JAVA I/O

Streams and Files

Lecture 06

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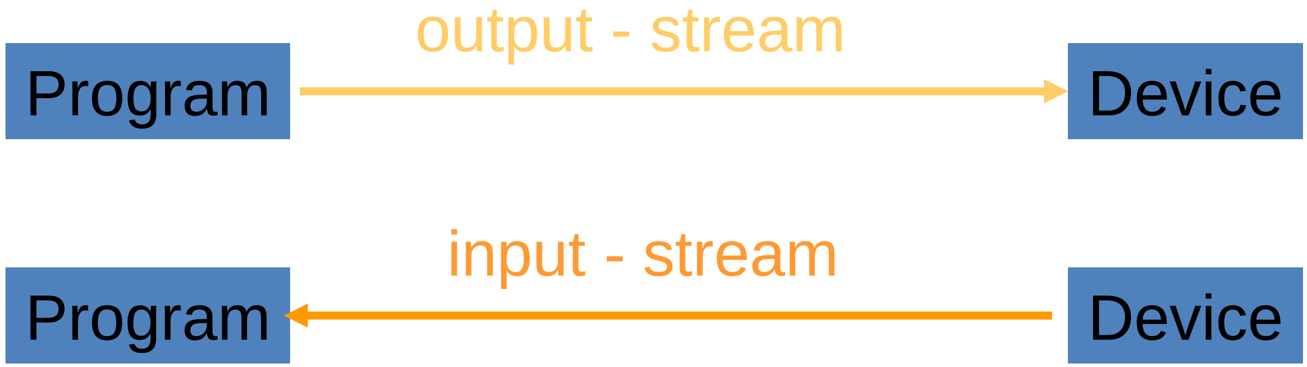
I/O

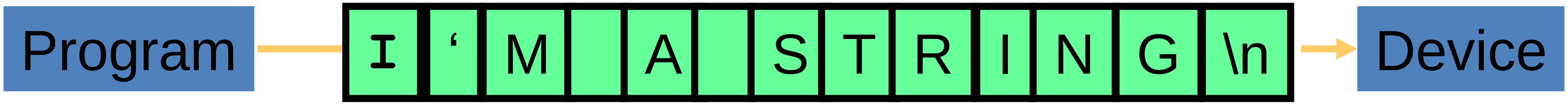
- Usual Purpose: storing data to ‘nonvolatile ‘ devices, e.g. harddisk
- Classes provided by package java.io
- Data is transferred to devices by ‘streams ‘



Streams

- JAVA distinguishes between 2 types of streams:

- Text – streams, containing ‘characters ‘



Program

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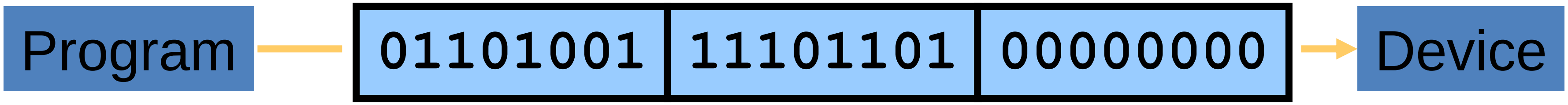
Device

- Binary Streams, containing 8 – bit information



Program

01101001	11101101	00000000

Device

Streams

- Streams in JAVA are Objects, of course !

- Having

- 2 types of streams (text / binary) and
- 2 directions (input / output)

- results in 4 base-classes dealing with I/O:

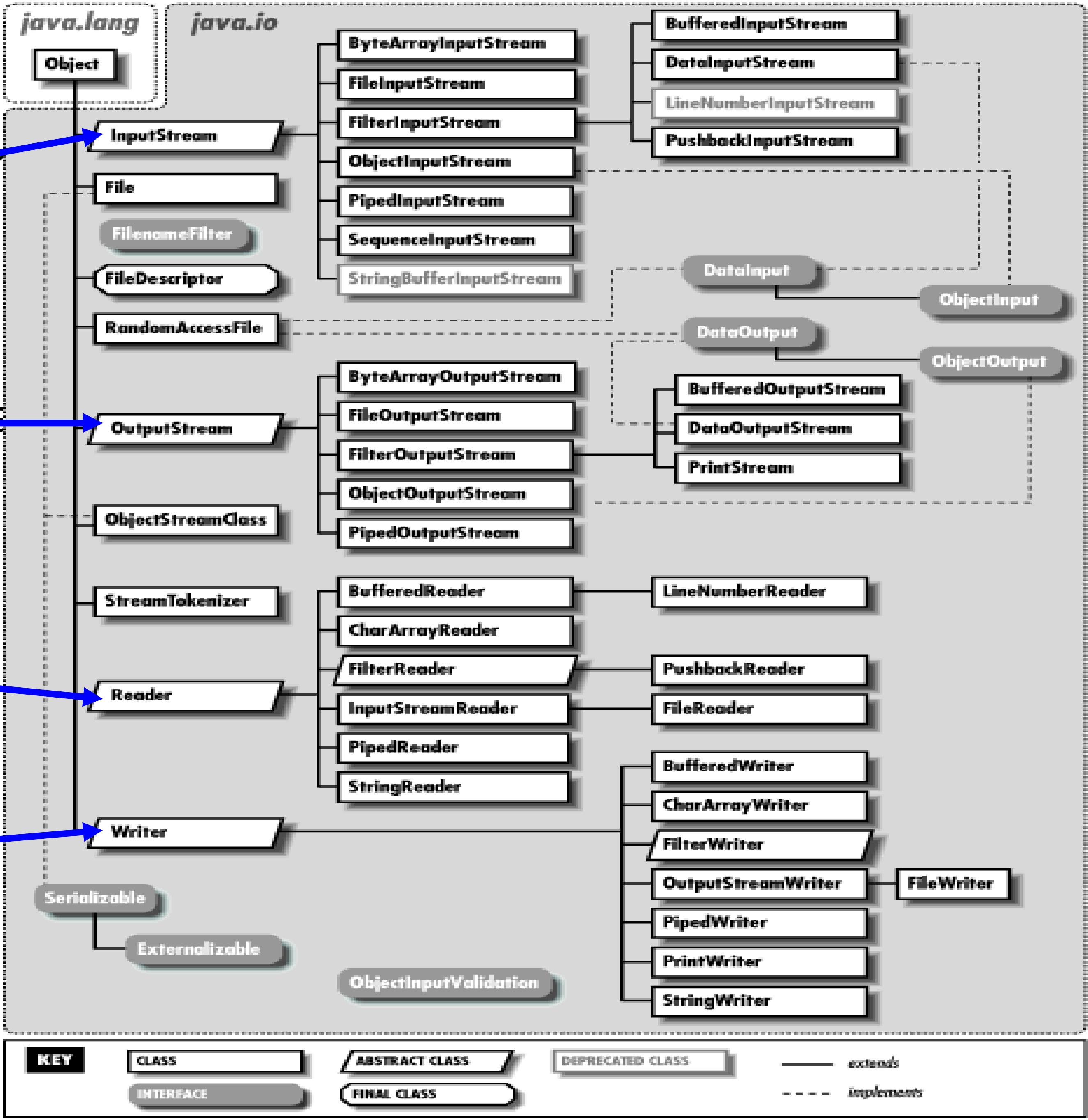
1. Reader: text-input
2. Writer: text-output
3. InputStream: byte-input
4. OutputStream: byte-output

