# Double Rainbow - Level 1

- **Name**: Double Rainbow - Level 1
- **Difficulty**: Medium
- **Author**: Katy P.
- **Flag**: ph0wn{a-one-of-a-kind}

## Description of the challenge

Katy is so happy. She has finished her first challenge based on Windows 10 IoT Core. The .NET world is so wonderful. You can create a library that is running on a Raspberry Pi, or your x64 desktop computer. No need to recompile, it just works. It was not an easy challenge to create, with many unexpected problems. But it is ready now. But... wait a minute. Oh no! What a mistake!

On the desk of the organizers, there is a Raspberry Pi 3B running Windows 10 IoT Core and a custom application, DoubleRainbow. The flag is given when you press the buttons in the right order. We provide on USB keys a disk image of the `Data` partition of the microSD card. There are also on the desk of the organizers. Find the code using this image and validate your finding on the actual hardware to get the flag.

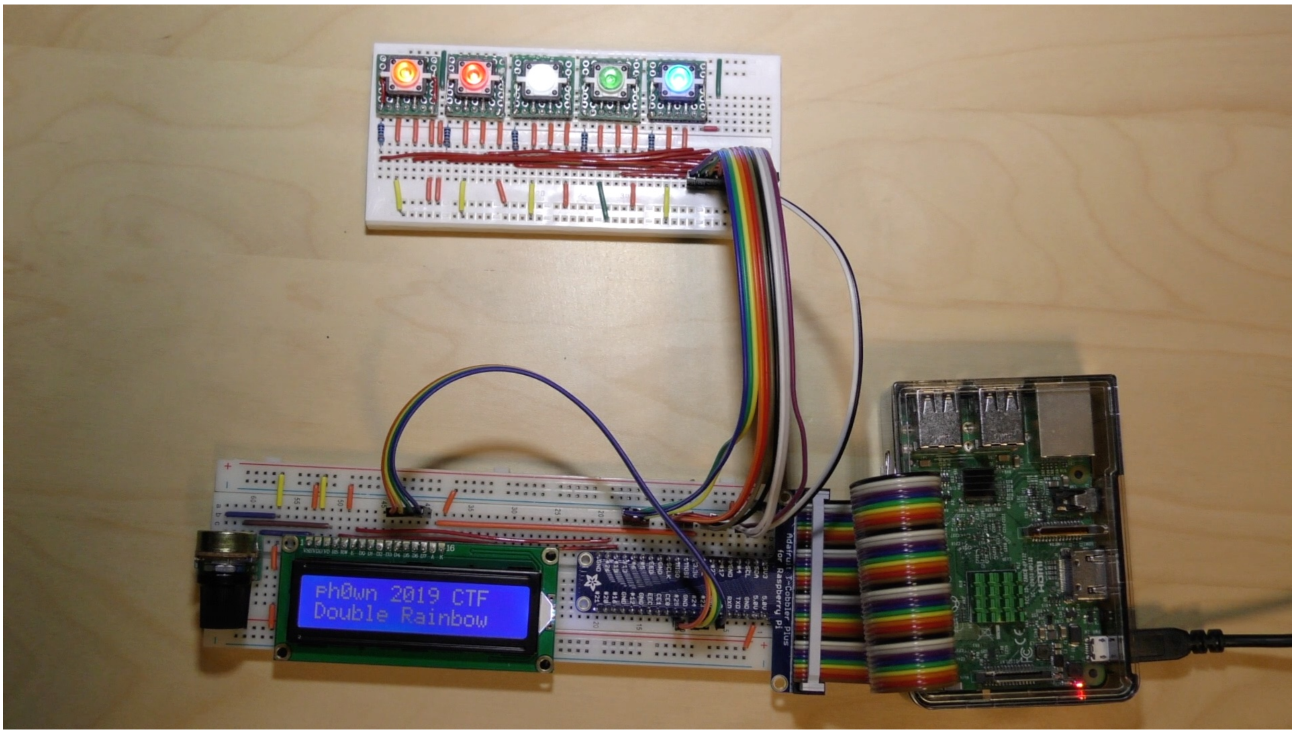
Notes: The USB keys contains both Level 1 and Level 2. This challenge can be solved using any operating system, you do not need to have Windows.

