Reading and Writing Data Incrementally Using Streams

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Overview

- An introduction to streams
- The benefits of streams
- .NET class hierarchy overview
- Using streams to read and write text
- Selectively processing part of stream
- Using streams to read and write binary data
- Using BinaryReader and BinaryWriter
- Specifying text encodings
- Using streams to append data
- Random FileStream access
- MemoryStream overview

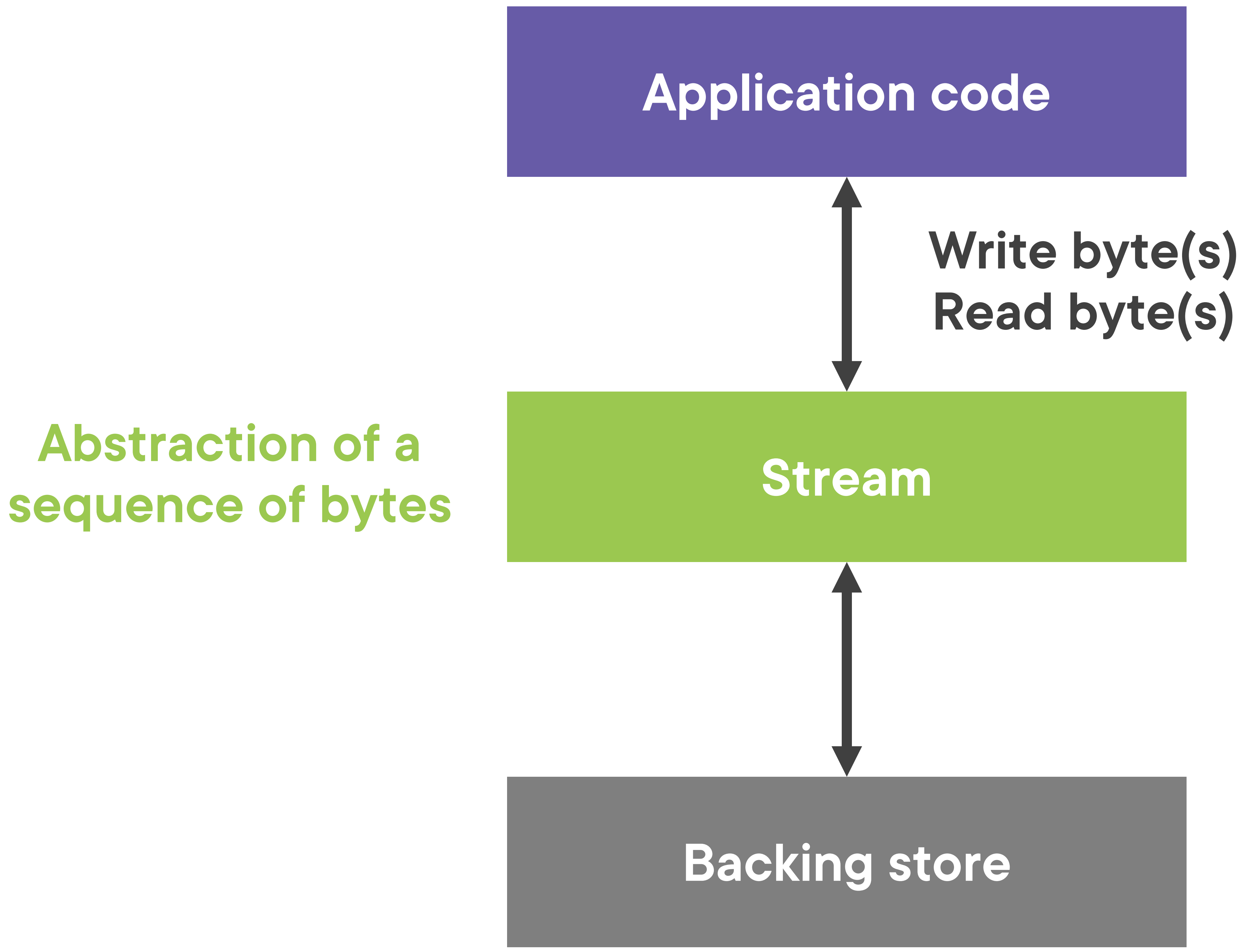
An Introduction to Streams

"…a stream is a sequence of bytes that you can use to read from and write to a backing store, which can be one of several storage mediums"