- InputStream
- OutputStrea

binary

- Reader
- Writer

text



Streams

- InputStream, OutputStream, Reader, Writer are abstract classes

- Subclasses can be classified by 2 different characteristics of sources / destinations:

  - For final device (data sink stream)
    purpose: serve as the source/destination of the stream
    (these streams 'really' write or read !)

  - for intermediate process (processing stream)
    Purpose: alters or manages information in the stream
    (these streams are 'luxury' additions, offering methods for convenient or more efficient stream-handling)

I/O: General Scheme

- In General:
- Reading (writing):
  - open an input (output) stream
  - while there is more information

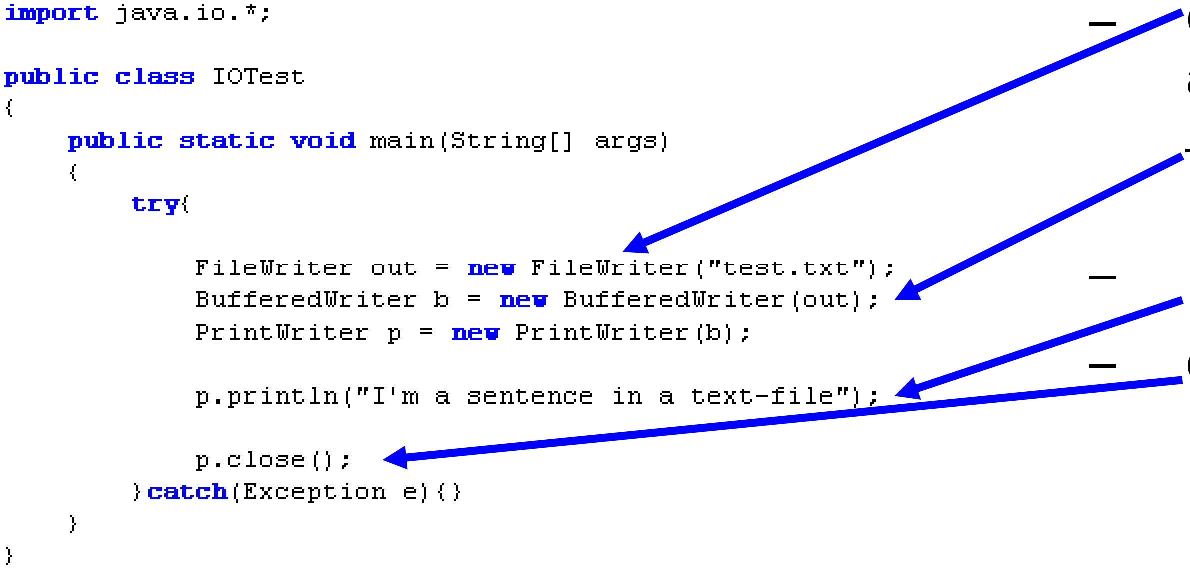
    read(write) next data from the stream
  - close the stream.

- In JAVA:
  - Create a stream object and associate it with a disk-file
    - Give the stream object the desired functionality
  - while there is more information

    read(write) next data from(to) the stream
  - close the stream.

