    dy *= -1;

                LCD.Clear();
                LCD.DrawText("Hello!", MyFont, ColorUtility.ColorFromRGB(250, 0, 0), x, y);
                LCD.Flush();

                Thread.Sleep(30);// Sleep for few milliseconds
            }
        }
    }
}
```

11.3. Images

NETMF supports BMP, JPG and GIF image types. However, some devices with small memory may support some or none of these image formats. Also, devices with smaller available memory may have support for BMP for example but the limited memory will limit the size of images you can load in memory before flushing them on the screen. If this happened, an out of memory exception will be raised. Draw a small BMP file, or download one from eh web. Lets try something under 50x50 pixels. This may seem too small on a PC but the emulator is 320x240 only. Here is what I am showing on the screen.



Using the exact same code as before but now bouncing my drawing.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Presentation;
using Microsoft.SPOT.Presentation.Media;

namespace NETMFBook
{
    public class Program
    {

        public static void Main()
        {
            int x = 55, y = 55; // position
            int dx = 4, dy = 6; // speed and direction

            Bitmap LCD = new Bitmap(320, 240);
            Bitmap Bunny = new Bitmap(Resources.GetBytes(Resources.BinaryResources.bunny),
Bitmap.BitmapImageType.Bmp);

            while (true)// Infinite loop
            {
                // Move
                x += dx; y += dy;
                // Bounce back!
                if (x < 0 || x > LCD.Width)
                    dx *= -1;
                if (y < 0 || y > LCD.Height)
                    dy *= -1;
```

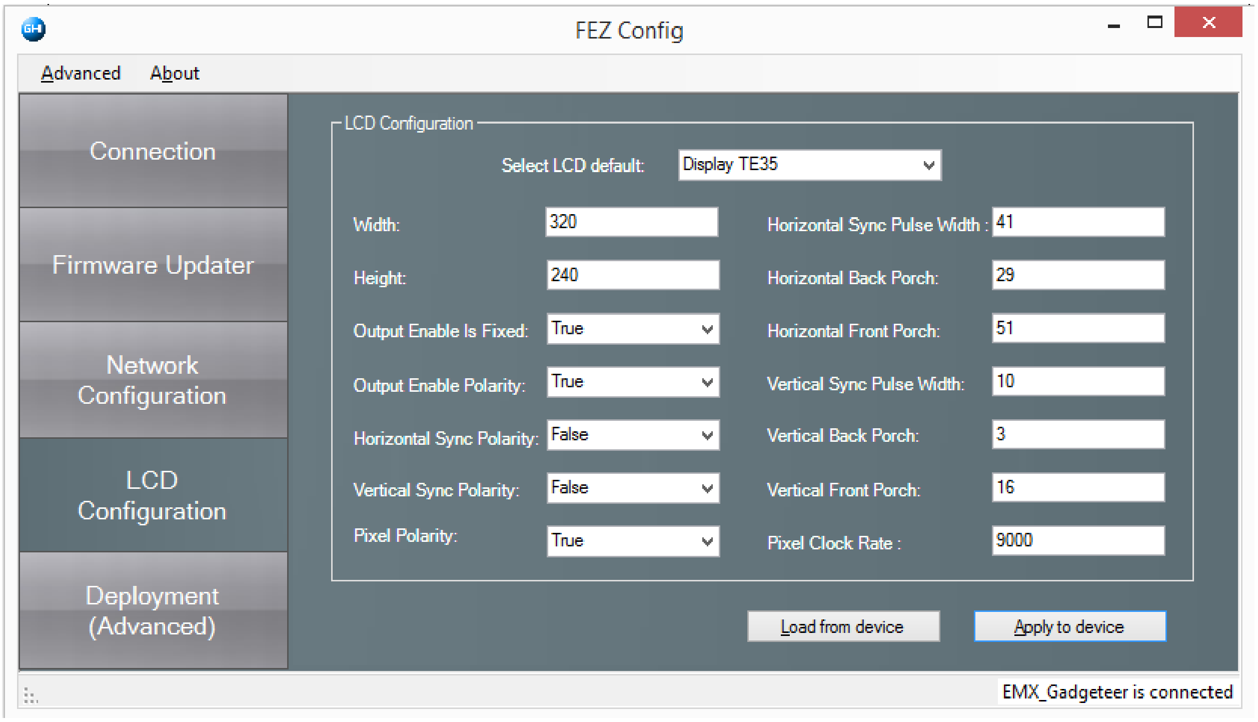
```
                LCD.Clear();
                LCD.DrawImage(x, y, Bunny, 0, 0, Bunny.Width, Bunny.Height);
                LCD.Flush();

                Thread.Sleep(30);// Sleep for few milliseconds
            }
        }
    }
}
```