Attachements:

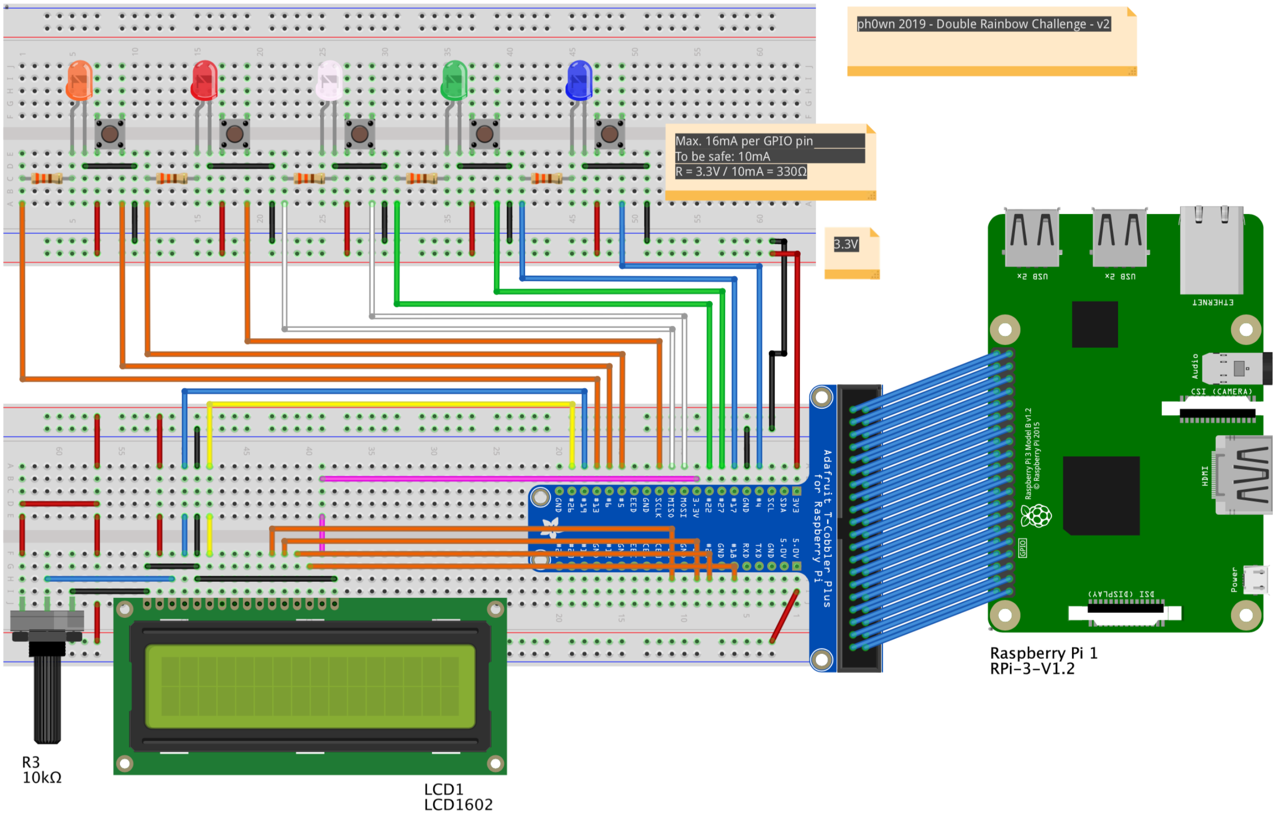
- A photo of the hardware
- The schema of the hardware used by the challenge

## Attachments

### Photo of the hardware



## Schema of the hardware



fritzing

## Solution

This challenge can be solved with almost any operating system. The solution presented here uses a fresh and up to date installation of Kali Linux.

The image `double-rainbow-level1.img.bz2` is compressed so the first thing to do is to decompress it:

```
bunzip2 double-rainbow-level1.img.bz2
```

We get a file `double-rainbow-level1.img` of 7.5 GiB.