Example 1

- Writing a textfile:

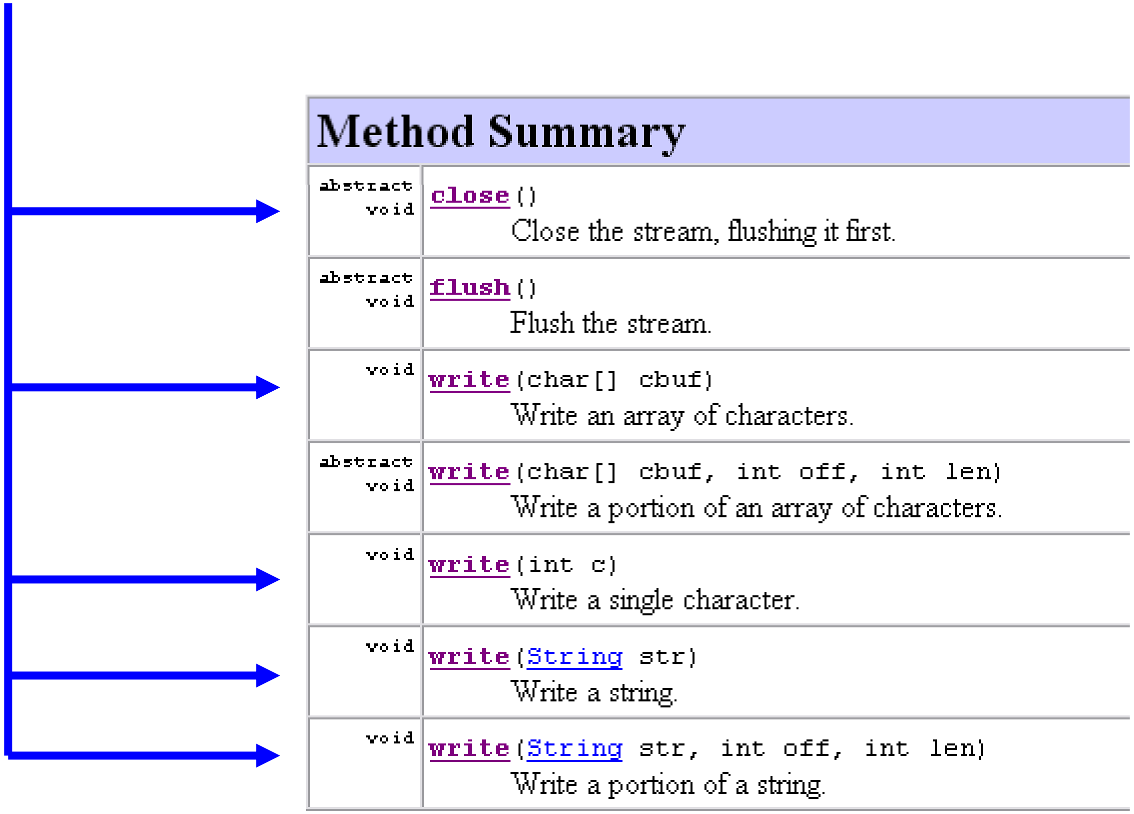


```
import java.io.*;

public class IOTest
{
    public static void main(String[] args)
    {
        try{

            FileWriter out = new FileWriter("test.txt");
            BufferedWriter b = new BufferedWriter(out);
            PrintWriter p = new PrintWriter(b);

            p.println("I'm a sentence in a text-file");

            p.close();
        }catch(Exception e){}
    }
}
```

- – Create a stream object and associate it with a disk-file
- – Give the stream object the desired functionality
- – write data to the stream
- – close the stream.

Writing Textfiles

- Class: FileWriter
- Frequently used methods:



Method Summary

abstract void	`close()` Close the stream, flushing it first.
abstract void	`flush()` Flush the stream.
void	`write(char[] cbuf)` Write an array of characters.
abstract void	`write(char[] cbuf, int off, int len)` Write a portion of an array of characters.
void	`write(int c)` Write a single character.
void	`write(String str)` Write a string.
void	`write(String str, int off, int len)` Write a portion of a string.

Writing Textfiles

- Using FileWriter
- is not very convenient (only String-output possible)
- Is not efficient (every character is written in a single step, invoking a huge overhead)

- Better: wrap FileWriter with processing streams
- BufferedWriter
- PrintWriter

Wrapping Textfiles

- BufferedWriter:
- Buffers output of FileWriter, i.e. multiple characters are processed together, enhancing efficiency

- PrintWriter
- provides methods for convenient handling, e.g. println()
- (remark: the System.out.println() – method is a method of the PrintWriter-instance System.out !)

Wrapping a Writer

- A typical codesegment for opening a convenient, efficient textfile:

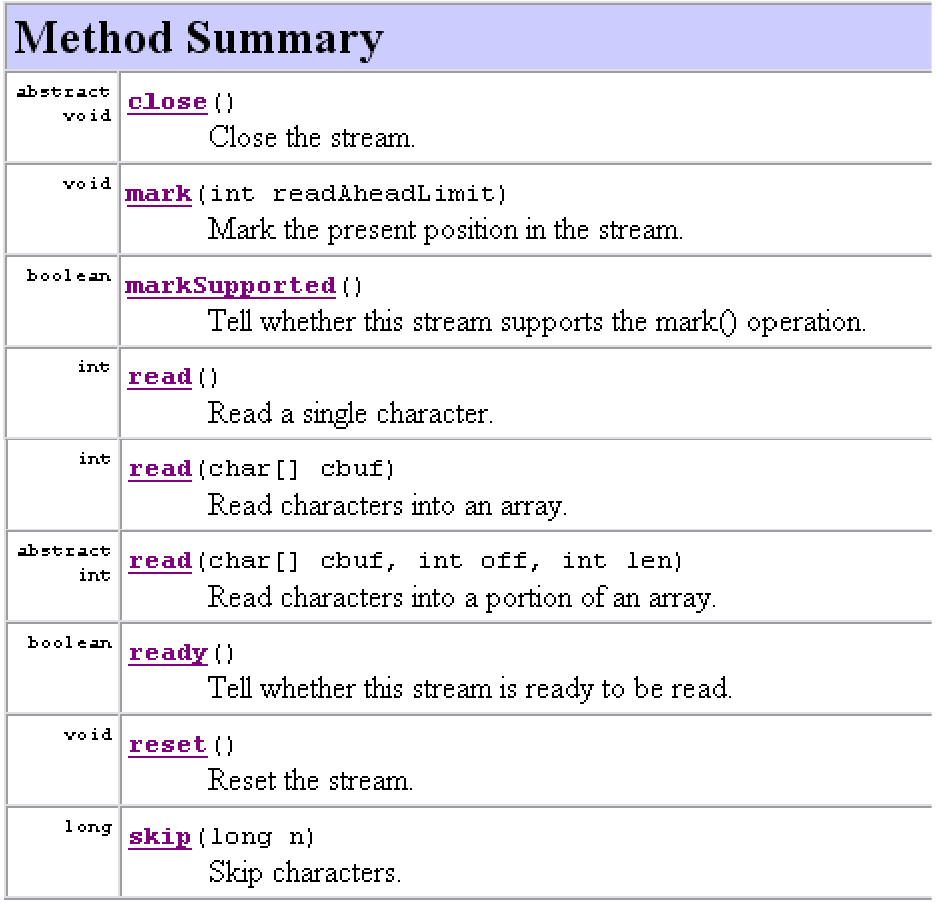
```
FileWriter out = new FileWriter("test.txt");
BufferedWriter b = new BufferedWriter(out);
PrintWriter p = new PrintWriter(b);
```