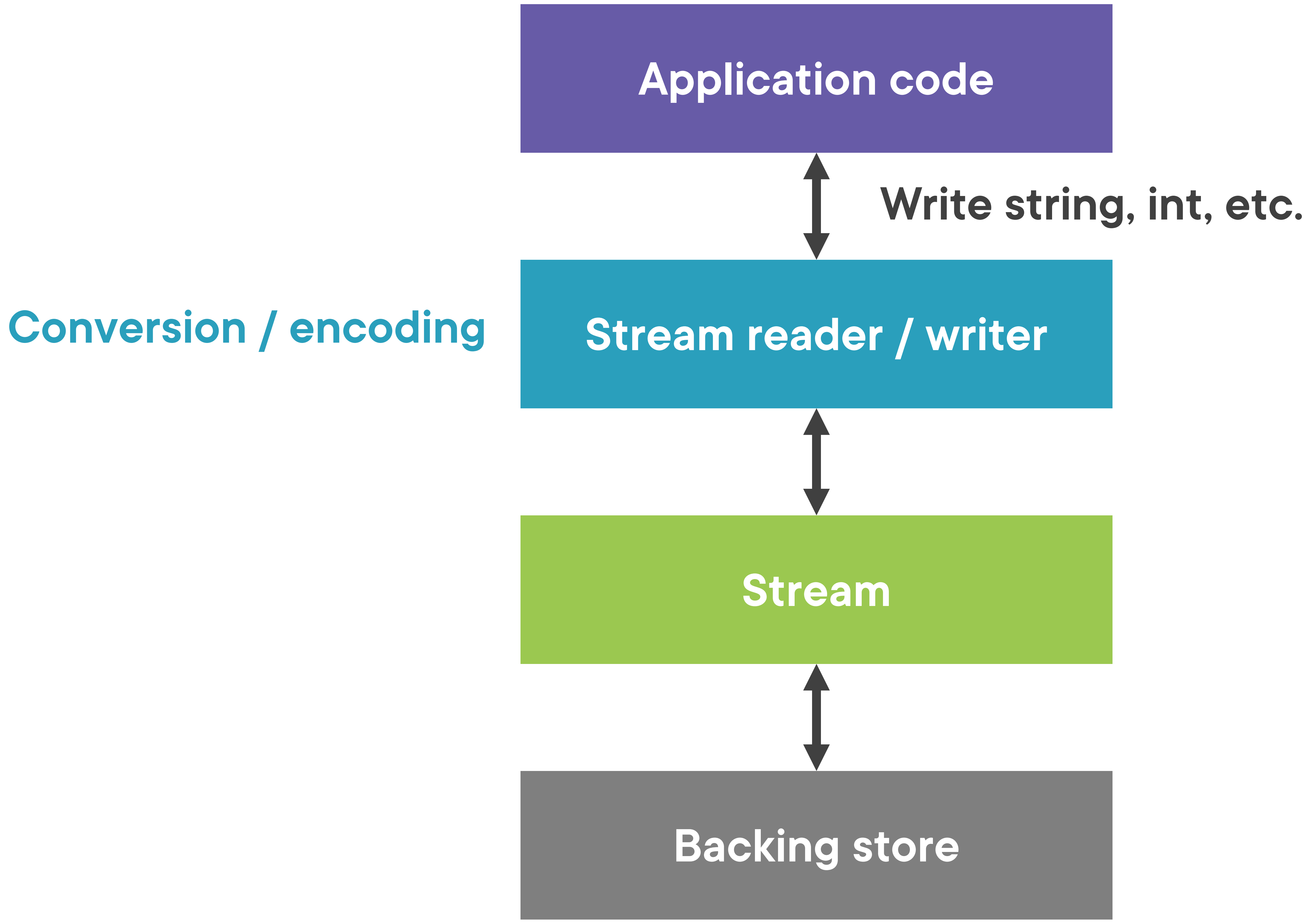
Microsoft Documentation

https://docs.microsoft.com/en-us/dotnet/standard/io/

An Introduction to Streams



An Introduction to Streams



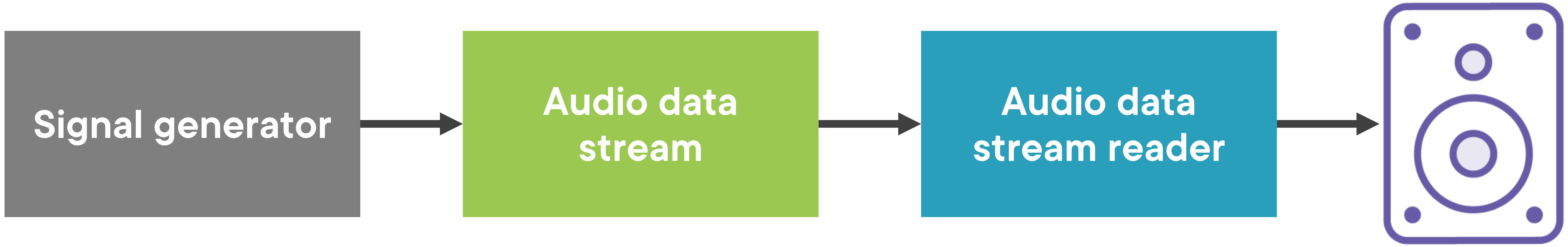
Examples of Backing Stores

Files

Input/output device/hardware

TCP/IP sockets

Non-Backing Store Streams



https://github.com/naudio/NAudio

The Benefits of Streams

Incremental data processing

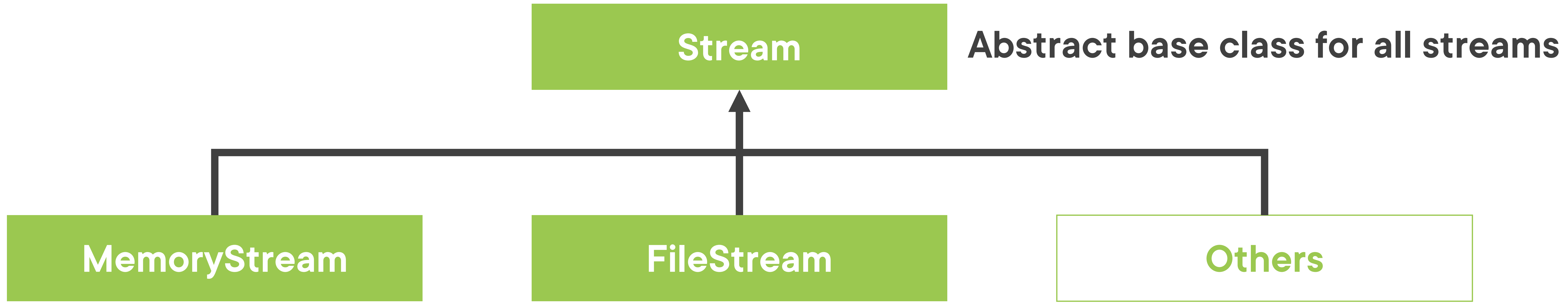
Abstraction of backing store

Flexibility / control

