Spanification

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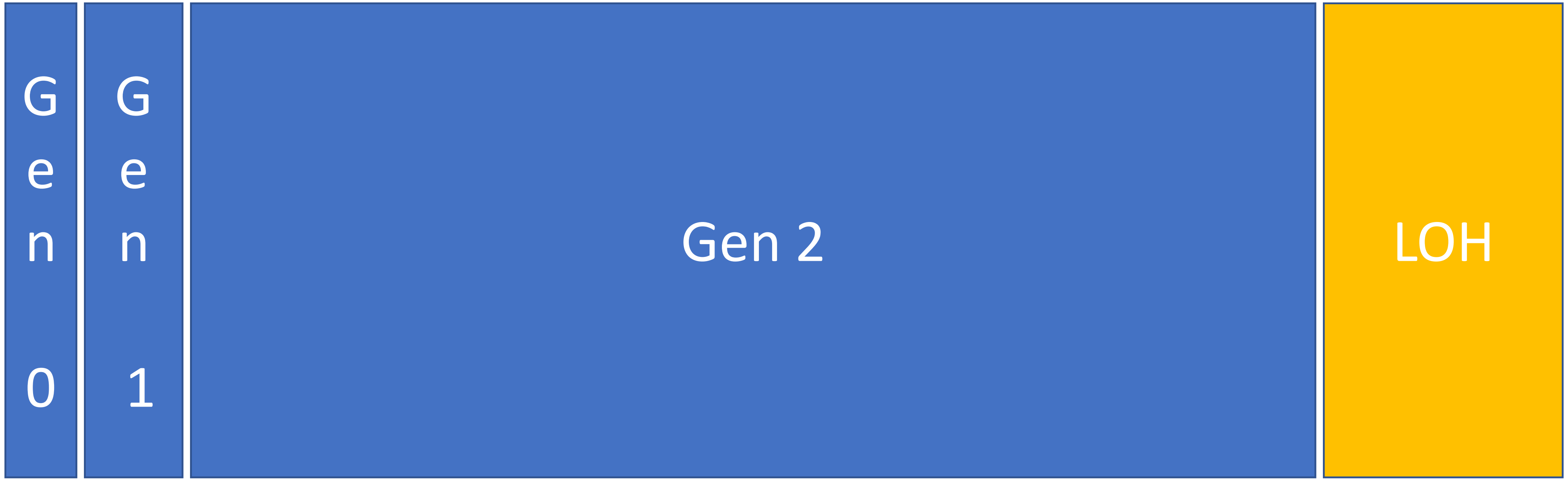
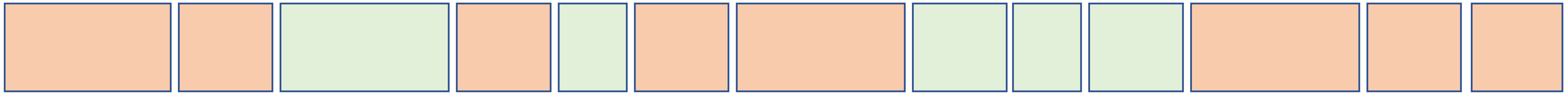
Managed Heap: Workstation mode

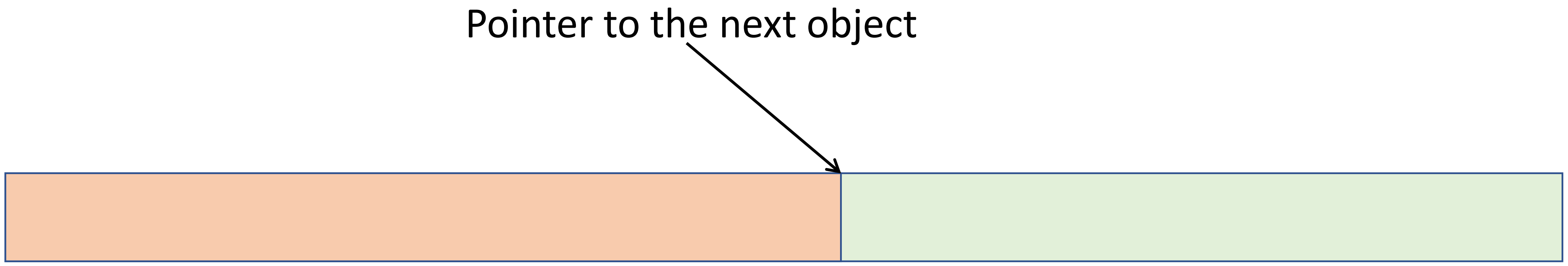


LOH: allocation: find a free segment in the list



Legend: 🟩 free 🟧 taken

SOH: allocation: pNext += requestedSize;

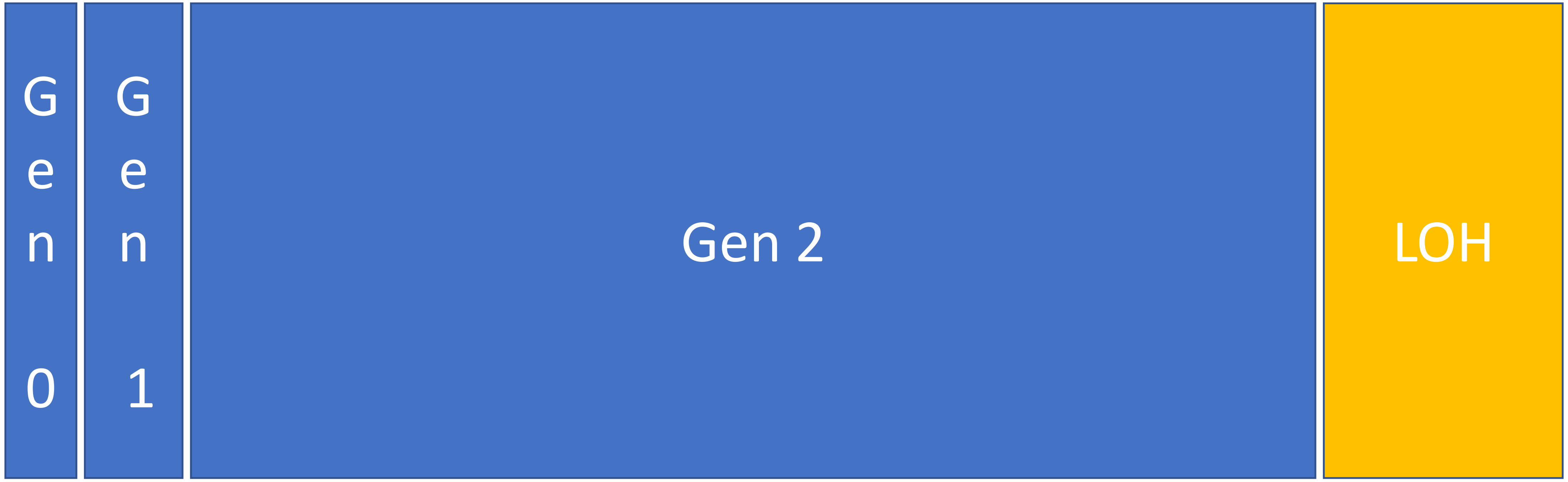


Legend: 🟩 free 🟧 taken

Garbage Collection

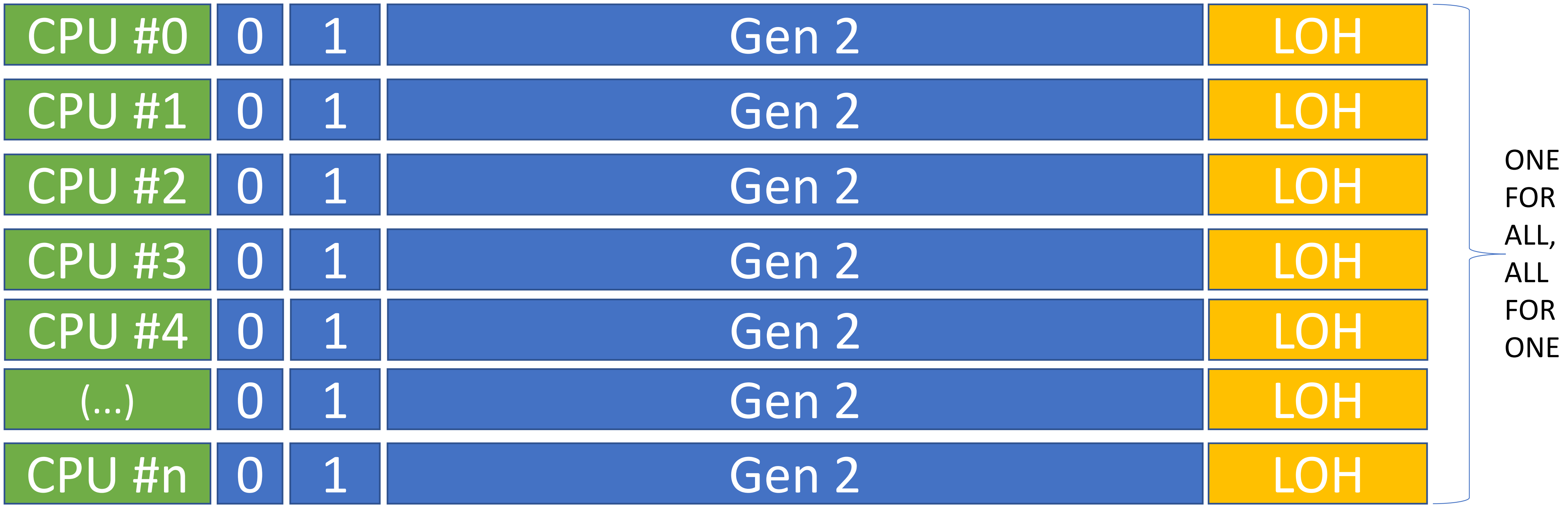
- Mark
  - Starting from the roots, mark all reachable objects as alive
  - In Background
- Sweep
  - Turning all non-reachable objects into a free space
  - Blocking
- Compact
  - To prevent fragmentation
  - Not always
  - Blocking

Cleanup: LOH = GEN 2 = FULL GC



~~LOH = GEN 2 = FULL GC~~

Managed Heap: Server mode



[Middle Ground between Server and Workstation GC by Maoni]

[Running with Server GC in a Small Container Scenario Part 0 by Maoni]

Unmanaged heap

- Allocate and Free on demand

```
IntPtr pointer = Marshal.AllocHGlobal(bytesCount);

try
{
    Consume(pointer, bytesCount);
}
finally
{
    Marshal.FreeHGlobal(pointer);
}
```

- Must not store managed references, just values
- It’s developer responsibility to free the memory
- Possible fragmentation issues

Stack

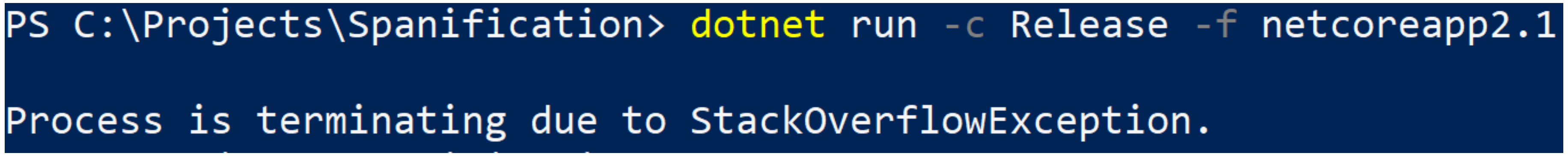
- Allocated on demand, freed with stack unwind

```
public unsafe void Stack(int bytesCount)
{
    byte* pointer = stackalloc byte[bytesCount];

    Consume(pointer, bytesCount);
} // the method ends, the stack unwinds
```