The next thing to do is to identify the partitions int this disk image:

```
fdisk -l double-rainbow-level1.img
```

```
Disk double-rainbow-level1.img: 7.41 GiB, 7948206080 bytes, 15523840 secto
rs
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disklabel type: dos
Disk identifier: 0xae420040

Device                     Boot   Start      End  Sectors  Size Id Type
double-rainbow-level1.img1 *       4096   135167   131072   64M  c W95 FAT
32 (LBA)
double-rainbow-level1.img2       147456  3074047  2926592  1.4G  7 HPFS/NT
FS/exFAT
double-rainbow-level1.img3      3074048  3076095     2048    1M 70 DiskSec
ure Multi-Boot
double-rainbow-level1.img4      3076096 15523839 12447744    6G  5 Extende
d
double-rainbow-level1.img5      3080192 15523839 12443648    6G  7 HPFS/NT
FS/exFAT
```

A description of partitions is available on Microsoft web site:
IoT Device Layout

In our case, we have:

| Device | Size | Content |
|---|---|---|
| img1 | 64 MiB | EFIESP |
| img2 | 1.4 GiB | MainOS |

| | | |
|---|---|---|
| img3 | 1 MiB | CrashDump |
| img4 | 6 GiB | Extended Volumes |
| img5 | 6 GiB | Data |

Custom applications are in the `Data` partition. In order to mount it we type:

```
mkdir /mnt/data
mount -t ntfs -o loop,ro,offset=$((3080192*512)) double-rainbow-level1.img
 /mnt/data
```

**Note**: `3080192` is given by `fdisk` (`Start` column). `512` is the number of bytes per allocation unit.

`/mnt/data/` now contains the `Data` partition:

```
ls -la
```

```
total 307252
drwxrwxrwx 1 root root      4096 Sep 22 22:13  .
drwxr-xr-x 3 root root      4096 Sep 24 19:45  ..
-rwxrwxrwx 1 root root     35296 Sep 22 20:07 '$UGM'
drwxrwxrwx 1 root root         0 Oct 27  2018  CrashDump
-rwxrwxrwx 1 root root 314572800 Sep 22 19:58  DedicatedDumpFile.sys
-rwxrwxrwx 1 root root         0 Oct 27  2018  FirstBoot.Complete
drwxrwxrwx 1 root root         0 Sep 22 22:13  .fseventsd
drwxrwxrwx 1 root root         0 Oct 27  2018  Logfiles
drwxrwxrwx 1 root root         0 Oct 27  2018  ProgramData
drwxrwxrwx 1 root root         0 Oct 27  2018  Programs
drwxrwxrwx 1 root root         0 Oct 27  2018  SharedData
drwxrwxrwx 1 root root         0 Oct 27  2018  SystemData
drwxrwxrwx 1 root root         0 Sep 22 18:12 'System Volume Information'
drwxrwxrwx 1 root root         0 Oct 27  2018  test
drwxrwxrwx 1 root root         0 Oct 27  2018  Users
drwxrwxrwx 1 root root         0 Oct 27  2018  Windows
```

We can study Microsoft's documentation in order to determine were the application is located. But we can also simply use `find` to get an idea:

```
find . -iname "double*"
```

```
./ProgramData/Microsoft/Windows/AppRepository/DoubleRainbow1-uwp_1.0.0.0_arm__r63asj4s1fa58.xml
./ProgramData/Microsoft/Windows/AppRepository/Packages/DoubleRainbow1-uwp_1.0.0.0_arm__r63asj4s1fa58
./Users/DefaultAccount/AppData/Local/DevelopmentFiles/DoubleRainbow1-uwpVS.Debug_ARM.sebas
./Users/DefaultAccount/AppData/Local/DevelopmentFiles/DoubleRainbow1-uwpVS.Debug_ARM.sebas/DoubleRainbow1.winmd
./Users/DefaultAccount/AppData/Local/DevelopmentFiles/DoubleRainbow1-uwpVS.Debug_ARM.sebas/DoubleRainbow1Lib.dll
./Users/DefaultAccount/AppData/Local/Packages/DoubleRainbow1-uwp_r63asj4s1fa58
```