Random access / seeking

Composability / pipelines

Stream Classes

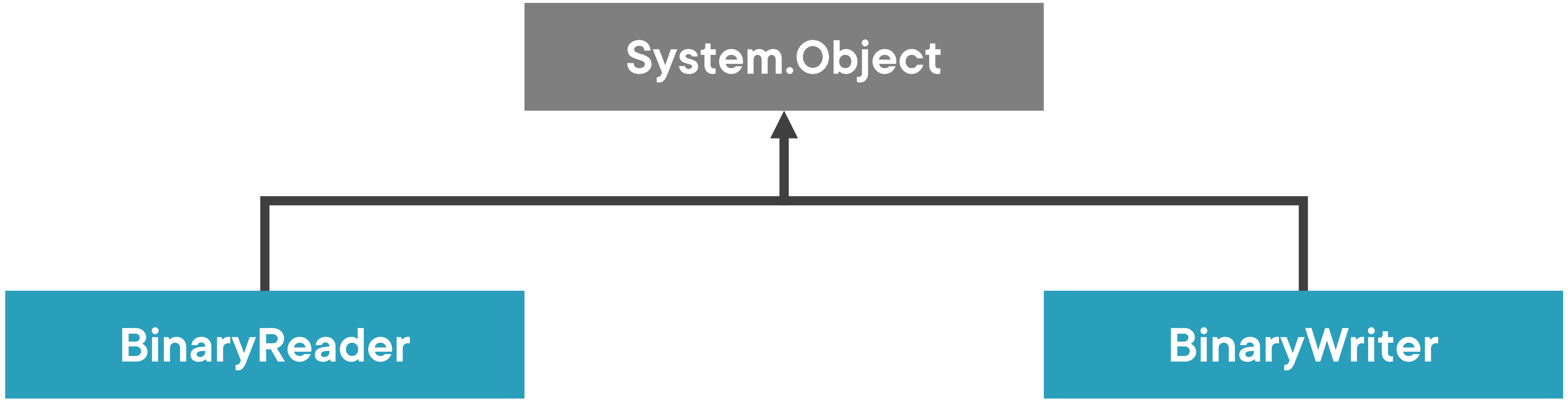


Backing store: memory

Backing store: file

System.IO.BufferedStream
System.IO.UnmanagedMemoryStream
System.IO.Compression.BrotliStream
System.IO.Compression.DeflateStream
System.IO.Compression.GZipStream
System.IO.Pipes.PipeStream
System.Net.Security.AuthenticatedStream
System.Net.Sockets.NetworkStream
System.Printing.PrintQueueStream
System.Security.Cryptography.CryptoStream
Etc.