- Until recently*, only values

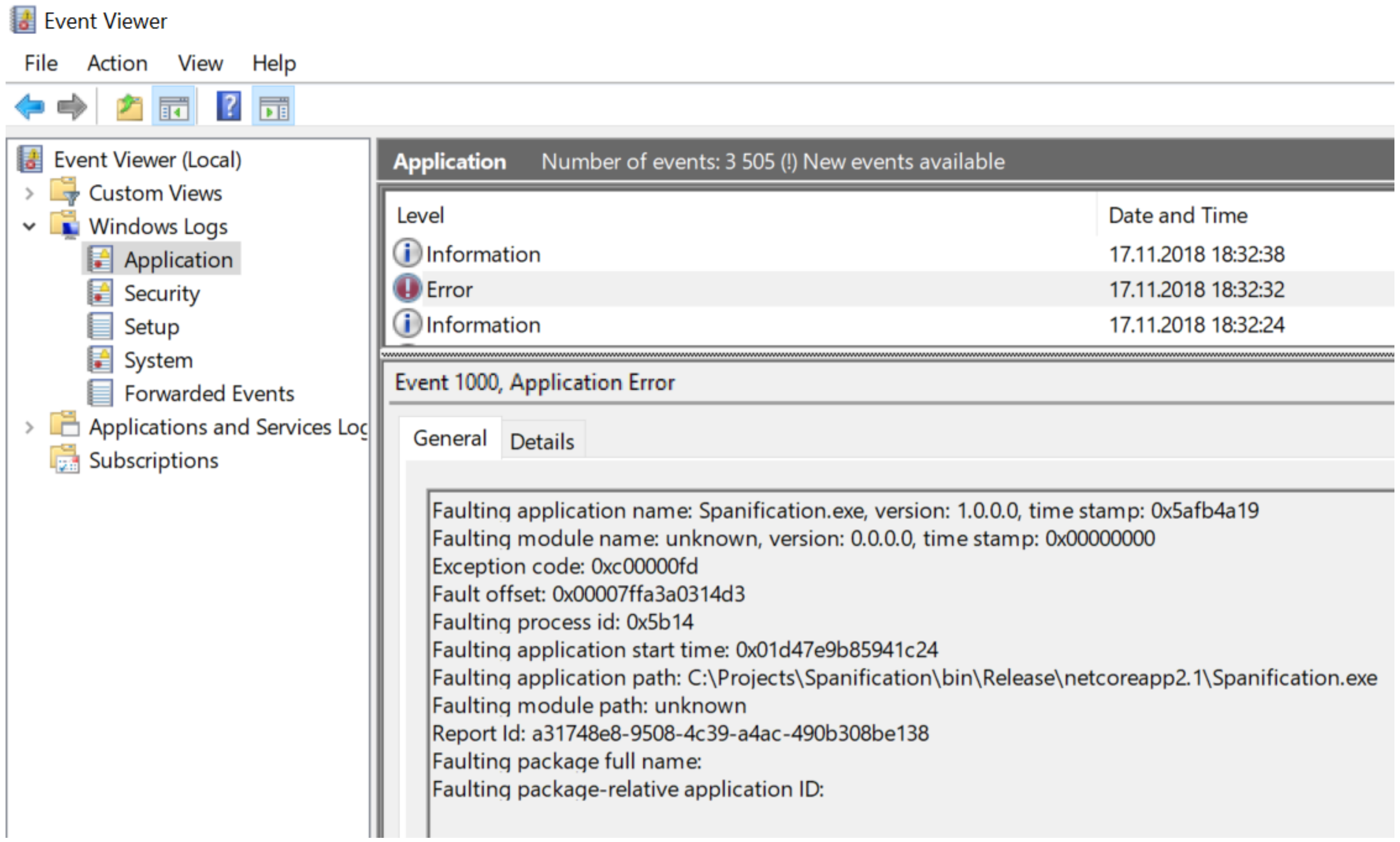
What is the output?

```
try
{
    byte* pointer = stackalloc byte[1_000_000 * 2]; // 2 MB

    Consume(pointer, 1_000_000 * 2);

    Console.WriteLine("OK");
}
catch (Exception e)
{
    Console.WriteLine("EXCEPTION");
}
```



```
PS C:\Projects\Spanification> dotnet run -c Release -f netcoreapp2.1

Process is terminating due to StackOverflowException.
```

Where can I find information about Unhandled Exceptions?



Level	Date and Time
Information	17.11.2018 18:32:38
Error	17.11.2018 18:32:32
Information	17.11.2018 18:32:24

Event 1000, Application Error

```
Faulting application name: Spanification.exe, version: 1.0.0.0, time stamp: 0x5afb4a19
Faulting module name: unknown, version: 0.0.0.0, time stamp: 0x00000000
Exception code: 0xc00000fd
Fault offset: 0x00007ffa3a0314d3
Faulting process id: 0x5b14
Faulting application start time: 0x01d47e9b85941c24
Faulting application path: C:\Projects\Spanification\bin\Release\netcoreapp2.1\Spanification.exe
Faulting module path: unknown
Report Id: a31748e8-9508-4c39-a4ac-490b308be138
Faulting package full name:
Faulting package-relative application ID:
```

Summary: Available Memory

	Managed heap	Unmanaged heap	Stack
Safe	Yes	No type safety	Type safe, but can be deadly
What can be allocated	References and values	Values only	Values only*
Allocation	Cheap	Cheap	Cheap
Deallocation	Comes at a price Can be blocking	Cheap	Immediate
Who cleans up	GC	Developer	OS

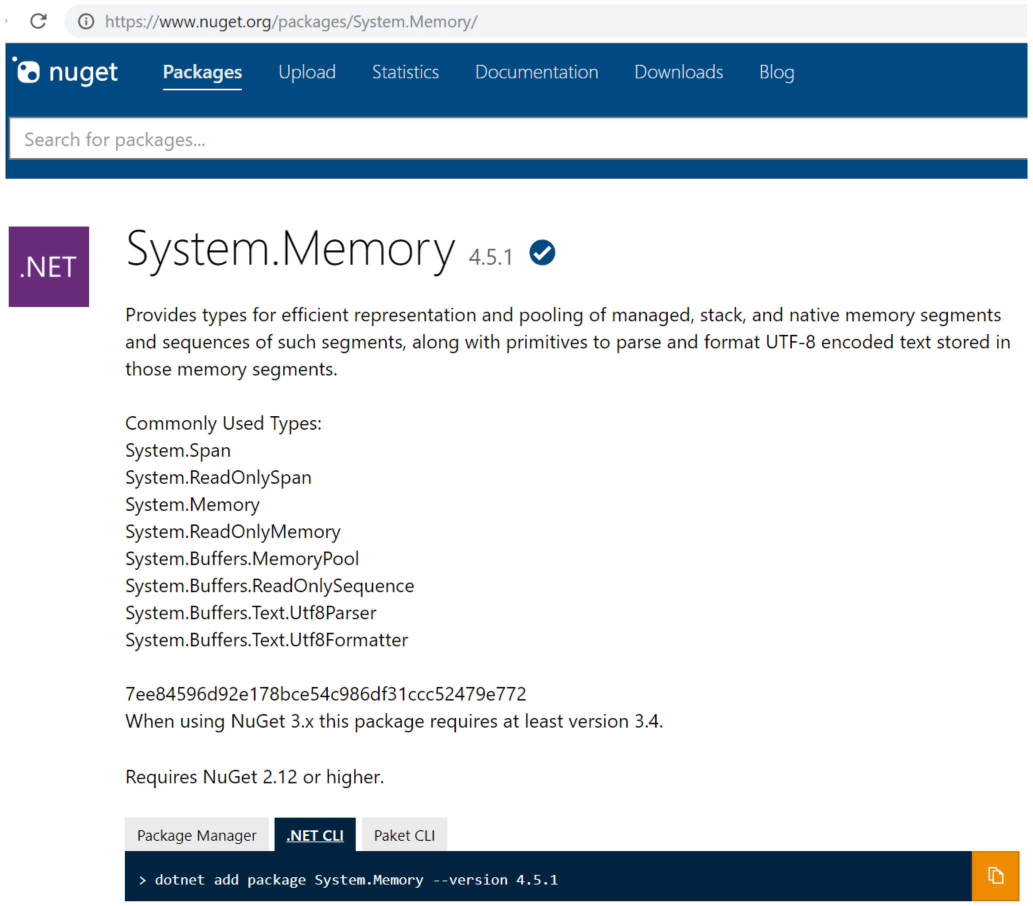
How to write a code that supports all kinds of memory

```
int Parse(string text)

int Parse(string text, int start, int length)

unsafe int Parse(char* pointer, int length)

unsafe int Parse(char* pointer, int start, int length)
```

Span<T>

- It provides a uniform API for working with:
  - Unmanaged memory buffers
  - Arrays and subarrays
  - Strings and substrings
- It’s fully **type-safe** and **memory-safe**
- Almost no overhead
- It’s a **readonly ref struct**

System.Memory NuGet package



System.Memory 4.5.1

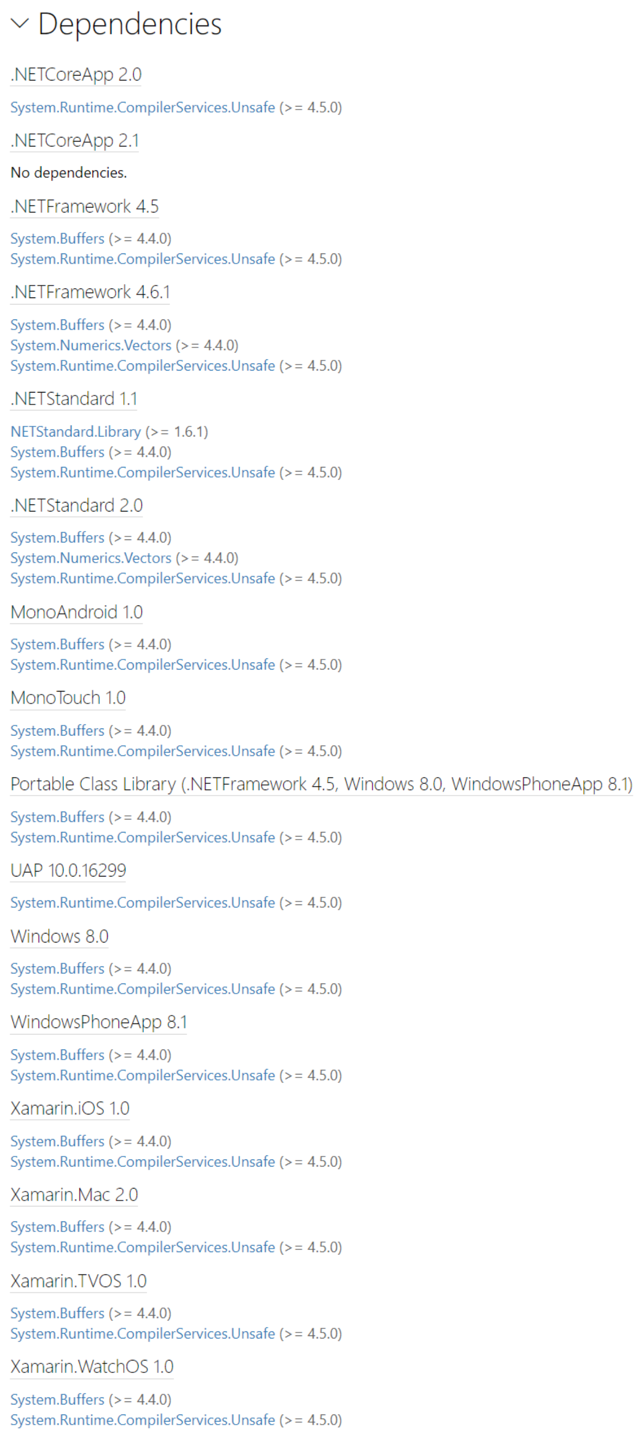
Provides types for efficient representation and pooling of managed, stack, and native memory segments and sequences of such segments, along with primitives to parse and format UTF-8 encoded text stored in those memory segments.