- Or with anonymous (‘unnamed ‘) objects:

```
PrintWriter p = new PrintWriter(
                     new BufferedWriter(
                       new FileWriter("test.txt")));
```

Reading Textfiles

- Class: ReadText
- Frequently used Methods:



Method Summary	
abstract void	**close**() Close the stream.
void	**mark**(int readAheadLimit) Mark the present position in the stream.
boolean	**markSupported**() Tell whether this stream supports the mark() operation.
int	**read**() Read a single character.
int	**read**(char[] cbuf) Read characters into an array.
abstract int	**read**(char[] cbuf, int off, int len) Read characters into a portion of an array.
boolean	**ready**() Tell whether this stream is ready to be read.
void	**reset**() Reset the stream.
long	**skip**(long n) Skip characters.

(The other methods are used for positioning, we don’t cover that here)

Wrapping a Reader

- Again:
- Using FileReader is not very efficient. Better
- wrap it with BufferedReader:

- BufferedReader br =
-    new BufferedReader(
-        new FileReader(“name“));

- Remark: BufferedReader contains the method readLine(), which is convenient for reading textfiles

EOF Detection

- Detecting the end of a file (EOF):
- Usually amount of data to be read is not known
- Reading methods return ‘impossible ‘ value if end of file is reached
- Example:
  - FileReader.read returns -1
  - BufferedReader.readLine() returns ‘null ‘
- Typical code for EOF detection:

```
while ((c = myReader.read() != -1){   // read and check c
        ...do something with c
}
```

Example 2: Copying a Textfile

```
import java.io.*;
public class IOTest
{
    public static void main(String[] args)
    {
        try{
            BufferedReader myInput = new BufferedReader(new FileReader("IOTest.java"));
            BufferedWriter myOutput = new BufferedWriter(new FileWriter("Test.txt"));

            int c;
            while ((c=myInput.read()) != -1)
                myOutput.write(c);

            myInput.close();
            myOutput.close();
        }catch(IOException e){}
    }
}
```

Binary Files

- Stores binary images of information identical to the binary images stored in main memory
- Binary files are more efficient in terms of processing time and space utilization
- drawback: not ‘human readable ‘, i.e. you can ‘t use a texteditor (or any standard-tool) to read and understand binary files

Binary Files

- Example: writing of the integer ’42‘
- TextFile: ‘4‘ ‘2‘ (internally translated to 2 16-bit representations of the characters ‘4‘ and ‘2‘)
- Binary-File: 00101010, one byte
- (= 42 decimal)

Writing Binary Files

- Class: FileOutputStream

- ... see FileWriter

- The difference:
- No difference in usage, only in output format

Reading Binary Files

- Class: FileInputStream
- ... see FileReader
- The difference:
- No difference in usage, only in output format

Binary vs. TextFiles

	pro	con
🟦	Efficient in terms of time and space	Preinformation about data needed to understand content
🟩	Human readable, contains redundant information	Not efficient

Binary vs. TextFiles

When use Text- / BinaryFiles ?

- ALWAYS use TextFiles for final results if there’s no imperative reason to favor efficiency against readability.

  Example: SIP - Standard

- Binary Files might be used for non-final interchange between programs

- Binary Files are always used for large amount of data (images, videos etc.), but there’s always an *exact* definition of the meaning of the bytestream