11.4. Configuring Displays

GHI Electronics extends the NETMF framework with ways to configure the system to accept many type of displays. There are two different display types that can be used, a parallel TFT displays and SPI displays. The parallel-connected displays use 16-bit color bus, horizontal and vertical sync signals and a pixel clock. Internally, this display is mapped to the memory directly. The system can update these displays very efficiently as they are memory mapped. The down side is that about 20 wires need to be connected to the display. Also, a proper set of configuration need to be set correctly in order fro the display to work. If the display looked shifted or nothing is showing then the the configuration is not set correctly.

Parallel TFT Displays

If display used is one of the displays modules offered by GHI Electronics then the default settings are included. These default settings are available in code in FEZ Config. We will try first to set them using FEZ Config. The steps are simple, open Fez Config, click the Display Configuration and then select the appropriate display., then click Apply to device. In my case, I have TE35 Display connected.



The board will reset and you should see some boot up messages on the screen. Go back to one of the examples we used earlier and deploy to the device instead of the emulator. Please note that the size of the LCD Bitmap in the code must match the display size.

Now, this is an example on how to set the a default display config in code.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;
using Microsoft.SPOT.Presentation;
using Microsoft.SPOT.Presentation.Media;
using GHI.Processor;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            Display.Populate(Display.GHIDisplay.DisplayTE35);
            if (Display.Save())
```

```
            {
                Debug.Print("Reboot...");
                // New config was saved, reset to take efect
                PowerState.RebootDevice(false);
            }

            Bitmap LCD = new Bitmap(320, 240);
            LCD.DrawEllipse(ColorUtility.ColorFromRGB(250, 250, 0), 50, 50, 30, 30);
            LCD.Flush();

            Thread.Sleep(Timeout.Infinite);
        }
    }
}
```

The user has full control over the settings as well. This snippet shows an example.

```
Display.HorizontalFrontPorch = 40;
Display.HorizontalSyncPolarity = false;
Display.HorizontalBackPorch = 20;
// ...
// ...

if (Display.Save())
{
    Debug.Print("Reboot...");
    // New config was saved, reset to take efect
    PowerState.RebootDevice(false);
}
```

SPI Displays

This is an extension by GHI Electronics that allow SPI displays to be flushed directly. A typical standard NETMF alternative is to get the bitmap data, then convert the data to a format that matches the display and then finally send the data over SPI. This process uses a lot of memory and is extremely slow. It will take few seconds to draw the display just once. Having this handled internally saves memory and greatly speeds up the refresh speed.

Another built in feature is in initializing the 1.8" display used by GHI Electronics. If the configuration is set to for the RS pin, the core will automatically initialize the display. Using other SPI display is possible, by initializing the display from the application first and then the flush will handle the data conversion internally.

This code will initialize and draw a circle on the G80 Development Board. If something else is being used, the pins need to be set properly to fit your needs.

Tip: Do not forget to add the Microsoft.SPOT.Graphics, GHI.Pins and GHI.Hardware.

assemblies.

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;
using Microsoft.SPOT.Presentation;
using Microsoft.SPOT.Presentation.Media;
using GHI.Processor;
using GHI.Pins;

namespace NETMFBook
{
    public class Program
    {
        public static void Main()
        {
            Display.Populate(Display.GHIDisplay.DisplayN18);
            Display.ControlPin = G80.Gpio.PE10;
            Display.BacklightPin = G80.Gpio.PC7;
            Display.ResetPin = G80.Gpio.PE12;
            Display.ChipSelectPin = G80.Gpio.PD10;
            Display.SpiModule = G80.SpiBus.Spi2;
            Display.Bpp = GHI.Utilities.Bitmaps.BitsPerPixel.BPP16_RGB_BE;
            Display.CurrentRotation = Display.Rotation.CounterClockwise90;
            Display.Save();

            var bmp = new Bitmap(160, 128);
            bmp.DrawEllipse(ColorUtility.ColorFromRGB(250,0,0), 5, 5, 5, 5);
            bmp.Flush();
        }
    }
}
```