Commonly Used Types:
System.Span
System.ReadOnlySpan
System.Memory
System.ReadOnlyMemory
System.Buffers.MemoryPool
System.Buffers.ReadOnlySequence
System.Buffers.Text.Utf8Parser
System.Buffers.Text.Utf8Formatter

7ee84596d92e178bce54c986df31ccc52479e772
When using NuGet 3.x this package requires at least version 3.4.

Requires NuGet 2.12 or higher.

```
> dotnet add package System.Memory --version 4.5.1
```



Dependencies

.NETCoreApp 2.0
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

.NETCoreApp 2.1
No dependencies.

.NETFramework 4.5
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

.NETFramework 4.6.1
System.Buffers (>= 4.4.0)
System.Numerics.Vectors (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

.NETStandard 1.1
NETStandard.Library (>= 1.6.1)
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

.NETStandard 2.0
System.Buffers (>= 4.4.0)
System.Numerics.Vectors (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

MonoAndroid 1.0
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

MonoTouch 1.0
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

Portable Class Library (.NETFramework 4.5, Windows 8.0, WindowsPhoneApp 8.1)
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

UAP 10.0.16299
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

Windows 8.0
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

WindowsPhoneApp 8.1
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

Xamarin.iOS 1.0
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

Xamarin.Mac 2.0
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

Xamarin.TVOS 1.0
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

Xamarin.WatchOS 1.0
System.Buffers (>= 4.4.0)
System.Runtime.CompilerServices.Unsafe (>= 4.5.0)

C# 7.2

```
Span<byte> stackMemory = stackalloc byte[256];
```

Error CS8107 Feature 'ref structs' is not available in C# 7.0. Please use language version 7.2 or greater.

```
<PropertyGroup>
  <LangVersion>7.2</LangVersion>
</PropertyGroup>
```

Supports **any** memory

```
Span<byte> stackMemory = stackalloc byte[256]; // C# 7.2

IntPtr unmanagedHandle = Marshal.AllocHGlobal(256);
Span<byte> unmanaged = new Span<byte>(unmanagedHandle.ToPointer(), 256);

char[] array = new char[] { 'i', 'm', 'p', 'l', 'i', 'c', 'i', 't’ };
Span<char> fromArray = array; // implicit cast

ReadOnlySpan<char> fromString = "Spanification".AsSpan();
```

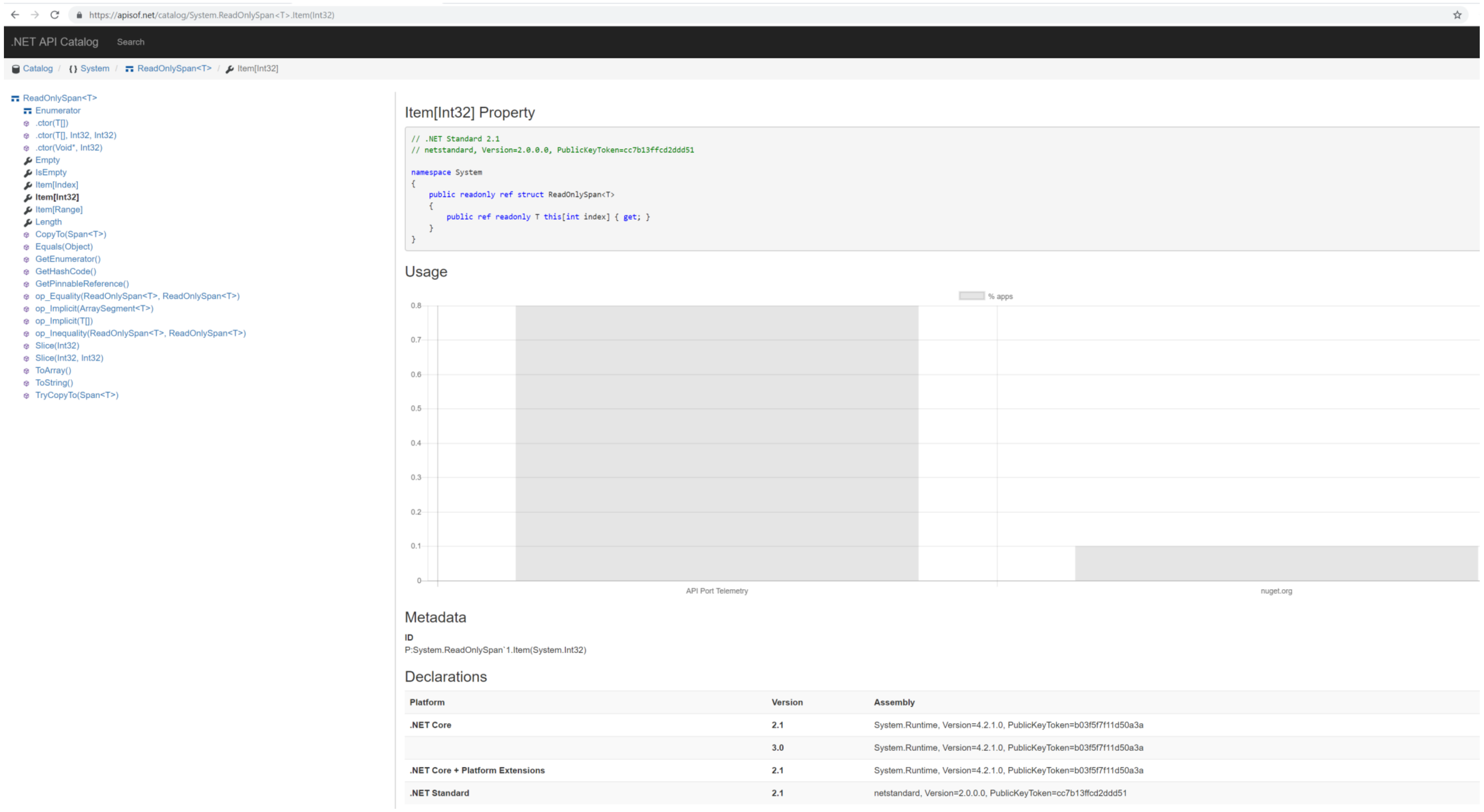
Span<T> API

```
public int Length { get; }
public ref T this[int index] { get; set; }

public Span<T> Slice(int start);
public Span<T> Slice(int start, int length);

public void Clear();
public void Fill(T value);

public void CopyTo(Span<T> destination);
public bool TryCopyTo(Span<T> destination);
```

ReadOnlySpan<T> API

```
public int Length { get; }
public readonly ref T this[int index] { get; }

public ReadOnlySpan<T> Slice(int start);
public ReadOnlySpan<T> Slice(int start, int length);

public void CopyTo(Span<T> destination);
public bool TryCopyTo(Span<T> destination);
```

https://apisof.net



https://apisof.net/catalog/System.ReadOnlySpan<T>.Item(Int32)

.NET API Catalog   Search

Catalog / { } System / ReadOnlySpan<T> / Item[Int32]

- ReadOnlySpan<T>
  - Enumerator
  - .ctor(T[])
  - .ctor(T[], Int32, Int32)
  - .ctor(Void*, Int32)
  - Empty
  - IsEmpty
  - Item[Index]
  - **Item[Int32]**
  - Item[Range]
  - Length
  - CopyTo(Span<T>)
  - Equals(Object)
  - GetEnumerator()
  - GetHashCode()
  - GetPinnableReference()
  - op_Equality(ReadOnlySpan<T>, ReadOnlySpan<T>)
  - op_Implicit(ArraySegment<T>)
  - op_Implicit(T[])
  - op_Inequality(ReadOnlySpan<T>, ReadOnlySpan<T>)
  - Slice(Int32)
  - Slice(Int32, Int32)
  - ToArray()
  - ToString()
  - TryCopyTo(Span<T>)

Item[Int32] Property

```
// .NET Standard 2.1
// netstandard, Version=2.0.0.0, PublicKeyToken=cc7b13ffcd2ddd51

namespace System
{
    public readonly ref struct ReadOnlySpan<T>
    {
        public ref readonly T this[int index] { get; }
    }
}
```

Usage

Metadata

ID
P:System.ReadOnlySpan`1.Item(System.Int32)

Declarations

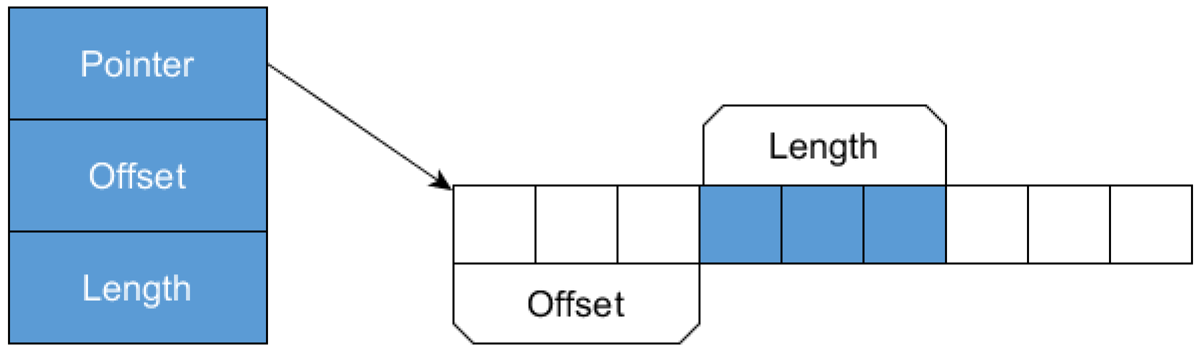
Platform	Version	Assembly
.NET Core	**2.1**	System.Runtime, Version=4.2.1.0, PublicKeyToken=b03f5f7f11d50a3a
	3.0	System.Runtime, Version=4.2.1.0, PublicKeyToken=b03f5f7f11d50a3a
.NET Core + Platform Extensions	**2.1**	System.Runtime, Version=4.2.1.0, PublicKeyToken=b03f5f7f11d50a3a
.NET Standard	**2.1**	netstandard, Version=2.0.0.0, PublicKeyToken=cc7b13ffcd2ddd51