  Example: JPG, MP3, BMP

Streams and Files

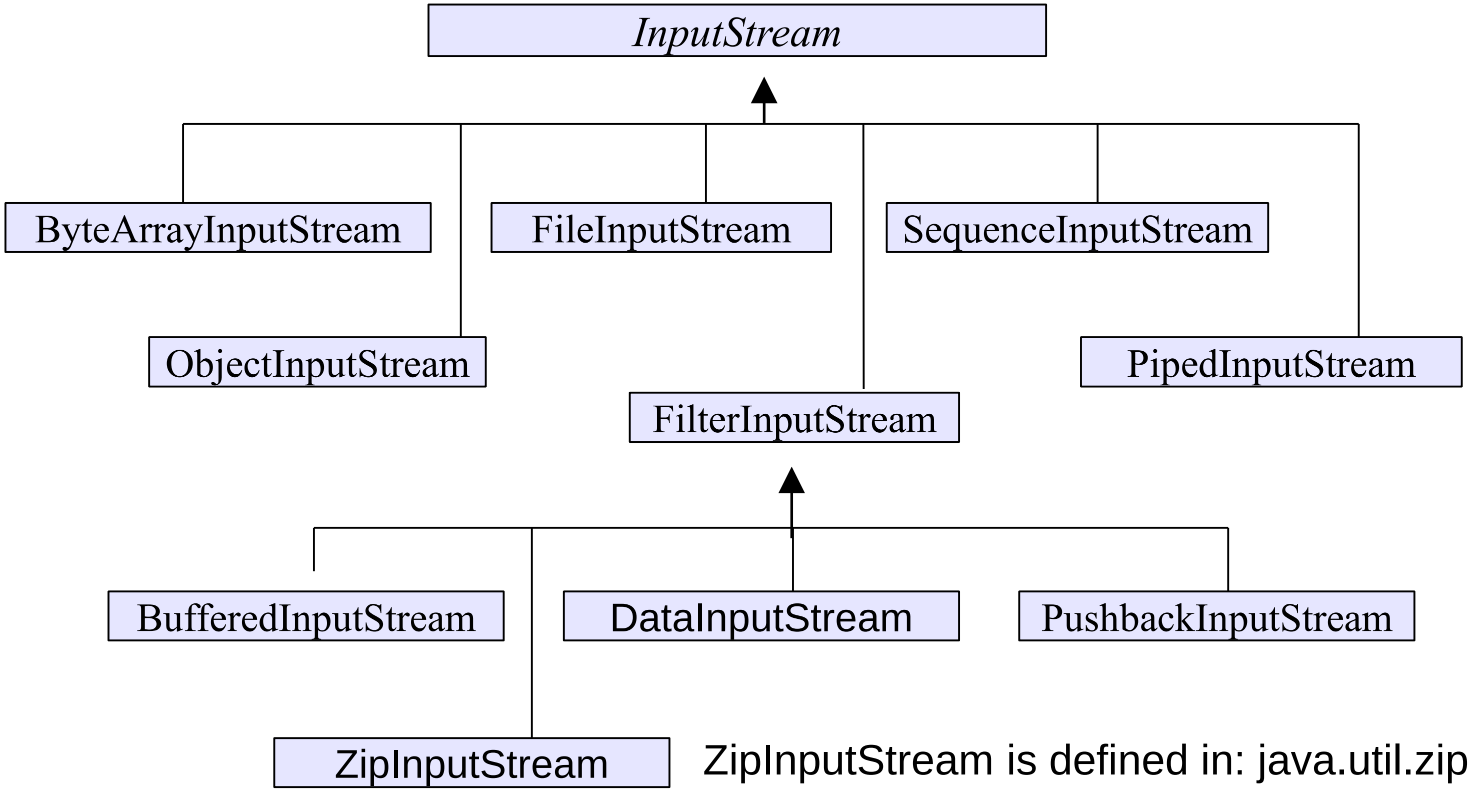
Have a look in detail….

Byte Oriented Streams

- There are many different types of Byte-Oriented Streams
  - Represented by different classes within the java.io.package
  - All byte-oriented streams are subclasses of a common Stream class
  - Input Streams are subclasses of the abstract class java.io.InputStream
  - Output Streams are subclasses of the abstract class java.io.OutputStream
  - All byte-oriented streams inherit basic methods from their respective superclasses
  - Some define new methods pertinent to the type of data they provide.
- Byte-oriented streams are closely related to the I/O streams provided by other programming languages like C, C++, and pascal.
- Because they are byte-oriented they are suitable for reading binary and ASCII data.
  - Byte-oriented streams do not work well with unicode text.

Byte-Oriented Input Stream Classes

- **The following is the byte-oriented input stream class hierarchy:**



ZipInputStream is defined in: java.util.zip

InputStream Methods

- Reading
  - read() methods will block until data is available to be read
  - two of the three read() methods return the number of bytes read
  - -1 is returned if the Stream has ended
  - throws IOException if an I/O error occurs. This is a checked exception

- There are 3 main read methods:

`int read()`

- Reads a single character. Returns it as integer

`int read(byte[] buffer)`

- Reads bytes and places them into buffer (max = size of buffer)
- returns the number of bytes read

InputStream Methods

- available() method returns the number of bytes which can be read without blocking
- skip() method skips over a number of bytes in the input stream
- close() method will close the input stream and release any system resources
- input streams optionally support repositioning the stream

can mark the stream at a certain point and 'rewind' the stream to that point later.

- methods that support repositioning are:

markSupported() returns true if repositioning is supported

Creating an InputStream

- InputStream is an abstract class
- Programmers can only instantiate subclasses.

- ByteArrayInputStream:
- Constructor is provided with a byte array.
- This byte array contains all the bytes provided by this stream
- Useful if the programmer wishes to provide access to a byte array using the stream interface.