Binary Reader and Writer



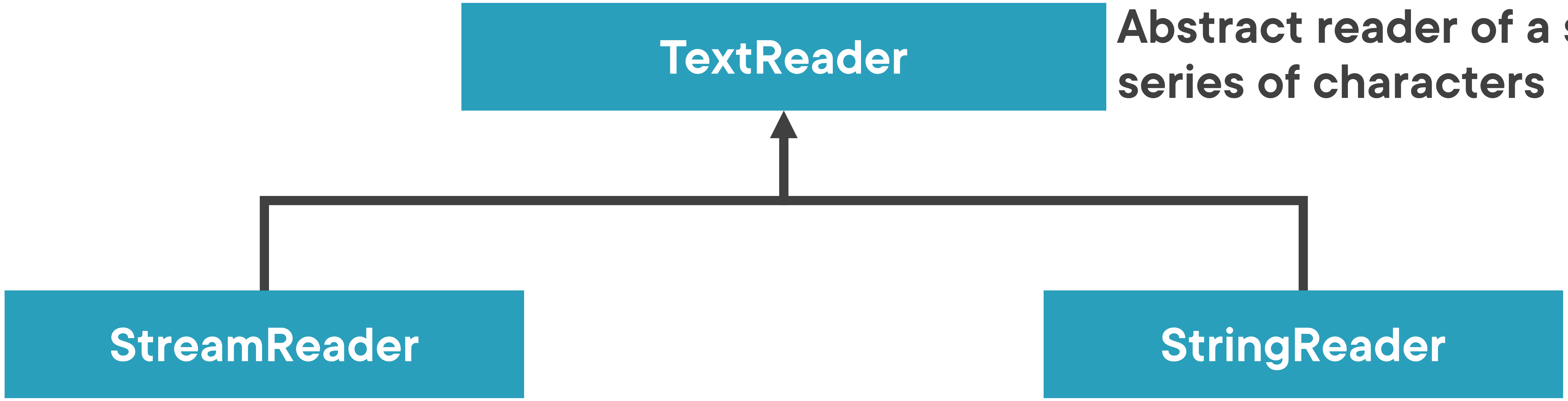
Read primitive types

bool ReadBoolean()
decimal ReadDecimal()
short ReadInt16()
char ReadChar()
Etc.

Write primitive types

Write(bool)
Write(decimal)
Write(short)
Write(char)
Etc.

TextReaders



Abstract reader of a sequential series of characters

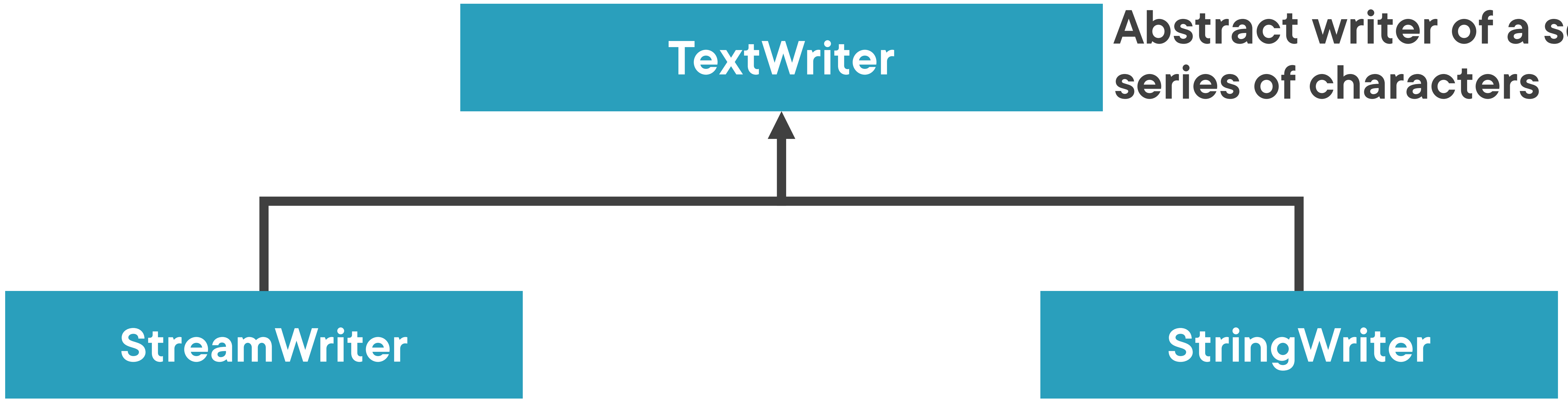
Reads characters from a byte stream using an encoding

string ReadLine()
string ReadToEnd()

Reads from a string object

int Read()
string ReadLine()
string ReadToEnd()

TextWriters



Abstract writer of a sequential series of characters

Writes characters to a stream using an encoding

Write(bool)
Write(decimal)
Write(int)
Write(char)
Etc.

Writes to a string (StringBuilder)

Write(bool)
Write(decimal)
Write(int)
Write(char)
Etc.

FileStreamOptions Properties

Mode Property

Specifies how to open/create the file

FileMode enum

Default: FileMode.Open

```
// Create a new file - exception if the file already exists
FileMode.CreateNew

// Create a new file - overwrites existing file if exists
FileMode.Create

// Open existing file - exception if file doesn't exist
FileMode.Open

// Open file if already exists, otherwise create new file
FileMode.OpenOrCreate

// Open file then truncate its size is zero bytes - exception if file doesn't exist
FileMode.Truncate

// Open existing file then seek to the end, otherwise create new file
FileMode.Append
```

FileStreamOptions Properties

Share Property

Specifies how the file will be shared by multiple processes when they try to open the specified file concurrently

FileShare enum (combinable)

Default: FileShare.Read

- “Allows subsequent opening of the file for reading. If this flag is not specified, any request to open the file for reading (by this process or another process) will fail until the file is closed.”

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

FileStreamOptions Properties

Options Property

Advanced/additional file options

FileOptions enum (combinable)

Default: FileOptions.None

FileOptions.RandomAccess

- "...file is accessed randomly. The system can use this as a hint to optimize file caching."

FileOptions.Asynchronous

- "... a file can be used for asynchronous reading and writing."