API Simplicity

```
~~int Parse(string text)~~

~~int Parse(string text, int start, int length)~~

~~unsafe int Parse(char* pointer, int length)~~

~~unsafe int Parse(char* pointer, int start, int length)~~

int Parse(Span<char> input)
```

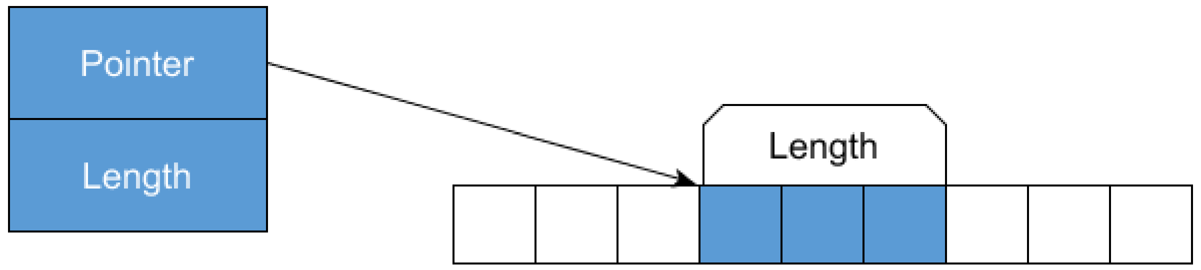
Span for existing runtimes

.NET Standard 1.1 (.NET 4.5.1+)

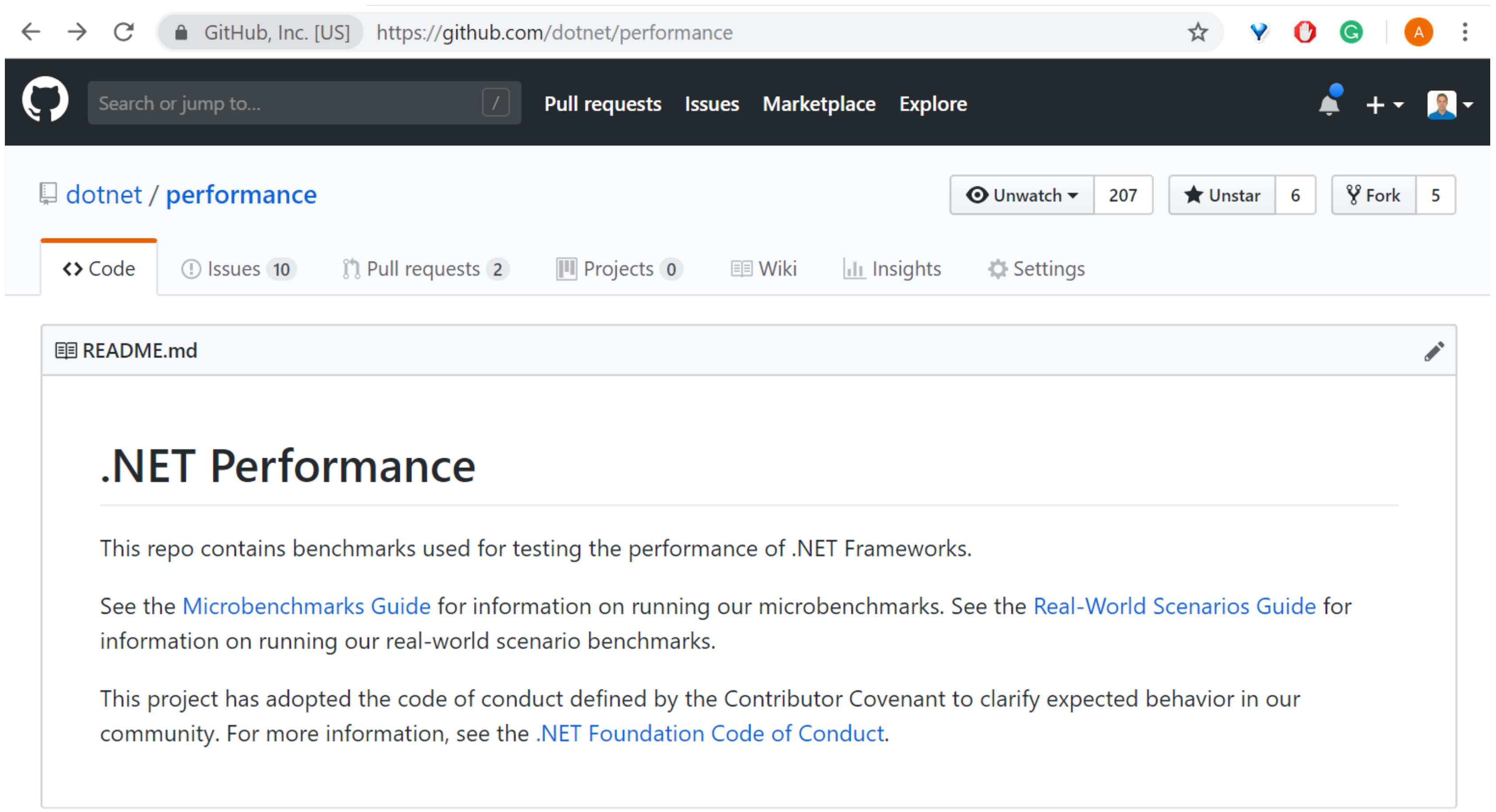


Span for new runtimes

.NET Core 2.0 and any other runtime supporting by-ref fields



https://github.com/dotnet/performance



.NET Performance

This repo contains benchmarks used for testing the performance of .NET Frameworks.

See the Microbenchmarks Guide for information on running our microbenchmarks. See the Real-World Scenarios Guide for information on running our real-world scenario benchmarks.

This project has adopted the code of conduct defined by the Contributor Covenant to clarify expected behavior in our community. For more information, see the .NET Foundation Code of Conduct.

--list flat --allCategories Span

```
Span.IndexerBench.Ref
Span.IndexerBench.Fixed1
Span.IndexerBench.Fixed2
Span.IndexerBench.Indexer1
Span.IndexerBench.Indexer2
Span.IndexerBench.Indexer3
Span.IndexerBench.Indexer4
Span.IndexerBench.Indexer5
Span.IndexerBench.Indexer6
Span.IndexerBench.ReadOnlyIndexer1
Span.IndexerBench.ReadOnlyIndexer2
Span.IndexerBench.WriteViaIndexer1
Span.IndexerBench.WriteViaIndexer2
Span.IndexerBench.KnownSizeArray
Span.IndexerBench.KnownSizeCtor
Span.IndexerBench.KnownSizeCtor2
Span.IndexerBench.SameIndex1
Span.IndexerBench.SameIndex2
Span.IndexerBench.CoveredIndex1
Span.IndexerBench.CoveredIndex2
Span.IndexerBench.CoveredIndex3
Span.Sorting.QuickSortSpan
Span.Sorting.BubbleSortSpan
System.Collections.Clear<Int32>.Span
System.Collections.Clear<String>.Span
System.Collections.CopyTo<Int32>.Span
System.Collections.CopyTo<Int32>.ReadOnlySpan
System.Collections.CopyTo<Int32>.Memory
System.Collections.CopyTo<Int32>.ReadOnlyMemory
System.Collections.CopyTo<String>.Span
System.Collections.CopyTo<String>.ReadOnlySpan
System.Collections.CopyTo<String>.Memory
System.Collections.CopyTo<String>.ReadOnlyMemory
System.Collections.IndexerSet<Int32>.Span
System.Collections.IndexerSet<String>.Span
System.Collections.IndexerSetReverse<Int32>.Span
System.Collections.IndexerSetReverse<String>.Span
System.Collections.IterateFor<Int32>.Span
System.Collections.IterateFor<Int32>.ReadOnlySpan
System.Collections.IterateFor<String>.Span
System.Collections.IterateFor<String>.ReadOnlySpan
System.Collections.IterateForEach<Int32>.Span
System.Collections.IterateForEach<Int32>.ReadOnlySpan
System.Collections.IterateForEach<String>.Span
System.Collections.IterateForEach<String>.ReadOnlySpan
System.Memory.Constructors_ValueTypesOnly<Byte>.SpanFromPointerLength
System.Memory.Constructors_ValueTypesOnly<Byte>.ReadOnlyFromPointerLength
System.Memory.Constructors_ValueTypesOnly<Int32>.SpanFromPointerLength
System.Memory.Constructors_ValueTypesOnly<Int32>.ReadOnlyFromPointerLength
System.Memory.Constructors<Byte>.SpanFromArray
System.Memory.Constructors<Byte>.ReadOnlySpanFromArray
System.Memory.Constructors<Byte>.SpanFromArrayStartLength
System.Memory.Constructors<Byte>.ReadOnlySpanFromArrayStartLength
System.Memory.Constructors<Byte>.SpanFromMemory
System.Memory.Constructors<Byte>.ReadOnlySpanFromMemory
System.Memory.Constructors<Byte>.SpanImplicitCastFromArray
System.Memory.Constructors<Byte>.ReadOnlySpanImplicitCastFromArray
System.Memory.Constructors<Byte>.SpanImplicitCastFromArraySegment
```

```
System.Memory.Constructors<Byte>.ReadOnlySpanImplicitCastFromArraySegment
System.Memory.Constructors<Byte>.ReadOnlySpanImplicitCastFromSpan
System.Memory.Constructors<Byte>.MemoryFromArray
System.Memory.Constructors<Byte>.ReadOnlyMemoryFromArray
System.Memory.Constructors<Byte>.MemoryFromArrayStartLength
System.Memory.Constructors<Byte>.ReadOnlyMemoryFromArrayStartLength
System.Memory.Constructors<Byte>.MemoryMarshalCreateSpan
System.Memory.Constructors<Byte>.MemoryMarshalCreateReadOnlySpan
System.Memory.Constructors<String>.SpanFromArray
System.Memory.Constructors<String>.ReadOnlySpanFromArray
System.Memory.Constructors<String>.SpanFromArrayStartLength
System.Memory.Constructors<String>.ReadOnlySpanFromArrayStartLength
System.Memory.Constructors<String>.SpanFromMemory
System.Memory.Constructors<String>.ReadOnlySpanFromMemory
System.Memory.Constructors<String>.SpanImplicitCastFromArray
System.Memory.Constructors<String>.ReadOnlySpanImplicitCastFromArray
System.Memory.Constructors<String>.SpanImplicitCastFromArraySegment
System.Memory.Constructors<String>.ReadOnlySpanImplicitCastFromArraySegment
System.Memory.Constructors<String>.ReadOnlySpanImplicitCastFromSpan
System.Memory.Constructors<String>.MemoryFromArray
System.Memory.Constructors<String>.ReadOnlyMemoryFromArray
System.Memory.Constructors<String>.MemoryFromArrayStartLength
System.Memory.Constructors<String>.ReadOnlyMemoryFromArrayStartLength
System.Memory.Constructors<String>.MemoryMarshalCreateSpan
System.Memory.Constructors<String>.MemoryMarshalCreateReadOnlySpan
System.Memory.Memory<Byte>.Pin
System.Memory.Memory<Byte>.ToArray
System.Memory.Memory<Char>.Pin
System.Memory.Memory<Char>.ToArray
System.Memory.MemoryMarshal<Byte>.GetReference
System.Memory.MemoryMarshal<Byte>.AsBytes
System.Memory.MemoryMarshal<Byte>.CastToByte
System.Memory.MemoryMarshal<Byte>.CastToInt
System.Memory.MemoryMarshal<Byte>.TryGetArray
System.Memory.MemoryMarshal<Byte>.Read
System.Memory.MemoryMarshal<Int32>.GetReference
System.Memory.MemoryMarshal<Int32>.AsBytes
System.Memory.MemoryMarshal<Int32>.CastToByte
System.Memory.MemoryMarshal<Int32>.CastToInt
System.Memory.MemoryMarshal<Int32>.TryGetArray
System.Memory.MemoryMarshal<Int32>.Read
System.Memory.ReadOnlyMemory<Byte>.Pin
System.Memory.ReadOnlyMemory<Byte>.ToArray
System.Memory.ReadOnlyMemory<Char>.Pin
System.Memory.ReadOnlyMemory<Char>.ToArray
System.Memory.ReadOnlySpan.StringAsSpan
System.Memory.ReadOnlySpan.GetPinnableReference
System.Memory.ReadOnlySpan.IndexOfString
System.Memory.Slice<Byte>.SpanStart
System.Memory.Slice<Byte>.SpanStartLength
System.Memory.Slice<Byte>.ReadOnlySpanStart
System.Memory.Slice<Byte>.ReadOnlySpanStartLength
System.Memory.Slice<Byte>.MemoryStart
System.Memory.Slice<Byte>.MemoryStartLength
System.Memory.Slice<Byte>.ReadOnlyMemoryStart
System.Memory.Slice<Byte>.ReadOnlyMemoryStartLength
System.Memory.Slice<String>.SpanStart
System.Memory.Slice<String>.SpanStartLength
```

```
System.Memory.Slice<String>.ReadOnlySpanStart
System.Memory.Slice<String>.ReadOnlySpanStartLength
System.Memory.Slice<String>.MemoryStart
System.Memory.Slice<String>.MemoryStartLength
System.Memory.Slice<String>.ReadOnlyMemoryStart
System.Memory.Slice<String>.ReadOnlyMemoryStartLength
System.Memory.Span<Byte>.Clear
System.Memory.Span<Byte>.Fill
System.Memory.Span<Byte>.Reverse
System.Memory.Span<Byte>.ToArray
System.Memory.Span<Byte>.SequenceEqual
System.Memory.Span<Byte>.SequenceCompareTo
System.Memory.Span<Byte>.StartsWith
System.Memory.Span<Byte>.EndsWith
System.Memory.Span<Byte>.IndexOfValue
System.Memory.Span<Byte>.LastIndexOfValue
System.Memory.Span<Byte>.LastIndexOfAnyValues
System.Memory.Span<Byte>.BinarySearch
System.Memory.Span<Byte>.GetPinnableReference
System.Memory.Span<Char>.Clear
System.Memory.Span<Char>.Fill
System.Memory.Span<Char>.Reverse
System.Memory.Span<Char>.ToArray
System.Memory.Span<Char>.SequenceEqual
System.Memory.Span<Char>.SequenceCompareTo
System.Memory.Span<Char>.StartsWith
System.Memory.Span<Char>.EndsWith
System.Memory.Span<Char>.IndexOfValue
System.Memory.Span<Char>.LastIndexOfValue
System.Memory.Span<Char>.LastIndexOfAnyValues
System.Memory.Span<Char>.BinarySearch
System.Memory.Span<Char>.GetPinnableReference
System.Memory.Span<Int32>.Clear
System.Memory.Span<Int32>.Fill
System.Memory.Span<Int32>.Reverse
System.Memory.Span<Int32>.ToArray
System.Memory.Span<Int32>.SequenceEqual
System.Memory.Span<Int32>.SequenceCompareTo
System.Memory.Span<Int32>.StartsWith
System.Memory.Span<Int32>.EndsWith
System.Memory.Span<Int32>.IndexOfValue
System.Memory.Span<Int32>.LastIndexOfValue
System.Memory.Span<Int32>.LastIndexOfAnyValues
System.Memory.Span<Int32>.BinarySearch
System.Memory.Span<Int32>.GetPinnableReference
```