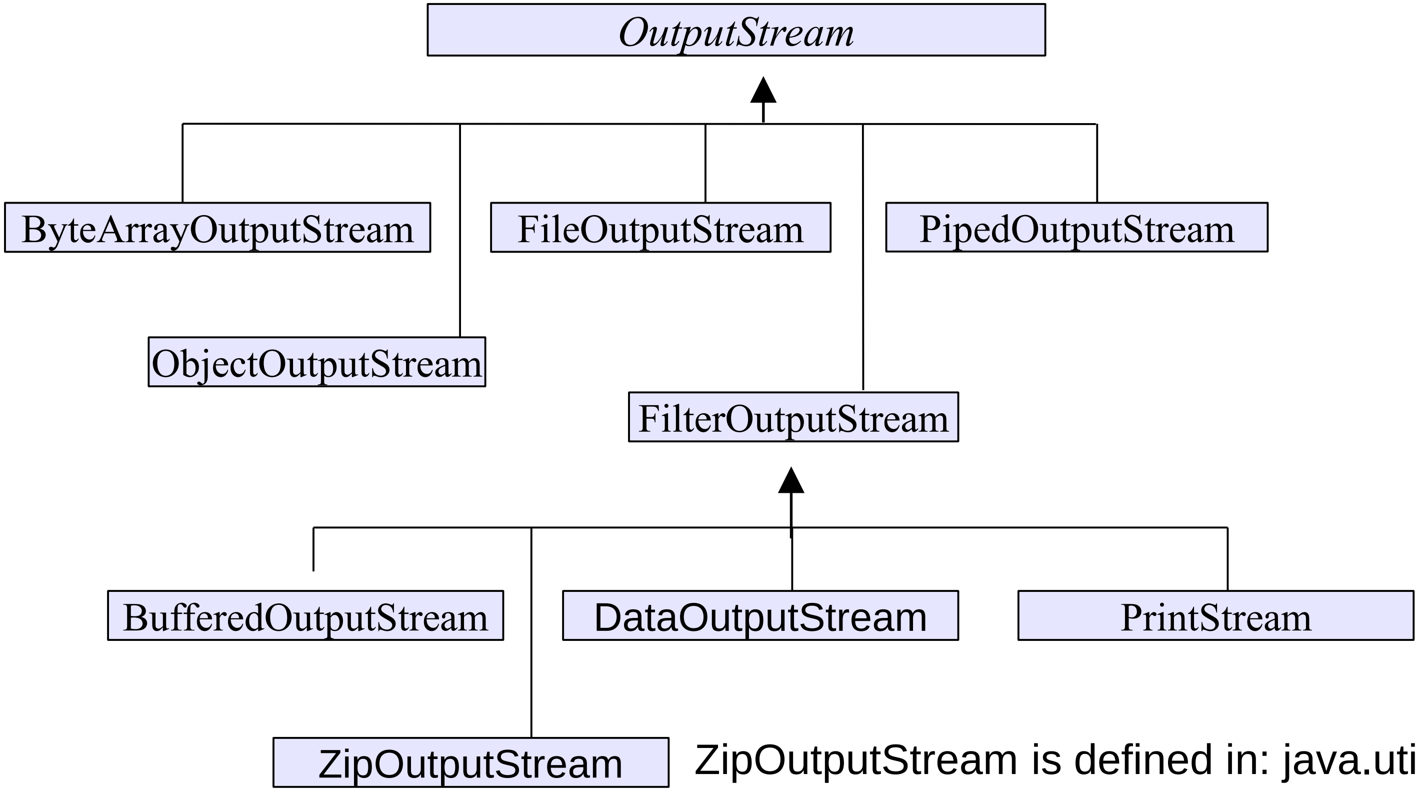
- FileInputStream:
- Constructor takes a filename, File object or FileDescriptor Object.
- Opens a stream to a file.

Creating an InputStream

- ObjectInputStream
  - Created from another input stream (such as FileInputStream)
  - Reads bytes from the stream (which represent serialized Objects) and converts them back into Objects
  - More on Serialization later in the Chapter.
- PipedInputStream:
  - Connects to an Instance of PipedOutputStream
  - A pipe represents a one-way stream through which 2 threads may communicate
  - Thread1 writes to a PipedOutputStream
  - Thread2 reads from the PipedInputStream
- SequenceInputStream:

Byte-Oriented Output Stream Classes

- **The following is the byte-oriented input stream class hierarchy:**



OutputStream

ByteArrayOutputStream

FileOutputStream

PipedOutputStream

ObjectOutputStream

FilterOutputStream

BufferedOutputStream

DataOutputStream

PrintStream

ZipOutputStream

ZipOutputStream is defined in: java.util.zip

OutputStream Methods

- Writing**:**
- write() methods write data to the stream. Written data is buffered.
- Use flush() to flush any buffered data from the stream.
- throws IOException if an I/O error occurs. This is a checked exception

- There are 3 main write methods:

`void write(int data)`

- Writes a single character
- Note: even though data is an integer, data must be set such that:
  - 0 <= data <= 255

`void write(byte[] buffer)`

- Writes all the bytes contained in buffer to the stream

OutputStream Methods

- flush**()**
  - To improve performance, almost all output protocols buffer output.
  - Data written to a stream is not actually sent until buffering thresholds are met.
  - Invoking flush() causes the OutputStream to clear its internal buffers.

- close()
  - Closes stream and releases any system resources.

Creating an OutputStream

- OutputStream is an abstract class.
  - Programmers instantiate one of its subclasses

- ByteArrayOutputStream:
  - Any bytes written to this stream will be stored in a byte array
  - The resulting byte array can be retrieved using toByteArray() method.

- FileOutputStream:
  - Constructor takes a filename, File object, or FileDescriptor object.
  - Any bytes written to this stream will be written to the underlying file.
  - Has one constructor which allows for appending to file:

```
FileOutputStream(String filename, boolean append)
```

- FilterOutputStream:

Creating an OutputStream

- ObjectOutputStream
  - Created from another output stream (such as FileOutputStream)
  - Programmers serialize objects to the stream using the writeObject() method
    - More on Serialization later in the Chapter.