The application is located in the folder `./Users/DefaultAccount/AppData/Local/DevelopmentFiles/DoubleRainbow1-uwpVS.Debug_ARM.sebas/`

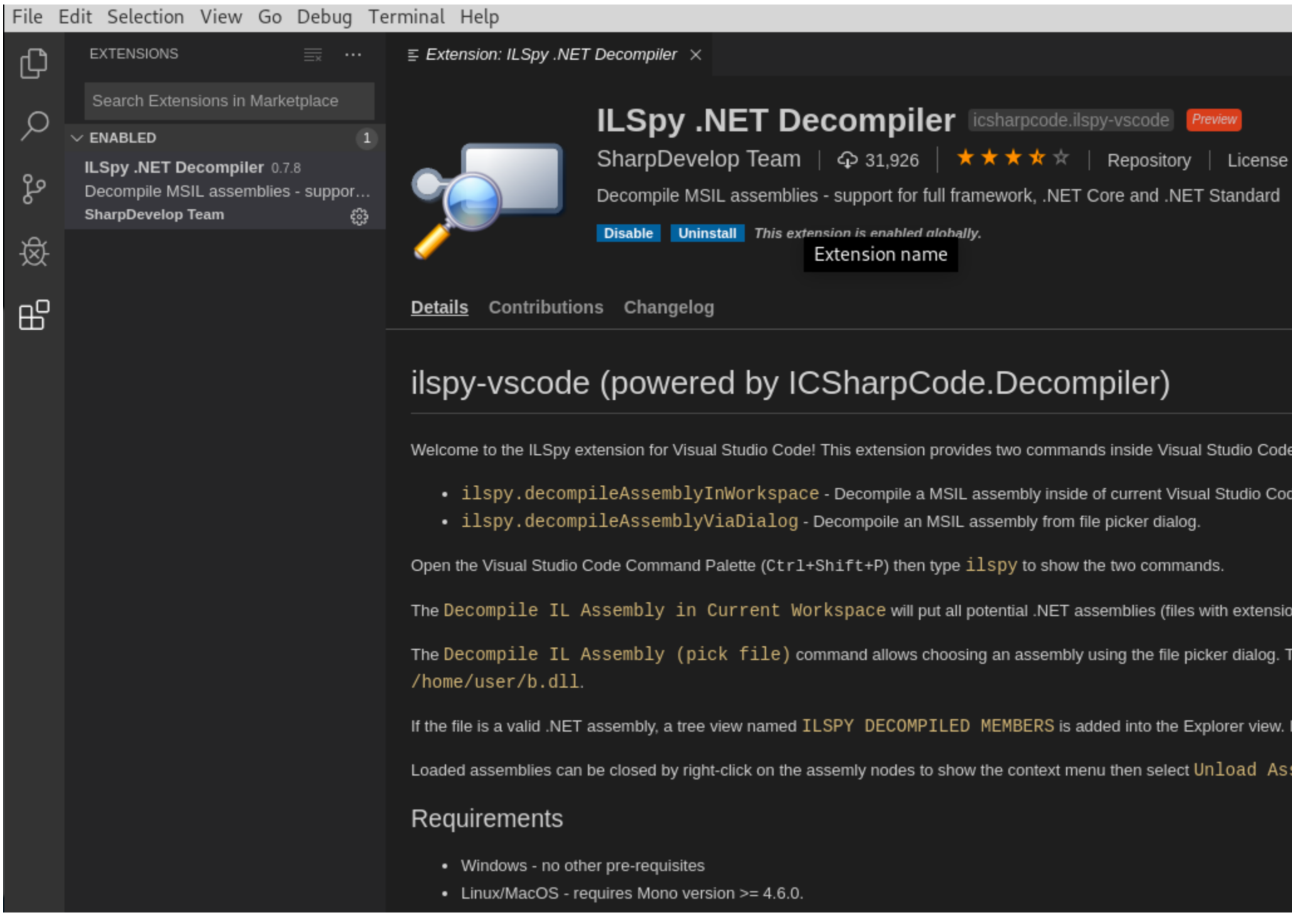
```
ls -la ./Users/DefaultAccount/AppData/Local/DevelopmentFiles/DoubleRainbow1-uwpVS.Debug_ARM.sebas/
```

```
total 384
drwxrwxrwx 1 root root 16384 Sep 22 19:55 .
drwxrwxrwx 1 root root 16384 Sep 22 19:55 ..
-rwxrwxrwx 1 root root  4053 Sep 22 19:56 AppxManifest.xml
drwxrwxrwx 1 root root 16384 Sep 22 19:53 Assets
-rwxrwxrwx 1 root root 16896 Sep 22 19:54 DoubleRainbow1Lib.dll
-rwxrwxrwx 1 root root  4608 Sep 22 19:56 DoubleRainbow1.winmd
drwxrwxrwx 1 root root     0 Sep 22 19:55 microsoft.system.package.metadata
-rwxrwxrwx 1 root root 24576 Oct 23  2018 Microsoft.UI.Xaml.Markup.winmd
-rwxrwxrwx 1 root root 57488 May 15  2018 Microsoft.Win32.Registry.dll
drwxrwxrwx 1 root root     0 Sep 22 19:53 Properties
-rwxrwxrwx 1 root root  5096 Sep 22 19:56 resources.pri
-rwxrwxrwx 1 root root 48712 Aug 13 16:09 System.Device.Gpio.dll
-rwxrwxrwx 1 root root 50736 Mar 12  2019 System.Runtime.dll
-rwxrwxrwx 1 root root 16456 Mar 12  2019 UWPShim.exe
-rwxrwxrwx 1 root root 14669 Sep 22 19:57 vs.appxrecipe
drwxrwxrwx 1 root root     0 Sep 22 19:53 WinMetadata
```