„Fast” vs „Slow” Span

```
dotnet run -c Release -f netcoreapp2.1 --filter System.Memory.Span<Char>.Reverse --runtimes net472 netcoreapp2.1
```

Method	Runtime	Size	Mean	Ratio	Allocated Memory/Op
Reverse	Clr	512	**217.8 ns**	**1.00**	-
Reverse	Core	512	**206.4 ns**	**0.95**	-

```
dotnet run -c Release -f netcoreapp2.1 --filter System.Memory.Span<Char>.Clear --runtimes net472 netcoreapp2.1
```

Method	Runtime	Size	Mean	Ratio	Allocated Memory/Op
Clear	Clr	512	**41.16 ns**	**1.00**	-
Clear	Core	512	**17.00 ns**	**0.41**	-

Creating substrings **before Span** (pseudocode)

```
string Substring(string text, int startIndex, int length)
{
    string result = new string(length); // ALLOCATION!

    Memory.Copy(text, result, startIndex, length); // COPYING

    return result;
}
```

Creating substrings **without allocation**! (pseudocode)

```
ReadOnlySpan<char> Slice(string text, int startIndex, int length)
    => new ReadOnlySpan<char>(

            ref text[0] + (startIndex * sizeof(char)),

            length);
```

Substring vs Slice: Benchmark

```
public class Slicing
{
    public IEnumerable<object> Arguments()
    {
        yield return "Substring vs Slice";
        yield return string.Join(", ", Enumerable.Repeat("Substring vs Slice", 1000));
    }

    [Benchmark(Baseline = true)]
    [ArgumentsSource(nameof(Arguments))]
    public string Substring(string text) => text.Substring(startIndex: text.Length / 2);

    [Benchmark]
    [ArgumentsSource(nameof(Arguments))]
    public ReadOnlySpan<char> Slice(string text) => text.AsSpan().Slice(start: text.Length / 2);
}
```

Substring vs Slice: Benchmark results

Method	text	Mean	StdDev	Ratio	Gen 0 /1k Op	Gen 1 /1k Op	Allocated Memory
Substring	Substring vs Slice	10.860 ns	0.0981 ns	1.00	0.0076	-	48 B
Slice	Substring vs Slice	1.151 ns	0.0151 ns	0.11	-	-	-

Substring vs Slice: Benchmark results

Method	text	Mean	StdDev	Ratio	Gen 0 /1k Op	Gen 1 /1k Op	Allocated Memory
Substring	Substring vs Slice	10.860 ns	0.0981 ns	1.00	0.0076	-	48 B
Slice	Substring vs Slice	1.151 ns	0.0151 ns	0.11	-	-	-
Substring	Substring vs Slice x1000	1,703.534 ns	8.8209 ns	1.000	3.1815	0.1984	20024 B
Slice	Substring vs Slice x1000	1.145 ns	0.0135 ns	0.001	-	-	-

Slice is O(1)

Method	text	Mean	StdDev	Ratio	Gen 0 /1k Op	Gen 1 /1k Op	Allocated Memory
Substring	Substring vs Slice	10.860 ns	0.0981 ns	1.00	0.0076	-	48 B
Slice	Substring vs Slice	**1.151 ns**	**0.0151 ns**	0.11	**-**	**-**	**-**
Substring	Substring vs Slice x1000	1,703.534 ns	8.8209 ns	1.000	3.1815	0.1984	20024 B
Slice	Substring vs Slice x1000	**1.145 ns**	**0.0135 ns**	0.001	**-**	**-**	**-**

Summary: Span basics

- Span<T> allows working with any kind of memory
- ReadOnlySpan<T> allows for read-only access
- Memory and type safe
- System.Memory package, C# 7.2
- .NET Standard implementation is fast, .NET Core is very fast
- Slice is O(1)

Let’s parse a Utf8 line of floats..

```
[Benchmark(Baseline = true)]
public float OldWay()
{
    float result = 0;

    string line = Encoding.UTF8.GetString(utf8line);

    string[] splitted = line.Split(' ', '\t’);

    foreach (string toParse in splitted)
        if (float.TryParse(toParse, out float parsed))
            result += parsed;

    return result;
}
```

Let’s Spanify it!

```
[Benchmark]
public float NewWay()
{
    float result = 0;

    ReadOnlySpan<byte> toParse = new ReadOnlySpan<byte>(utf8line);
    while (!toParse.IsEmpty)
    {
        if (!Utf8Parser.TryParse(toParse, out float parsed, out int bytesConsumed))
            break;

        result += parsed;
        toParse = toParse.Slice(start: bytesConsumed + 1); // 1 is for ' '
    }

    return result;
}
```

18% boost, no allocations

Method	Count	Mean	Ratio	Gen 0/1k Op	Allocated Memory
OldWay	100	15.74 us	1.00	3.5706	7496 B
NewWay	100	12.67 us	0.81	-	-
OldWay	1000	153.90 us	1.00	35.1563	74096 B
NewWay	1000	126.33 us	0.82	-	-

Utf8Parser

```
class Utf8Parser
{
    bool TryParse(ReadOnlySpan<byte> source, out bool value, out int bytesConsumed, char standardFormat = '\0’)
    bool TryParse(ReadOnlySpan<byte> source, out byte value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out DateTime value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out DateTimeOffset value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out decimal value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out double value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out System.Guid value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out short value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out int value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out long value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out sbyte value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out float value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out TimeSpan value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out ushort value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out uint value, out int bytesConsumed, char standardFormat = '\0')
    bool TryParse(ReadOnlySpan<byte> source, out ulong value, out int bytesConsumed, char standardFormat = '\0')
}
```

Utf8Formatter

```
class Utf8Formatter
{
    bool TryFormat(bool value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(byte value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(DateTime value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(DateTimeOffset value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(decimal value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(double value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(Guid value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(short value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(int value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(long value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(sbyte value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(float value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(TimeSpan value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(ushort value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(uint value, Span<byte> destination, out int bytesWritten, StandardFormat format)
    bool TryFormat(ulong value, Span<byte> destination, out int bytesWritten, StandardFormat format)
}
```

Let’s parse 6.5GB ML file line by line

```
[Benchmark(Baseline = true)]
public float OldWay()
{
    float result = 0;

    foreach (var line in File.ReadLines(FilePath))
    {
        string[] splitted = line.Split(' ');
        foreach (string toParse in splitted)
            if (float.TryParse(toParse, out float parsed))
                result += parsed;
    }

    return result;
}
```

Let’s Spanify it!

```
using (var fileStream = new FileStream(FilePath, FileMode.Open, FileAccess.Read))
{


















}
```

Let’s Spanify it!

```
using (var fileStream = new FileStream(FilePath, FileMode.Open, FileAccess.Read))
{
    byte[] buffer = new byte[16000 * 8]; // 128 KB
    int bytesRead = 0;

    while ((bytesRead = fileStream.Read(buffer, 0, buffer.Length)) > 0)
    {













    }
}
```