11.5. Glide

For more advanced graphical application with beautiful user interfaces, GHI Electronics offer a free and open source library, called Glide. Each screen, called a window, is constructed and rendered from a simple XML text. It supports many components, like buttons and lists.

The website also hosts a window designer for glide. Drag and drop what you need and the website will generate the XML text.

Learn more at https://www.ghielectronics.com/glide

11.6. Touch

Touch screen support is part of what NETMF offers. Use Glide library for graphics with touch. The Glide source code is a great resource for learning more about graphics and touch.

12. Garbage Collector

When programming in older languages like C or C++, programmers had to keep track of objects and release them when necessary. If an object is created and not released then this object is using resources from the system that will never be freed. This is called memory leak, which is the common problem in non-managed system. A program that is leaking memory will contentiously use more memory till the system runs out of memory and probably crashes. Those bugs are usually very difficult to find in code.

Modern languages have garbage collector's that keeps track of the used objects. When the system runs low on memory resources, the garbage collector jumps in and searches through all objects and frees the ones with no “references”. Do you remember how we created objects before using the “new” keyword and then we assigned the object to a “reference”? An object can have multiple references and the garbage collector will not remove the object till it has zero references.

```
// A new object
OutputPort Ref1 = new OutputPort(Cpu.Pin.GPIO_Pin3, true);
// second reference for same object
OutputPort Ref2 = Ref1;
// lose the first reference
Ref1 = null;
// Our object is still referenced
// it will not be removed yet
// now remove the second reference
Ref2 = null;
// from this point on, the object is ready to be
// removed by the garbage collector
```

Tip: That the object is not removed immediately. When needed, the Garbage collector will run and remove the unused objects. This can be an issue in some rare cases because the garbage collector needs some time to search and remove objects. It will only be few milliseconds but what if your application can't afford that? If so, the garbage collector can be forced to run at a desired anytime.

```
//force the garbage collector
uint FreeMemory = Debug.GC(true);
```

Note how the returned value is the free memory size.

12.1. Losing Resources

The garbage collector ease's object allocation but it can also cause problems if we are not careful. Here is a good example. Let's say we need a pin to be high. We create an OutputPort object and set the pin high. Later on we lose the “reference” for that object. The pin will still be high when the reference is lost so all seem to be good. After a few minutes, or hours, the garbage collector kicks in and it finds this unreferenced object, so it will be removed. Freeing an OutputPort will cause the pin to change its state to input. Now, the pin is not high any longer!

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
{
    public class Program
    {
        static void Foo()
        {
            // Turn the LED on
            OutputPort LED = new OutputPort(GHI.Pins.G80.Gpio.PE13, true);
            // Set the pin high
            LED.Write(true);
        }

        public static void Main()
        {
            // Call Foo, which turns the LED on
            Foo();
            // All sem okay but it is not!
            Debug.Print("Before GC");
            Thread.Sleep(10000); // Wait Ten seconds
            Debug.GC(true);
            Debug.Print("After GC");

            Thread.Sleep(Timeout.Infinite);
        }
    }
}
```

The fix is easy, keep the LED reference alive!