- PipedOutputStream:
  - Connects to an Instance of PipedInputStream
  - A pipe represents a one-way stream through which 2 threads may communicate
    - Thread1 writes to a PipedOutputStream
    - Thread2 reads from the PipedInputStream

Example - Copy a File

```
import java.io.*;

public class CopyFile
{
public void copyFile(String inputFilename, String outputFilename)
{
try
{
FileInputStream fpin = new FileInputStream(inputFilename);
FileOutputStream fpout = new FileOutputStream(outputfilename);
byte buffer = new byte[8192];
int length = 0;
while ((length = fpin.read(buffer, 0, buffer.length)) > 0)
{
fpout.write(buffer, 0, length);
}
fpout.flush();
fpout.close();
fpin.close();
}
catch (IOException x)
{
System.out.println("Error:" + x);
}
}
}
```

Limitations of Byte Oriented Streams

- Byte oriented streams are attractive to programmers familiar with C, C++ or who have UNIX experience
  - They are identical to what these programmers are used to

- Because they are byte-oriented, they are inflexible when dealing with multi-byte characters
  - Byte oriented streams only directly support ASCII
  - International fonts would require extra work for the programmer

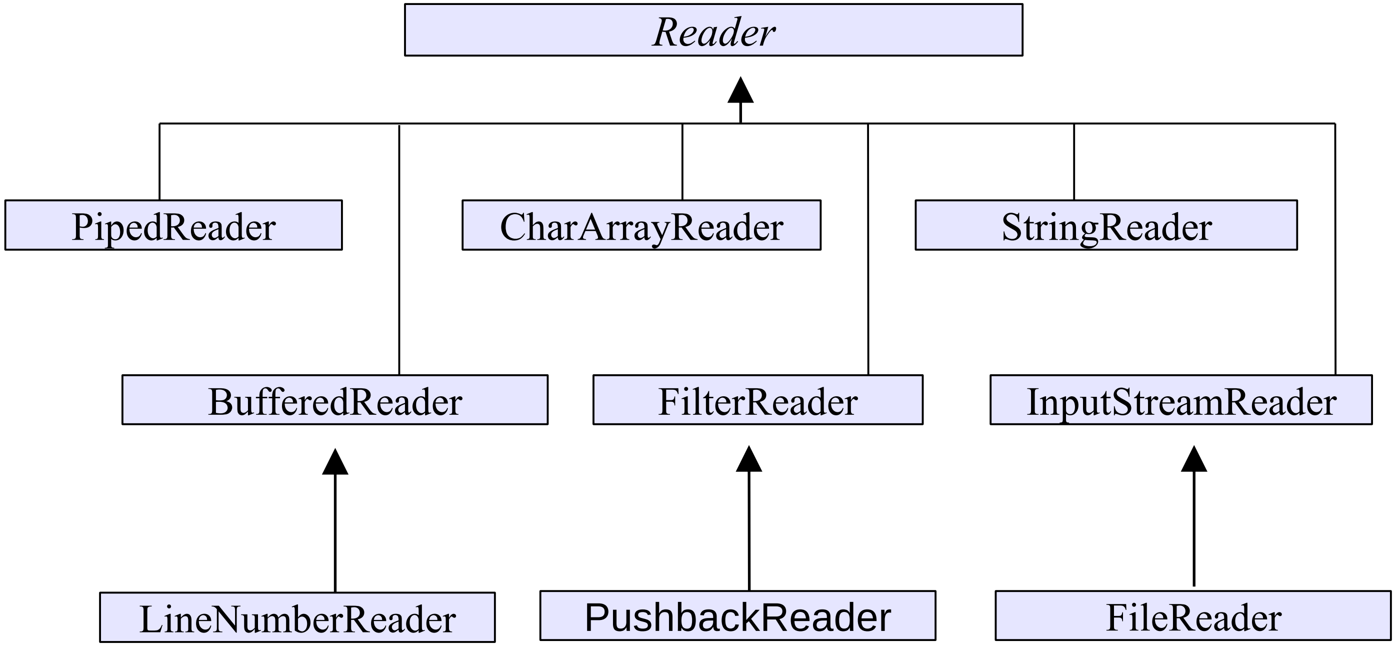
- Character based streams
  - Abstract classes are Reader and Writer
  - Can be used in conjunction with byte-oriented streams
  - Useful when reading and writing text (character data)

Character-Oriented Streams

- There are many different types of Character-Oriented Streams
  - Represented by different classes within the java.io.package
  - All character-oriented streams are subclasses of an abstract class
    - Writers are subclasses of the abstract class java.io.Writer
    - Readers are subclasses of the abstract class java.io.Reader
  - All character-oriented streams inherit basic methods from their respective superclasses
    - Some define new methods pertinent to the type of data they provide.
- Character oriented streams can be used in conjunction with byte-oriented streams:
  - Use InputStreamReader to "convert" an InputStream to a Reader
  - Use OutputStreamWriter to "convert" an OutputStream to a Writer

Character-Oriented Reader Classes

- **The following is the byte-oriented input stream class hierarchy:**



Reader Methods

- Reading
  - read() methods will block until data is available to be read
  - two of the three read() methods return the number of bytes read
    - -1 is returned if the Stream has ended
  - throws IOException if an I/O error occurs. This is a checked exception

- There are 3 main read methods:

`int read()`

- Reads a single character. Returns it as integer

`int read(char[] buffer)`

- Reads bytes and places them into buffer (max = size of buffer)
  - returns the number of bytes read

Reader Methods

- close() method closes the stream

- mark(int readAheadLimit) marks the current location
  - Parameter specifies the number of characters which can be read before the marks becomes invalid

- ready() returns true if there is data to be read from the stream
  - returns true if the stream is guaranteed not to block upon next read.