Let’s Spanify it!

```
using (var fileStream = new FileStream(FilePath, FileMode.Open, FileAccess.Read))
{
    byte[] buffer = new byte[16000 * 8]; // 128 KB
    int bytesRead = 0;

    while ((bytesRead = fileStream.Read(buffer, 0, buffer.Length)) > 0)
    {
        var slice = new ReadOnlySpan<byte>(buffer, start: 0, length: bytesRead); // bytesRead != buffer.Length

        int newLineLength = 0;
        while ((newLineLength = slice.IndexOf((byte)0x0A)) > 0) // 0x0A = new line
        {




        }


    }
}
```

Let’s Spanify it!

```
using (var fileStream = new FileStream(FilePath, FileMode.Open, FileAccess.Read))
{
    byte[] buffer = new byte[16000 * 8]; // 128 KB
    int bytesRead = 0;

    while ((bytesRead = fileStream.Read(buffer, 0, buffer.Length)) > 0)
    {
        var slice = new ReadOnlySpan<byte>(buffer, start: 0, length: bytesRead); // bytesRead != buffer.Length

        int newLineLength = 0;
        while ((newLineLength = slice.IndexOf((byte)0x0A)) > 0) // 0x0A = new line
        {
            ReadOnlySpan<byte> utf8Line = slice.Slice(0, newLineLength);

            result += Parse(utf8Line);

            slice = slice.Slice(start: newLineLength + 1);
        }


    }
}
```

Let’s Spanify it!

```
using (var fileStream = new FileStream(FilePath, FileMode.Open, FileAccess.Read))
{
    byte[] buffer = new byte[16000 * 8]; // 128 KB
    int bytesRead = 0;

    while ((bytesRead = fileStream.Read(buffer, 0, buffer.Length)) > 0)
    {
        var slice = new ReadOnlySpan<byte>(buffer, start: 0, length: bytesRead); // bytesRead != buffer.Length

        int newLineLength = 0;
        while ((newLineLength = slice.IndexOf((byte)0x0A)) > 0) // 0x0A = new line
        {
            ReadOnlySpan<byte> utf8Line = slice.Slice(0, newLineLength);

            result += Parse(utf8Line);

            slice = slice.Slice(start: newLineLength + 1);
        }

        fileStream.Seek(-1 * slice.Length, SeekOrigin.Current); // we go back where the last line started
    }
}
```

The difference

Method	Mean	Ratio	Gen 0/Op	Gen 1/Op	Gen 2/1 Op	Allocated Memory
OldWay	138.9 s	1.00	11562	636	1	72 760 971 232 B
NewWay	104.3 s	0.75	-	-	-	128 200 B

72760971232 B - 128200 B = 72.76 GB

MemoryExtensions

AsMemory
AsSpan
BinarySearch
CompareTo
Contains
CopyTo
EndsWith
Equals
IndexOf
IndexOfAny
IsWhiteSpace
LastIndexOf
LastIndexOfAny
Overlaps
Reverse
SequenceCompareTo
SequenceEqual
StartsWith
ToLower
ToLowerInvariant
ToUpper
ToUpperInvariant
Trim
TrimEnd
TrimStart

dotnet/corefx/src/System.Memory/ref/System.Memory.cs

What can be improved here?

```
using (var fileStream = new FileStream(FilePath, FileMode.Open, FileAccess.Read))
{
    byte[] buffer = new byte[16000 * 8]; // 128 KB
    int bytesRead = 0;

    while ((bytesRead = fileStream.Read(buffer, 0, buffer.Length)) > 0)
    {
        var slice = new ReadOnlySpan<byte>(buffer, start: 0, length: bytesRead); // bytesRead != buffer.Length

        int newLineLength = 0;
        while ((newLineLength = slice.IndexOf((byte)0x0A)) > 0) // 0x0A = new line
        {
            ReadOnlySpan<byte> utf8Line = slice.Slice(0, newLineLength);

            result += Parse(utf8Line);

            slice = slice.Slice(start: newLineLength + 1);
        }

        fileStream.Seek(-1 * slice.Length, SeekOrigin.Current); // we go back where the last line started
    }
}
```

ArrayPool

```
using (var fileStream = new FileStream(FilePath, FileMode.Open, FileAccess.Read))
{
    ArrayPool<byte> pool = ArrayPool<byte>.Shared;
    byte[] buffer = pool.Rent(16000 * 8); // 128 KB

    try
    {
        // (...)
    }
    finally
    {
        pool.Return(buffer);
    }
}
```

Parsing 6.5 GB file allocating just 176 B

Method	Mean	Ratio	Gen 0/Op	Gen 1/Op	Gen 2/1 Op	Allocated Memory
OldWay	138.9 s	1.00	11562	636	1	72 760 971 232 B
NewWay	104.3 s	0.75	-	-	-	128 200 B
NewWayPool	104.2 s	0.75	-	-	-	176 B

Async

```
public float NewWayArrayPool()
{
    // (...)
    while ((bytesRead = fileStream.Read(buffer, 0, buffer.Length)) > 0)


public async Task<float> NewWayArrayPoolAsync()
{
    // (...)
    while ((bytesRead = await fileStream.ReadAsync(buffer, 0, buffer.Length)) > 0)
```

error CS4012: Parameters or locals of type 'ReadOnlySpan<byte>' cannot be declared in async methods or lambda expressions.

Span<T> is a Stack Only type (ref struct)

- Why:
  - Span<T> can point to stack-allocated memory
  - When the method ends or throws everything that was allocated on the stack is destroyed
- Advantages:
  - Safe Concurrency – only one thread has access at the same time (no Struct Tearing)
  - Short lifetime - fewer interior pointers for GC to track

Stack Only: Must not be stored on a heap

```
class SomeClass
{
    StackOnly<byte> field;
}


async Task Method(StackOnly<byte> bytes)
```

Memory<T>

```
public readonly struct Memory<T>
{
    private readonly object _object; // String, Array or OwnedMemory
    private readonly int _index;
    private readonly int _length;

    public Span<T> Span { get; }

    public Memory<T> Slice(int start)
    public Memory<T> Slice(int start, int length)

    public MemoryHandle Pin()
}
```

Pass Memory from async to sync to get Span

```
public async Task<float> NewWayArrayPoolAsync()
{
    using (var fileStream = new FileStream(FilePath, FileMode.Open, FileAccess.Read))
    {
        byte[] buffer = ArrayPool<byte>.Shared.Rent(16000 * 8); // 128 KB

        while ((bytesRead = await fileStream.ReadAsync(buffer, 0, buffer.Length)) > 0)
        {
            ParseBlock(new ReadOnlyMemory<byte>(buffer, start: 0, length: bytesRead), fileStream, ref result);
        }

        ArrayPool<byte>.Shared.Return(buffer);
    }
}

private void ParseBlock(ReadOnlyMemory<byte> memory, FileStream fileStream, ref float result)
{
    ReadOnlySpan<byte> slice = memory.Span;

    // using Span from here
```

Parsing 6.5 GB in asynchronous way

Method	Mean	Ratio	Gen 0/Op	Gen 1/Op	Gen 2/1 Op	Allocated Memory
OldWay	138.9 s	1.00	11562	636	1	72 760 971 232 B
NewWay	104.3 s	0.75	-	-	-	128 200 B
NewWayPool	104.2 s	0.75	-	-	-	176 B
NewWayPoolAsync	107.5 s	0.77	-	-	-	131 848 B

Generic Parser

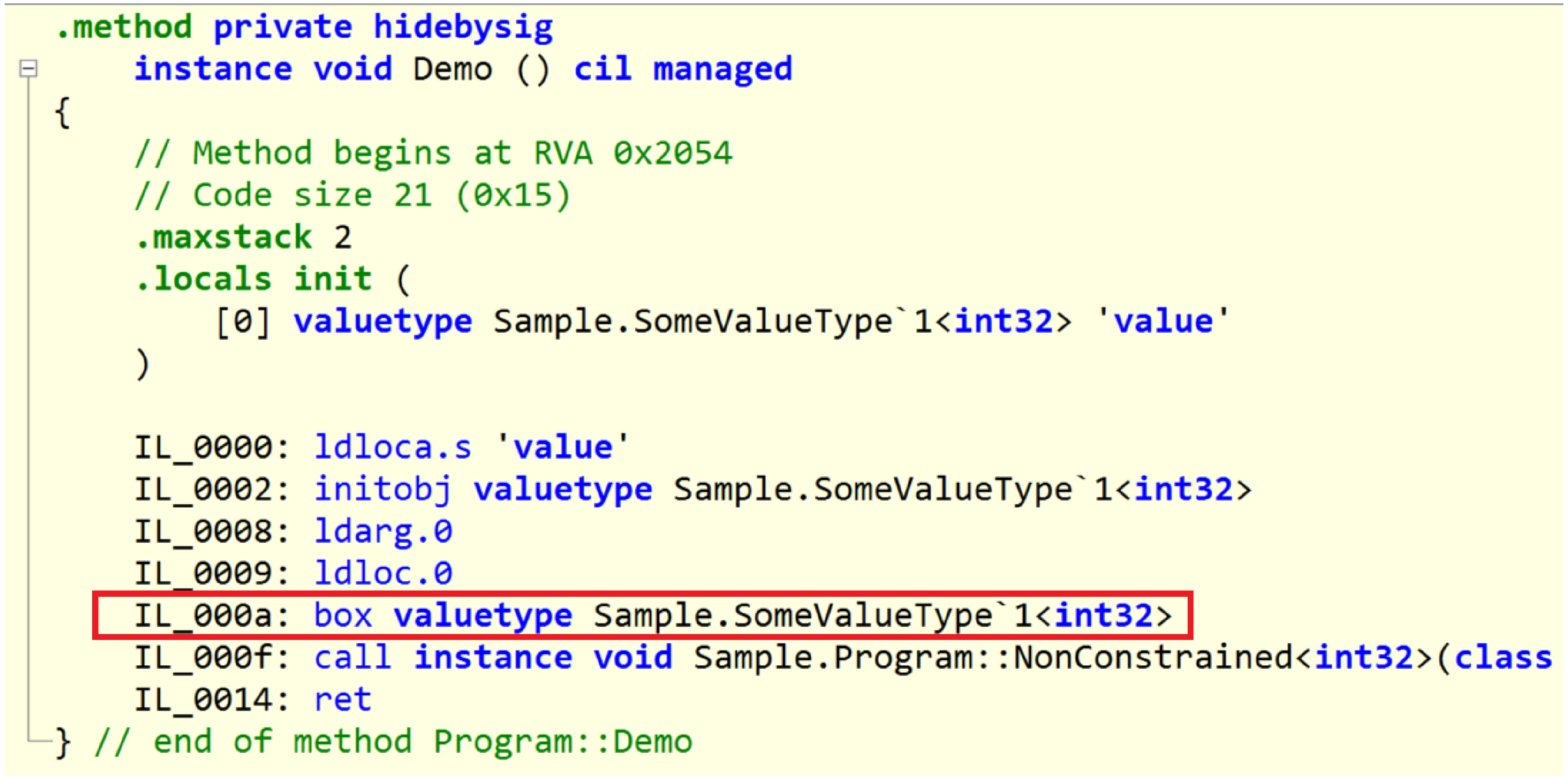
```
public List<T> ParseFile<T>(string path, Func<ReadOnlySpan<byte>, T> lineParser)
{
    // (...)
    ReadOnlySpan<byte> utf8Line = slice.Slice(0, newLineLength);

    list.Add(lineParser(utf8Line));
```

```
error CS0306: The type 'ReadOnlySpan<byte>' may not be used as a type argument
```