If you know a little .NET development, this should looks familiar.

What we can try to do is to decompile the .NET application. There are several decompilers available for Linux, macOS and Windows. A solution that works for these 3 operating system is to use Microsoft Visual Studio Code and the ILSpy .NET Decompiler plugin.

- To install Visual Studio Code, go to https://code.visualstudio.com/
- Select the appropriate package for your operating system. Here we choose `.deb`
- Install with the command: `sudo dpkg -i code_1.38.1-1568209190_amd64.deb`
- Once installed, start Visual Studio Code and click on the **Extensions** icon on the left
- In the Search box, type `ILSpy` and select **ILSpy .NET Decompiler**
- Click on **Install**


File Edit Selection View Go Debug Terminal Help
EXTENSIONS
Search Extensions in Marketplace
ENABLED 1
ILSpy .NET Decompiler 0.7.8
Decompile MSIL assemblies - suppor...
SharpDevelop Team
Extension: ILSpy .NET Decompiler
ILSpy .NET Decompiler icsharpcode.ilspy-vscode Preview
SharpDevelop Team | 31,926 | ★★★★☆ | Repository | License
Disable
Uninstall
Extension name
Details Contributions Changelog

Decompile MSIL assemblies - support for full framework, .NET Core and .NET Standard

*This extension is enabled globally.*

ilspy-vscode (powered by ICSharpCode.Decompiler)

Welcome to the ILSpy extension for Visual Studio Code! This extension provides two commands inside Visual Studio Code

- `ilspy.decompileAssemblyInWorkspace` - Decompile a MSIL assembly inside of current Visual Studio Coc
- `ilspy.decompileAssemblyViaDialog` - Decompoile an MSIL assembly from file picker dialog.

Open the Visual Studio Code Command Palette (`Ctrl+Shift+P`) then type `ilspy` to show the two commands.

The `Decompile IL Assembly in Current Workspace` will put all potential .NET assemblies (files with extensio

The `Decompile IL Assembly (pick file)` command allows choosing an assembly using the file picker dialog. T `/home/user/b.dll`.

If the file is a valid .NET assembly, a tree view named `ILSPY DECOMPILED MEMBERS` is added into the Explorer view.

Loaded assemblies can be closed by right-click on the assemly nodes to show the context menu then select `Unload As`

Requirements

- Windows - no other pre-requisites
- Linux/MacOS - requires Mono version >= 4.6.0.