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

FileStreamOptions Properties

PreallocationSize Property

Requests that the OS pre-allocates a specified amount of space on disk before creating a file

long (size in bytes)

Default: 0

Just a hint to the OS and "is not a strong guarantee."

E.g. When creating large files (when size is known in advance) set PreallocationSize to be the file length

- May reduce disk fragmentation
- May improve performance

FileStreamOptions Properties

BufferSize Property

Specifies buffer size for reading/writing data

Allows .NET to optimize performance

Reduce the number of expensive OS read/write calls

int

Default: 4096 (bytes)

Set to 1 to disable buffering in .NET

Specifying Text Encodings

```
new StreamReader(inputFileStream, Encoding.UTF32)
new StreamReader(inputFileStream, new UTF8Encoding(true))
new StreamWriter(OutputFilePath, Encoding.UTF32)
new StreamWriter(OutputFilePath, new UTF8Encoding(true))
```

```
// No explicit encoding overload
File.OpenText(InputFilePath) // Expects file to be UTF-8
File.CreateText(OutputFilePath) // UTF-8 output encoding
```

Specifying Text Encodings

```
new BinaryReader(inputFileStream, Encoding.UTF32)
new BinaryWriter(outputFileStream, Encoding.UTF32)


// UTF-8 encoding
new BinaryReader(inputFileStream)
new BinaryWriter(outputFileStream)
```

Using Streams to Append Data

```
var streamWriter = new StreamWriter(@"C:\data.txt", true);


streamWriter.Write("Content to append...");
streamWriter.WriteLine("Content to append with new line...");
```

Using Streams to Append Data

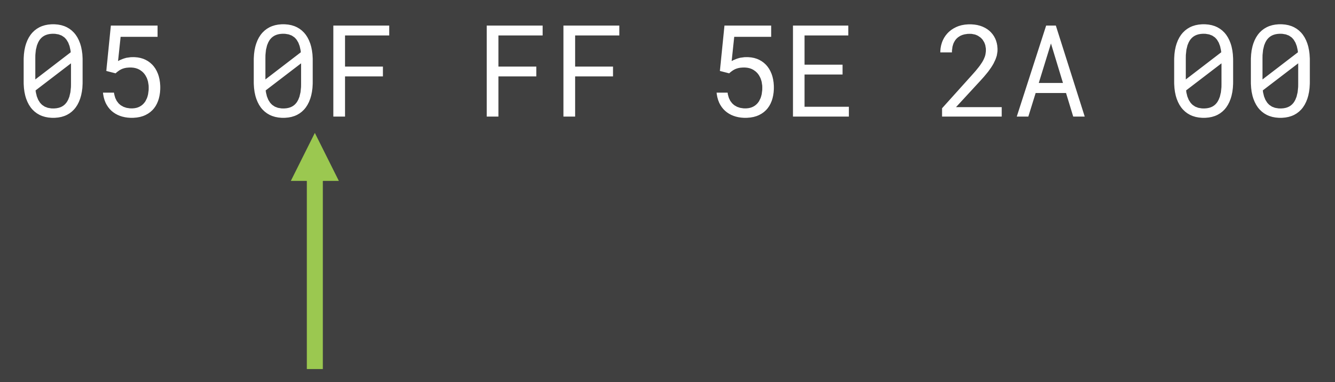
```
FileStream fs = File.Open(@"C:\data.data", FileMode.Append);
var binaryWriter = new BinaryWriter(fs);

binaryWriter.Write(42); // append to end of file
```

Random FileStream Access

```
05 0F FF 5E 2A 00
```

```
fileStream.Position = 0; // zero-based

int firstByte = fileStream.ReadByte(); // 05
```

Random FileStream Access



```
05 0F FF 5E 2A 00
```

```
fileStream.Position = 0; // zero-based
int firstByte = fileStream.ReadByte(); // 05
```

Random FileStream Access

```
05 0F FF 5E 2A 00
```

```
fileStream.Position = 2;
```

Random FileStream Access

```
05 0F FF 5E 2A 00
      ↑
```

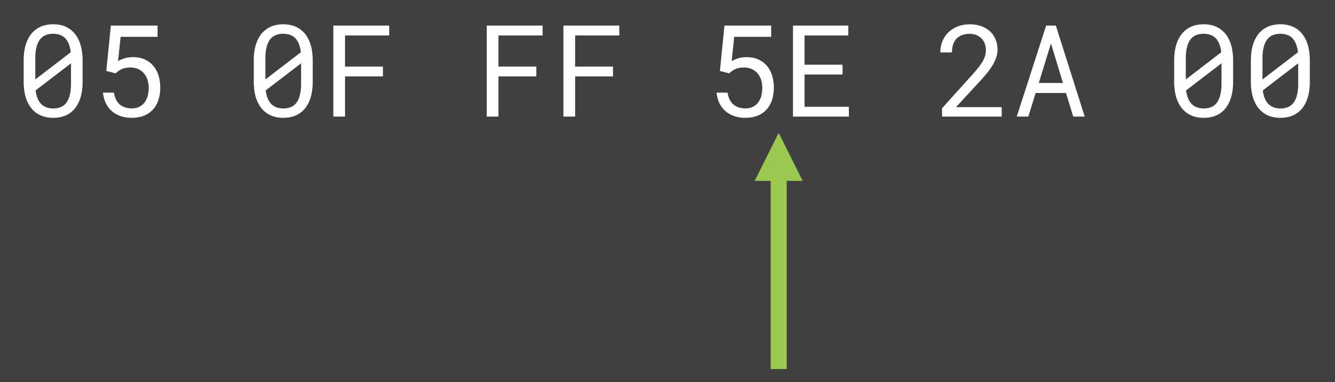
```
fileStream.Position = 2;

int thirdByte = fileStream.ReadByte(); // FF
```