Stack Only: No Heap Limitations

```
struct SomeValueType<T> : IEnumerable<T> { }

void NonConstrained<T>(IEnumerable<T> collection)

void Demo()
{
    var value = new SomeValueType<int>();
    NonConstrained(value);
}
```

Boxing == Heap. Heap != Stack



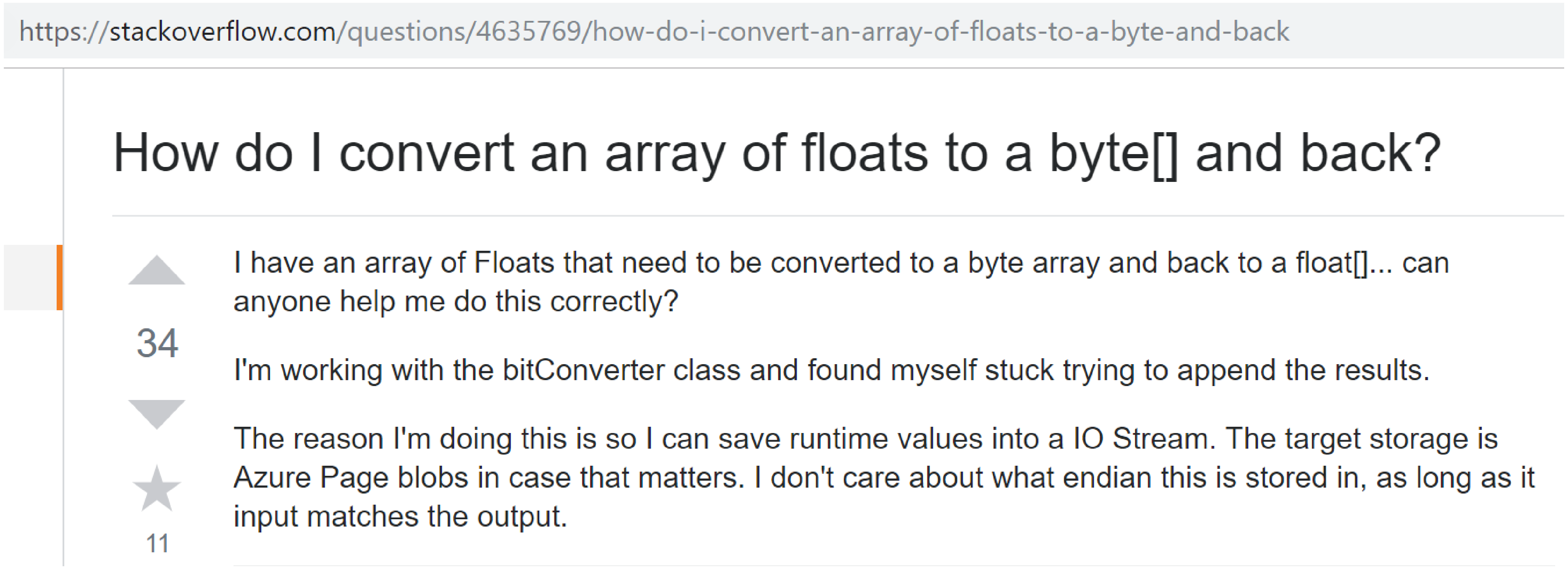
```
.method private hidebysig
    instance void Demo () cil managed
{
    // Method begins at RVA 0x2054
    // Code size 21 (0x15)
    .maxstack 2
    .locals init (
        [0] valuetype Sample.SomeValueType`1<int32> 'value'
    )

    IL_0000: ldloca.s 'value'
    IL_0002: initobj valuetype Sample.SomeValueType`1<int32>
    IL_0008: ldarg.0
    IL_0009: ldloc.0
    IL_000a: box valuetype Sample.SomeValueType`1<int32>
    IL_000f: call instance void Sample.Program::NonConstrained<int32>(class
    IL_0014: ret
} // end of method Program::Demo
```

What Func and Action are?

```
namespace System
{
    public delegate void Action();
    public delegate void Action<in T>(T obj);
    public delegate void Action<in T1, in T2>(T1 arg1, T2 arg2);
    public delegate void Action<in T1, in T2, in T3>(T1 arg1, T2 arg2, T3 arg3);
    public delegate void Action<in T1, in T2, in T3, in T4>(T1 arg1, T2 arg2, T3 arg3, T4 arg4);
    public delegate void Action<in T1, in T2, in T3, in T4, in T5>(T1 arg1, T2 arg2, T3 arg3, T4 arg4, T5 arg5);
    public delegate void Action<in T1, in T2, in T3, in T4, in T5, in T6>(T1 arg1, T2 arg2, T3 arg3, T4 arg4, T5 arg5, T6 arg6);
    public delegate void Action<in T1, in T2, in T3, in T4, in T5, in T6, in T7>(T1 arg1, T2 arg2, T3 arg3, T4 arg4, T5 arg5, T6 arg6, T7 arg7);
    public delegate void Action<in T1, in T2, in T3, in T4, in T5, in T6, in T7, in T8>(T1 arg1, T2 arg2, T3 arg3, T4 arg4, T5 arg5, T6 arg6, T7 arg7, T8 arg8);

    public delegate TResult Func<out TResult>();
    public delegate TResult Func<in T, out TResult>(T arg);
    public delegate TResult Func<in T1, in T2, out TResult>(T1 arg1, T2 arg2);
    public delegate TResult Func<in T1, in T2, in T3, out TResult>(T1 arg1, T2 arg2, T3 arg3);
    public delegate TResult Func<in T1, in T2, in T3, in T4, out TResult>(T1 arg1, T2 arg2, T3 arg3, T4 arg4);
    public delegate TResult Func<in T1, in T2, in T3, in T4, in T5, out TResult>(T1 arg1, T2 arg2, T3 arg3, T4 arg4, T5 arg5);
    public delegate TResult Func<in T1, in T2, in T3, in T4, in T5, in T6, out TResult>(T1 arg1, T2 arg2, T3 arg3, T4 arg4, T5 arg5, T6 arg6);
    public delegate TResult Func<in T1, in T2, in T3, in T4, in T5, in T6, in T7, out TResult>(T1 arg1, T2 arg2, T3 arg3, T4 arg4, T5 arg5, T6 arg6, T7 arg7);
    public delegate TResult Func<in T1, in T2, in T3, in T4, in T5, in T6, in T7, in T8, out TResult>(T1 arg1, T2 arg2, T3 arg3, T4 arg4, T5 arg5, T6 arg6, T7 arg7, T8 arg8);

    public delegate int Comparison<in T>(T x, T y);

    public delegate TOutput Converter<in TInput, out TOutput>(TInput input);

    public delegate bool Predicate<in T>(T obj);
}
```

Generic Parser

```
public delegate T ParsingFunc<T>(ReadOnlySpan<byte> input);

public List<T> ParseFile<T>(string path, ParsingFunc<T> lineParser)
{
    // (...)
    ReadOnlySpan<byte> utf8Line = slice.Slice(0, newLineLength);

    list.Add(lineParser(utf8Line));
```


https://stackoverflow.com/questions/4635769/how-do-i-convert-an-array-of-floats-to-a-byte-and-back

How do I convert an array of floats to a byte[] and back?

34

11

I have an array of Floats that need to be converted to a byte array and back to a float[]... can anyone help me do this correctly?

I'm working with the bitConverter class and found myself stuck trying to append the results.

The reason I'm doing this is so I can save runtime values into a IO Stream. The target storage is Azure Page blobs in case that matters. I don't care about what endian this is stored in, as long as it input matches the output.

MemoryMarshal.Cast

```
private float[] arrayOfFloats;
// (...) setup

[Benchmark(Baseline = true)]
public byte[] OldWay()
{
    var byteArray = new byte[arrayOfFloats.Length * 4];

    Buffer.BlockCopy(arrayOfFloats, 0, byteArray, 0, byteArray.Length);

    return byteArray;
}

[Benchmark]
public Span<byte> NewWay() => MemoryMarshal.Cast<float, byte>(arrayOfFloats);
```

MemoryMarshal.Cast is O(1)

Method	**Count**	**Mean**	**Ratio**	**Gen 0/1k Op**	**Allocated Memory/Op**
OldWay	4	13.2849 ns	1.00	0.0190	40 B
NewWay	4	0.6356 ns	0.05	-	-
OldWay	1000	311.4184 ns	1.000	1.9155	4024 B
NewWay	1000	0.6123 ns	0.002	-	-

MemoryMarshal.Read is also O(1)

```
[StructLayout(LayoutKind.Explicit)]
public struct Bid
{
    [FieldOffset(0)]
    public float Value;

    [FieldOffset(4)]
    public long ProductId;

    [FieldOffset(12)]
    public long UserId;

    [FieldOffset(20)]
    public DateTime Time;
}

public class BinaryRead
{
    public Bid Deserialize(ReadOnlySpan<byte> serialized) => MemoryMarshal.Read<Bid>(serialized);
}
```

MemoryMarshal API

```
class MemoryMarshal
{
    ReadOnlySpan<byte> AsBytes<T>(ReadOnlySpan<T> span) where T : struct
    Span<byte> AsBytes<T>(Span<T> span) where T : struct
    Memory<T> AsMemory<T>(ReadOnlyMemory<T> memory)
    ref readonly T AsRef<T>(ReadOnlySpan<byte> span) where T : struct
    ref T AsRef<T>(Span<byte> span) where T : struct
    ReadOnlySpan<TTo> Cast<TFrom, TTo>(ReadOnlySpan<TFrom> span) where TFrom : struct where TTo : struct
    Span<TTo> Cast<TFrom, TTo>(Span<TFrom> span) where TFrom : struct where TTo : struct
    Memory<T> CreateFromPinnedArray<T>(T[] array, int start, int length)
    ReadOnlySpan<T> CreateReadOnlySpan<T>(ref T reference, int length)
    Span<T> CreateSpan<T>(ref T reference, int length)
    ref T GetReference<T>(ReadOnlySpan<T> span)
    ref T GetReference<T>(Span<T> span)
    T Read<T>(ReadOnlySpan<byte> source) where T : struct
    IEnumerable<T> ToEnumerable<T>(ReadOnlyMemory<T> memory)
    bool TryGetArray<T>(ReadOnlyMemory<T> memory, out ArraySegment<T> segment)
    bool TryGetMemoryManager<T, TManager>(ReadOnlyMemory<T> memory, out TManager manager)
    bool TryGetString(ReadOnlyMemory<char> memory, out string text, out int start, out int length)
    bool TryRead<T>(ReadOnlySpan<byte> source, out T value) where T : struct
    bool TryWrite<T>(Span<byte> destination, ref T value) where T : struct
    void Write<T>(Span<byte> destination, ref T value) where T : struct
}
```