```
using System;
using System.Threading;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;

namespace NETMFBook
```

```
{
    public class Program
    {
        static OutputPort LED;
        static void Foo()
        {
            // Turn the LED on
            LED = new OutputPort(GHI.Pins.G80.Gpio.PE13, true);
            // Set the pin high
            LED.Write(true);
        }

        public static void Main()
        {
            // Call Foo, which turns the LED on
            Foo();
            // All sem okay but it is not!
            Debug.Print("Before GC");
            Thread.Sleep(10000); // Wait Ten seconds
            Debug.GC(true);
            Debug.Print("After GC");

            Thread.Sleep(Timeout.Infinite);
        }
    }
}
```

In the first example, the LED reference was local to the method. So when the method finished, the reference is lost.

Tip: If a program worked properly but then it stopped after the GC ran then the problem is most likely what was described above.

IMPORTANT: When debugging applications, it is useful to enable the GC messages. These messages show in the output window.

```
Debug.EnableGCMessages(true);
```

12.2. Dispose

The garbage collector will free objects at some point but a resource can be released immediately. Most objects have a Dispose method. If an object needs to be freed at anytime, we can “dispose” of it. Disposing an object is very important in NETMF. When we create a new InputPort object, the assigned pin is reserved. That pin is locked until its disposed.

13. Topics not Covered

This book is meant to be a beginner getting started guide. It did not cover every single detail. It also did not cover any of the following topics. Of course NETMF includes even more features! The online documentation will include some tutorials and other books to cover some of these topics. The internet is also full of

13.1. Serial Buses

NETMF includes support for many common serial buses.

UART Serial port, the most common use in in the RS232 serial ports on PCs.

https://www.ghielectronics.com/docs/15/uart-serial

SPI, a fast four wire serial protocol with one master and slave(s).

https://www.ghielectronics.com/docs/14/spi

I2C, an addressable two wire interface with a master and slave(s).

https://www.ghielectronics.com/docs/12/i2c

CAN, a noise immune high speed bus, common in automotive and industrial control.

https://www.ghielectronics.com/docs/110/can

OneWire, a low speed single wire bus. Most commonly used with temperature sensors.

https://www.ghielectronics.com/docs/16/onewire

13.2. Networking

This is a very large topic and deserves its own book. NETMF supports .NET Sockets, very similar to the PC and the full .NET. It also supports HTTP and DPWS. For security it supports SSL and SHTTP.

The built I support is available for Ethernet and GHI extend this support with WiFi and PPP.

This is a tutorial to get started

https://www.ghielectronics.com/docs/30/networking

13.3. Accessing files and Folders

NETMF supports FAT16 and FAT32 files, with complete support for folder, files and long file name. The standard support includes SD card support and GHI extends that with support for USB memory drives.

https://www.ghielectronics.com/docs/51/accessing-folders-and-files

13.4. Register Access

Register access provides the system with a way to access the processor internal regiters directly from C#.

https://www.ghielectronics.com/docs/108/register-access

13.5. Runtime Loadable Procedures (RLP)

https://www.ghielectronics.com/docs/50/rlp

13.6. XML

Full XML support is part of NETMF, for reading (parsing) and writing XML files/streams.

https://www.ghielectronics.com/docs/32/xml

13.7. Crypto and Security

NETMF includes full cryptography libraries along with SSL for networking. GHI Electronics also extends that with a simple, yet very fast XTEA method. Small devices that do not have SSL and cryptography support still include XTEA.

https://www.ghielectronics.com/docs/49/xtea

13.8. Database

SQLite databse is NETMF extension aded by GHIElectronics. Databases can be created in memory or on files.

https://www.ghielectronics.com/docs/135/sqlite-database

13.9. Signal Capture and Generate

GHI Electronics adds an extension to read the state transitions on a pin and record the time of the transition in an array. A good example is in capturing the signal coming from a IR remote control.

https://www.ghielectronics.com/docs/106/signal-capture

Another extension is also added by GHI Electronics to generate signals. This can be used to generate signals, like to simulate an IR remote control, or even generate PWM in software.

https://www.ghielectronics.com/docs/24/signal-generator

13.10. In-Field Update

NETMF systems can pull updates automatically from the network or from a memory card. Thanks to this GHI Electronics extension, the update is seamless and easily automated.

https://www.ghielectronics.com/docs/147/in-field-update