Random FileStream Access

```
05 0F FF 5E 2A 00
```

```
fileStream.Position = 2;

int thirdByte = fileStream.ReadByte(); // FF
```

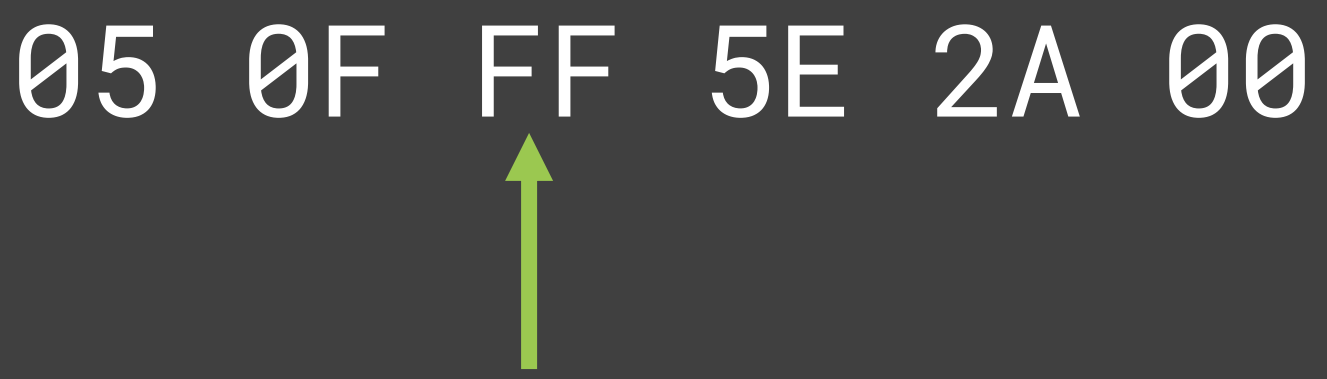
Random FileStream Access



```
05 0F FF 5E 2A 00
```

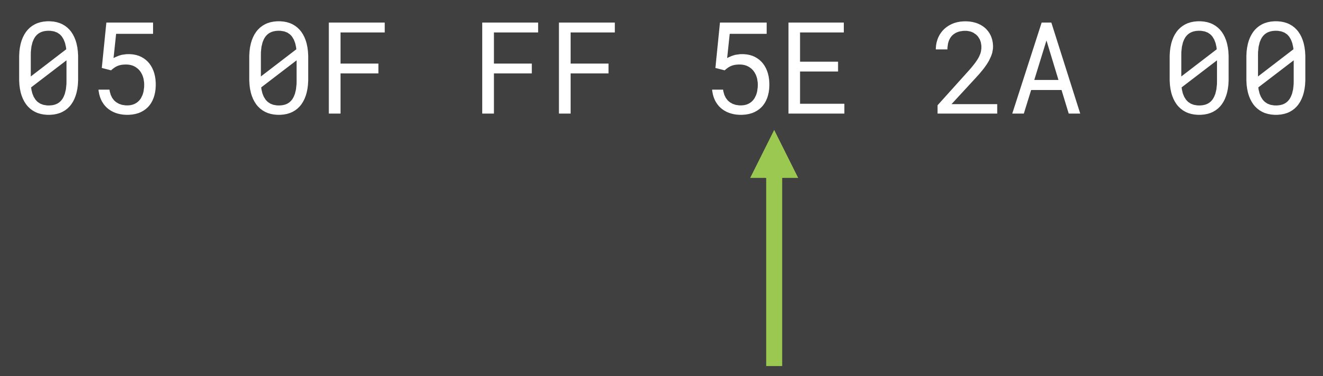
```csharp
fileStream.Seek(2, SeekOrigin.Begin);
```

Random FileStream Access



```
fileStream.Seek(2, SeekOrigin.Begin);

thirdByte = fileStream.ReadByte(); // FF
```

Random FileStream Access



```
fileStream.Seek(2, SeekOrigin.Begin);

thirdByte = fileStream.ReadByte(); // FF
```