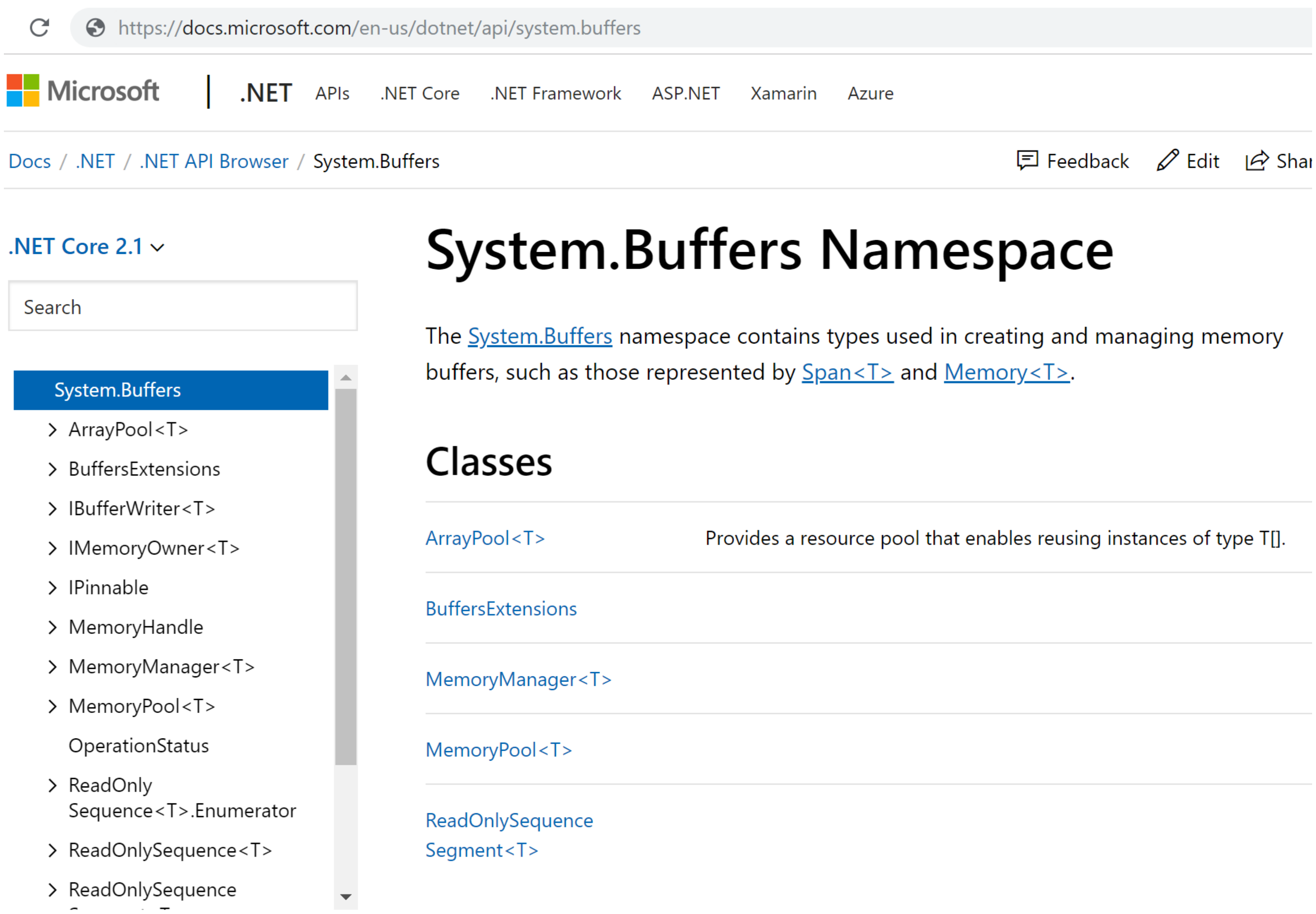
BinaryPrimitives

```
private byte[] output;
private int position;

public void WriteInt64BigEndian(long value)
{
    EnsureSize(sizeof(long));
    BinaryPrimitives.WriteInt64BigEndian(output.AsSpan(position, sizeof(long)), value);
    position += sizeof(long);
}
```

System.Buffers.BinaryPrimitives API

```
short ReadInt16BigEndian(ReadOnlySpan<byte> source);
short ReadInt16LittleEndian(ReadOnlySpan<byte> source);
int ReadInt32BigEndian(ReadOnlySpan<byte> source);
int ReadInt32LittleEndian(ReadOnlySpan<byte> source);
long ReadInt64BigEndian(ReadOnlySpan<byte> source);
long ReadInt64LittleEndian(ReadOnlySpan<byte> source);
ushort ReadUInt16BigEndian(ReadOnlySpan<byte> source);
ushort ReadUInt16LittleEndian(ReadOnlySpan<byte> source);
uint ReadUInt32BigEndian(ReadOnlySpan<byte> source);
uint ReadUInt32LittleEndian(ReadOnlySpan<byte> source);
ulong ReadUInt64BigEndian(ReadOnlySpan<byte> source);
ulong ReadUInt64LittleEndian(ReadOnlySpan<byte> source);
ulong ReverseEndianness(ulong value);
ushort ReverseEndianness(ushort value);
byte ReverseEndianness(byte value);
long ReverseEndianness(long value);
int ReverseEndianness(int value);
short ReverseEndianness(short value);
uint ReverseEndianness(uint value);
sbyte ReverseEndianness(sbyte value);
bool TryReadInt16BigEndian(ReadOnlySpan<byte> source, out short value);
bool TryReadInt16LittleEndian(ReadOnlySpan<byte> source, out short value);
bool TryReadInt32BigEndian(ReadOnlySpan<byte> source, out int value);
bool TryReadInt32LittleEndian(ReadOnlySpan<byte> source, out int value);
bool TryReadInt64BigEndian(ReadOnlySpan<byte> source, out long value);
bool TryReadInt64LittleEndian(ReadOnlySpan<byte> source, out long value);
bool TryReadUInt16BigEndian(ReadOnlySpan<byte> source, out ushort value);
bool TryReadUInt16LittleEndian(ReadOnlySpan<byte> source, out ushort value);
bool TryReadUInt32BigEndian(ReadOnlySpan<byte> source, out uint value);
bool TryReadUInt32LittleEndian(ReadOnlySpan<byte> source, out uint value);
bool TryReadUInt64BigEndian(ReadOnlySpan<byte> source, out ulong value);
bool TryReadUInt64LittleEndian(ReadOnlySpan<byte> source, out ulong value);
```

```
bool TryWriteInt16BigEndian(Span<byte> destination, short value);
bool TryWriteInt16LittleEndian(Span<byte> destination, short value);
bool TryWriteInt32BigEndian(Span<byte> destination, int value);
bool TryWriteInt32LittleEndian(Span<byte> destination, int value);
bool TryWriteInt64BigEndian(Span<byte> destination, long value);
bool TryWriteInt64LittleEndian(Span<byte> destination, long value);
bool TryWriteUInt16BigEndian(Span<byte> destination, ushort value);
bool TryWriteUInt16LittleEndian(Span<byte> destination, ushort value);
bool TryWriteUInt32BigEndian(Span<byte> destination, uint value);
bool TryWriteUInt32LittleEndian(Span<byte> destination, uint value);
bool TryWriteUInt64BigEndian(Span<byte> destination, ulong value);
bool TryWriteUInt64LittleEndian(Span<byte> destination, ulong value);
void WriteInt16BigEndian(Span<byte> destination, short value);
void WriteInt16LittleEndian(Span<byte> destination, short value);
void WriteInt32BigEndian(Span<byte> destination, int value);
void WriteInt32LittleEndian(Span<byte> destination, int value);
void WriteInt64BigEndian(Span<byte> destination, long value);
void WriteInt64LittleEndian(Span<byte> destination, long value);
void WriteUInt16BigEndian(Span<byte> destination, ushort value);
void WriteUInt16LittleEndian(Span<byte> destination, ushort value);
void WriteUInt32BigEndian(Span<byte> destination, uint value);
void WriteUInt32LittleEndian(Span<byte> destination, uint value);
void WriteUInt64BigEndian(Span<byte> destination, ulong value);
void WriteUInt64LittleEndian(Span<byte> destination, ulong value);
```


https://docs.microsoft.com/en-us/dotnet/api/system.buffers

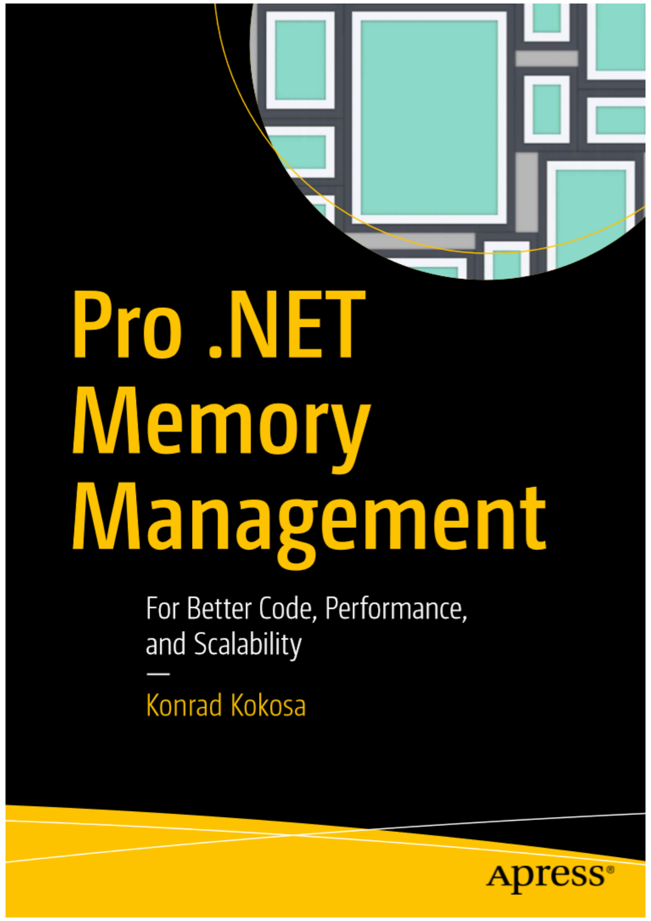
System.Buffers Namespace

The System.Buffers namespace contains types used in creating and managing memory buffers, such as those represented by Span<T> and Memory<T>.

Classes

ArrayPool<T>	Provides a resource pool that enables reusing instances of type T[].
BuffersExtensions	
MemoryManager<T>	
MemoryPool<T>	
ReadOnlySequence Segment<T>	

Chapter XIV: Advanced Techniques


Pro .NET Memory Management
For Better Code, Performance, and Scalability
Konrad Kokosa
Apress

Summary

- Span<T> makes it easy and safe to use any kind of memory
- System.Memory package, C# 7.2
- Memory<T> has no stack-only limitations
- Don’t copy memory! Slice it!
- Use Utf8Parser and Utf8Formatter when working with UTF8
- Prefer read-only versions over mutable ones
- Prefer safe managed memory over native memory

Questions?

Thank you!