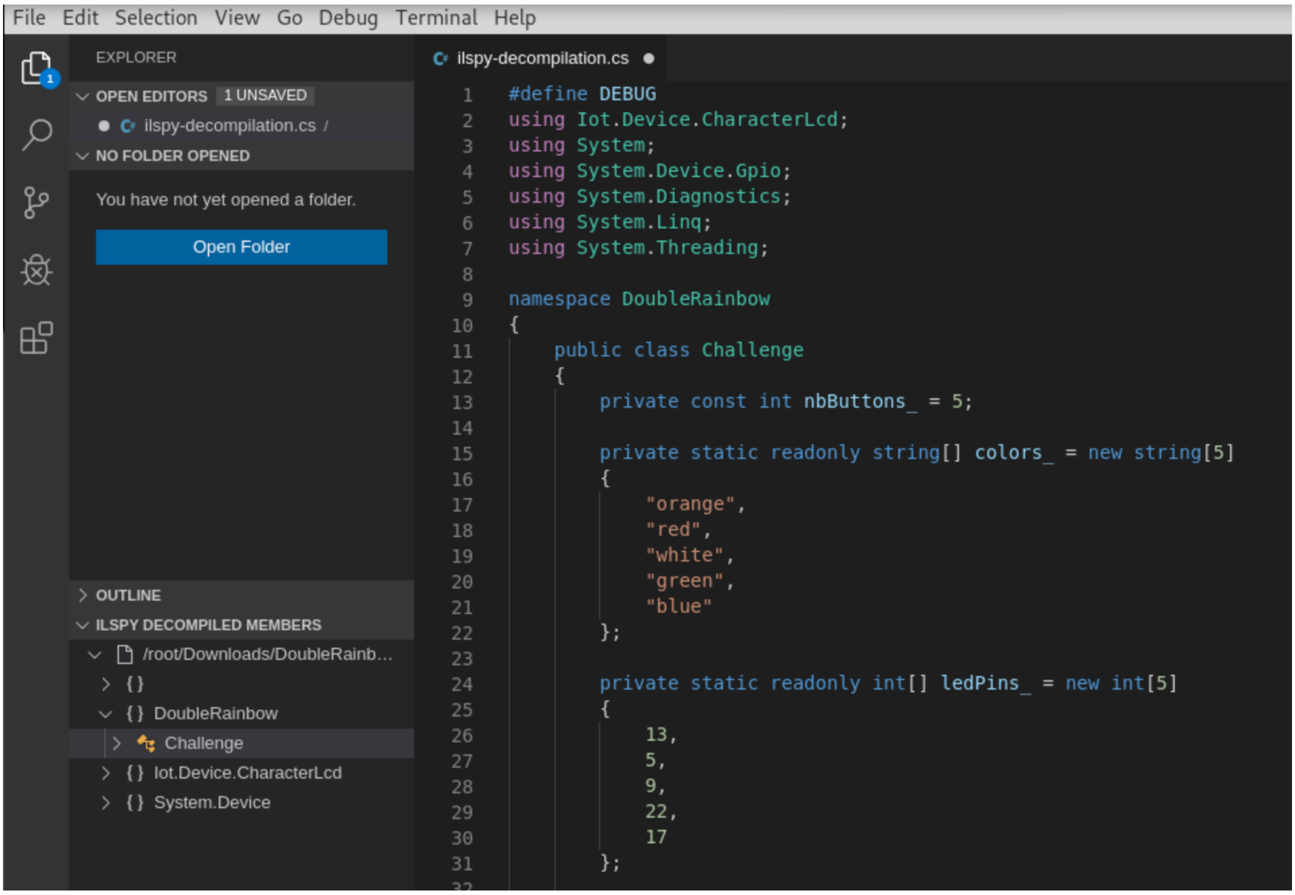
- On Linux and macOS, we also have to install Mono:

```
sudo apt install apt-transport-https dirmngr gnupg ca-certificates
sudo apt-key adv --keyserver hkp://keyserver.ubuntu.com:80 --recv-keys 3FA
7E0328081BFF6A14DA29AA6A19B38D3D831EF
echo "deb https://download.mono-project.com/repo/debian stable-buster main
" | sudo tee /etc/apt/sources.list.d/mono-official-stable.list
sudo apt update
sudo apt install mono-devel
```

The installation takes some time.