Random FileStream Access

```
05 0F FF 5E 2A 00
```

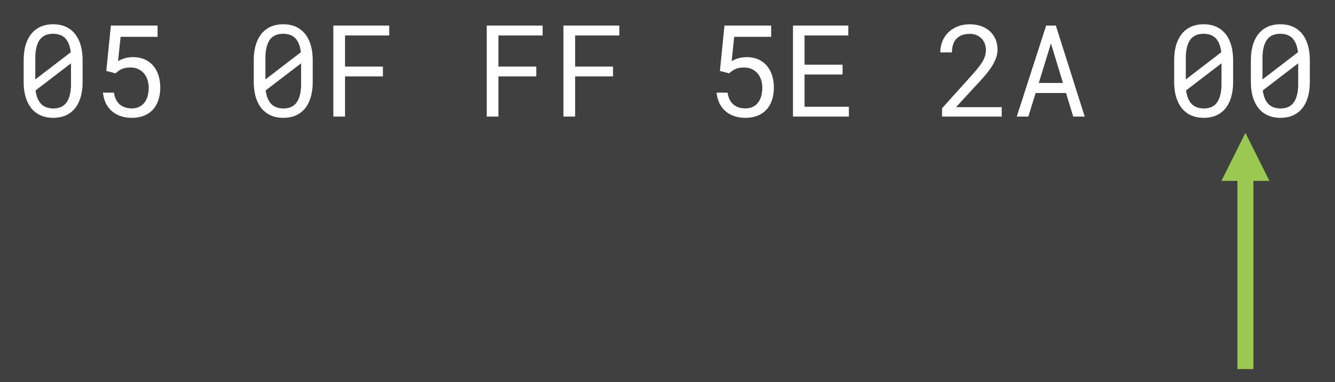
```
fileStream.Seek(1, SeekOrigin.Current);
```

Random FileStream Access

```
05 0F FF 5E 2A 00
```

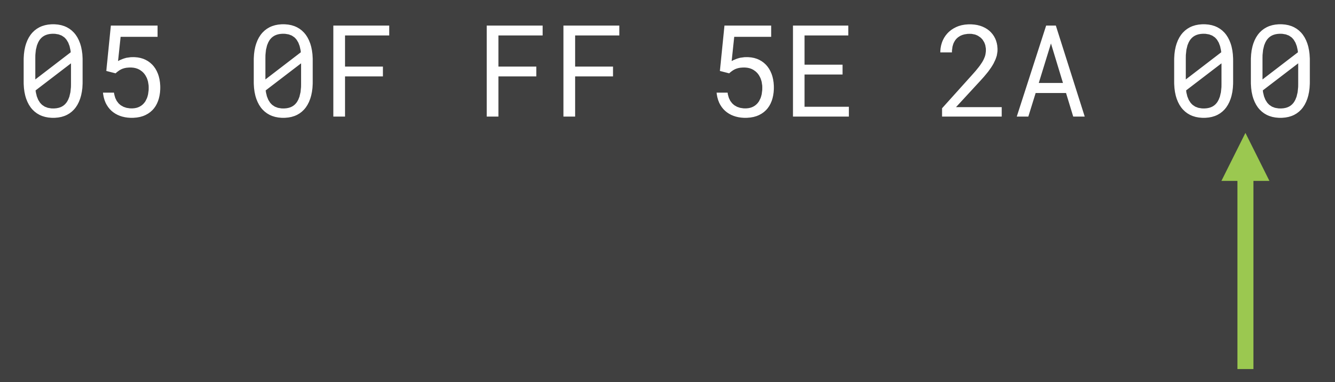
```
fileStream.Seek(1, SeekOrigin.Current);

int fifthByte = fileStream.ReadByte(); // 2A
```

Random FileStream Access



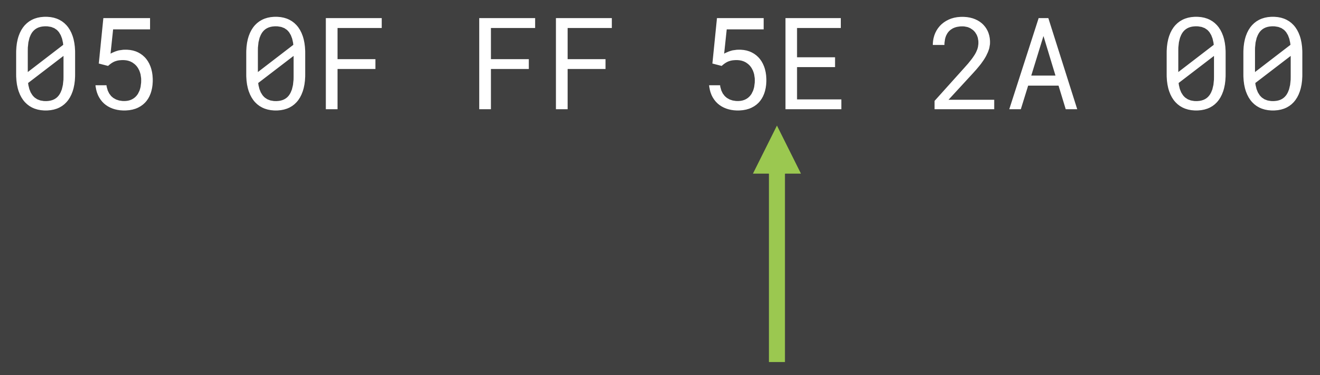
```
fileStream.Seek(1, SeekOrigin.Current);
int fifthByte = fileStream.ReadByte(); // 2A
```

Random FileStream Access



```
fileStream.Seek(-3, SeekOrigin.End);
```

Random FileStream Access



```
05 0F FF 5E 2A 00
```

```
fileStream.Seek(-3, SeekOrigin.End);
int threeFromEnd = fileStream.ReadByte(); // 5E
```

Random FileStream Access

```
05 0F FF 5E 2A 00
             ↑
```

```
fileStream.Seek(-3, SeekOrigin.End);

int threeFromEnd = fileStream.ReadByte(); // 5E
```

Not all streams support random access / seeking.