We can now decompile .NET code:

- In Visual Studio Code, press **F1** and type `ILSpy`.
- Select `ILSpy: Decompile IL Assembly (pick file)`
- Select `DoubleRainbow1Lib.dll` in `/mnt/Data/Users/DefaultAccount/AppData/Local/DevelopmentFiles/DoubleRainbow1-uwpVS.Debug_ARM.sebas/`
- Be sure **Explorer** is selected (on the left) in Visual Studio Code and under **ILSPY DECOMPILED MEMBERS** you will see the namespaces inside this library
- You can close **ilspy-decompilation.il** in the right to have more space. What we need is the C# code.
- Click on **Challenge** under **DoubleRainbow** to get the code of the challenge in C#



You have not yet opened a folder.

```
#define DEBUG
using Iot.Device.CharacterLcd;
using System;
using System.Device.Gpio;
using System.Diagnostics;
using System.Linq;
using System.Threading;

namespace DoubleRainbow
{
    public class Challenge
    {
        private const int nbButtons_ = 5;

        private static readonly string[] colors_ = new string[5]
        {
            "orange",
            "red",
            "white",
            "green",
            "blue"
        };

        private static readonly int[] ledPins_ = new int[5]
        {
            13,
            5,
            9,
            22,
            17
        };
```

- The code contains:

```
private string[] level1Flag = new string[2]
{
    "ph0wn{our-hearts",
    "-in-vain}"
};

private string[] level2Flag = new string[2]
{
    "ph0wn{fell-under",
    "-your-spell}"
};
```

But these codes are hoaxes (they are taken from a song of Britney Spears, not Katy Perry - Yes "Double Rainbow" is a song of Katy Perry). Finding the codes with just `strings` would be too easy.

- The code is not too difficulty to understand. When a button is pressed, `ButtonCallback` is called:

```
private void ButtonCallback(object sender, PinValueChangedEventArgs pinValueChangedEventArgs)
{
    int num = pin2index_[pinValueChangedEventArgs.get_PinNumber()];
    Debug.Assert(num >= 0);
    lock (codeLock_)
    {
        if (codeIndex_ > 0)
        {
            LightLED(code_[codeIndex_ - 1], on: false);
        }
        code_[codeIndex_++] = num;
        LightLED(num);
        WriteLines($"Color #{codeIndex_} pressed", colors_[num]);
        if (codeIndex_ >= code_.Length)
        {
            VerifyCode();
        }
    }
}
```

- The first line convert the pin number into a color's index
- Then there is a `lock` since the code is asynchronous and to avoid the case when a button is pressed when another one is currently processed.
- The first `LightLED` is used to switch the previous button off.
- Then the color's index is stored in `code_` and `code_Index_` is incremented. So

the sequence of buttons we press is recorded into `code_`.

- The button is light on (second `LightLED`)
- Some message is written on the LCD screen (`Color #x pressed`)
- If `codeIndex_` is greater than `code_.Length`, `VerifyCode` is called. So the code is verified when the `code_` buffer is full (5 colors).

So let's look at `VerifyCode`:

```
private void VerifyCode()
{
    LightLED(code_[codeIndex_ - 1], on: false);
    Wait(1.0);
    if (code1_.SequenceEqual(code_))
    {
        WriteFlag("Congrats", "Go to Desk");
    }
    else
    {
        WriteLines("Wrong Code", "Try again", 2);
    }
    codeIndex_ = 0;
    Welcome();
}
```

It simply compares `code_` with `code1_` and `code1_` is:

```
private readonly int[] code1_ = new int[5]
{
    0,
    1,
    0,
    4,
    3
};
```

The colors are given by:

```
private static readonly string[] colors_ = new string[5]
{
    "orange",
    "red",
    "white",
    "green",
    "blue"
};
```

And it gives:

| code_1 | colors_ |
|---|---|
| 0 | orange |
| 1 | red |
| 0 | orange |
| 4 | blue |
| 3 | green |

**orange, red, orage, blue, green**

- When validating on the actual hardware, you get the actual flag:

```
ph0wn{a-one-of-a-kind}
```