Stream.CanSeek

MemoryStream Overview

```
using var memoryStream = new MemoryStream();
using var memoryStreamWriter = new StreamWriter(memoryStream);
using var fileStream = new FileStream(@"C:\data.txt",
                                      FileMode.Create);

memoryStreamWriter.WriteLine("Line 1");
memoryStreamWriter.WriteLine("Line 2");

// Ensure everything's written to memory stream
memoryStreamWriter.Flush();

memoryStream.WriteTo(fileStream);
```

Asynchronous Streams

```
string currentLine = inputStreamReader.ReadLine();
string currentLine = await inputStreamReader.ReadLineAsync();

outputStreamWriter.Write(currentLine);
await outputStreamWriter.WriteAsync(currentLine);

outputStreamWriter.WriteLine(currentLine);
await outputStreamWriter.WriteLineAsync(currentLine);
```

Asynchronous Streams

```
int nextByte = inputFileStream.ReadByte();
int nextByte = inputFileStream.ReadByteAsync(); // ERROR

public Task<int> ReadAsync(byte[] buffer,
                           int offset,
                           int count,
                           CancellationToken ...);

public ValueTask<int> ReadAsync(Memory<byte> buffer,…);

public Task WriteAsync(byte[] buffer, …);
public ValueTask WriteAsync(ReadOnlyMemory<byte> buffer, …);
```

Asynchronous Streams in C# 8.0

```
// Don't confuse with System.IO streams
// "Asynchronous enumerables"
// Get a "stream" of results

public interface IAsyncEnumerable<out T>
{
    IAsyncEnumerator<T> GetAsyncEnumerator(
             CancellationToken cancellationToken = default);
}
```

```
public static async IAsyncEnumerable<int> TakeSensorReadings()
{
    var rnd = new Random();

    for (int i = 0; i < 10; i++)
    {

        await Task.Delay(1_000);



        int temp = rnd.Next(minValue: -10, maxValue: 50);



        yield return temp;
    }
}
```

```
public static async IAsyncEnumerable<int> TakeSensorReadings()
{
    var rnd = new Random();

    for (int i = 0; i < 10; i++)
    {

        await Task.Delay(1_000);



        int temp = rnd.Next(minValue: -10, maxValue: 50);



        yield return temp;
    }
}
```

```csharp
await foreach (var reading in TakeSensorReadings())
{
    Console.WriteLine($"Sensor reading: {reading}");
}
```

Perform processing during enumeration and return multiple values asynchronously in a pull-based fashion.

Thread-Safe File IO

RandomAccess Class

Low-level API

Read/write byte(s)

Offset-based

Stateless (e.g. no pointer to current position)

Thread-safe reading and writing

Methods that use a SafeFileHandle (wrapper class for OS file handles)

- GetLength(…)
- Read(…)
- ReadAsync(…)
- Write(…)
- WriteAsync(…)

```
using SafeFileHandle inputFileHandle =
            File.OpenHandle(InputFilePath, FileMode.Open);

using SafeFileHandle outputFileHandle =
            File.OpenHandle(OutputFilePath,
                            FileMode.CreateNew,
                            FileAccess.Write);

var inputFileLength = RandomAccess.GetLength(inputFileHandle);

var singleByteBuffer = new Span<byte>(new byte[1]);

byte largestByte = 0;
```

```
for (int fileOffset = 0; fileOffset < inputFileLength;
     fileOffset++)
{
    RandomAccess.Read(inputFileHandle,
                      singleByteBuffer,
                      fileOffset);

    RandomAccess.Write(outputFileHandle,
                       singleByteBuffer,
                       fileOffset);

    if (singleByteBuffer[0] > largestByte)
    {
        largestByte = singleByteBuffer[0];
    }
}
```

```
var largestByteBuffer =
                   new Span<byte>(new byte[1] { largestByte });

RandomAccess.Write(outputFileHandle,
                   largestByteBuffer,
                   inputFileLength);
```

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

Summary

An introduction to streams

The benefits of streams

.NET class hierarchy overview

new StreamReader(inputFileStream)

File.OpenText(InputFilePath)

Selectively processing part of stream

Using streams to read and write binary data

outputFileStream.WriteByte(...)

new BinaryReader(inputFileStream)

Text encodings & appending data

Random access & MemoryStreams

Up Next:
Reading and Writing CSV Data