- reset() returns the stream to its previously marked location

- skip(long n) skips over n bytes

Creating a Reader Object

- Reader is abstract. Programmers instantiate one of its subclasses.
  - BufferedReader
    - Reads text from the character input stream
    - Provides buffering to provide efficient reading of characters, arrays and lines
  - CharArrayReader
    - Similar to ByteArrayInputStream
    - Constructor takes a character array. The character array provides the characters for the stream.
  - FilterReader
    - An abstract class for filtering character streams
    - Filtering will be discussed later in the chapter

Creating a Reader Object

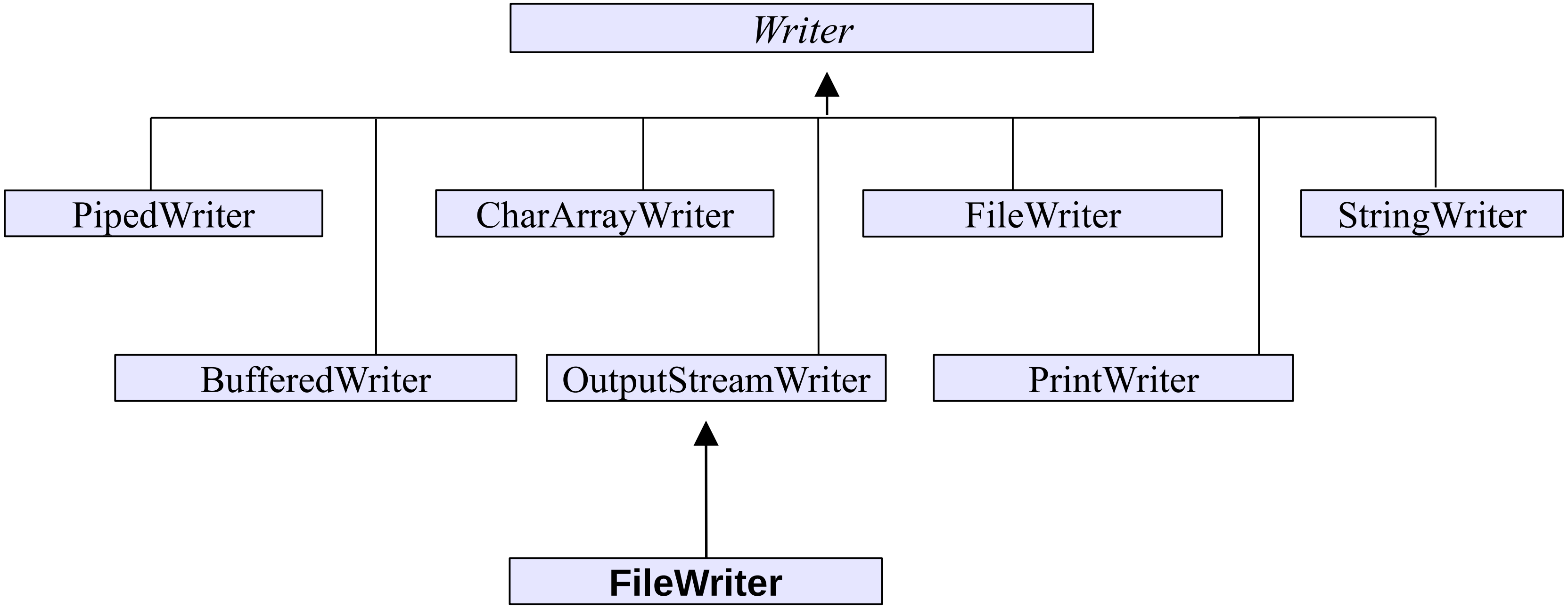
- InputStreamReader
  - This class acts as a bridge from byte streams to character streams
  - InputStreamReader takes an InputStream parameter to its constructor
  - The InputStreamReader reads bytes from the InputStream and translates them into characters according to the specified encoding.
- PipedReader
  - Similar to PipedInputStream
  - Connects to an Instance of PipedWriter
  - A pipe represents a one-way stream through which 2 threads may communicate
  - Thread1 writes to a PipedWriter
  - Thread2 reads from the PipedReader
- StringReader

Creating a Reader Object

- LineNumberReader (subclass of BufferedReader)
  - A stream which keeps track of how many lines there have been
  - A line is terminated with a linefeed, carriage return or a carriage return followed immediately by a linefeed.
- PushbackReader (subclass of FilterReader)
  - A stream which allows characters to be pushed back into the stream after being read
  - The number of characters which can be pushed back is specified when instantiated. Default = 1
- FileReader (subclass of InputStreamReader)
  - A convenience class to provide a character based stream from file.
  - Alternatively, open the file using a FileInputStream and then pass that stream to an InputStreamReader instance.

Character-Oriented Writer Classes

- **The following is the byte-oriented input stream class hierarchy:**



Writer

PipedWriter

CharArrayWriter

FileWriter

StringWriter

BufferedWriter

OutputStreamWriter

PrintWriter

FileWriter

Writer Methods

- There are 5 main write methods:

```
void write(int c)
```

- Writes a single character.

```
void write(char[] buffer)
```

- Writes an array of characters

```
void write(char[] buffer, int offset, int length)
```

- Writes a portion of an array of characters
- First character written is starts at buffer[offset]
- length indicates how many characters to write.

```
void write(String aString)
```

- Writes aString to the stream

Creating a Writer Object

- Writer is abstract. Programmers instantiate one of its subclasses.
  - BufferedWriter
    - Writes text to the character stream
    - Provides buffering to provide efficient writing of characters, arrays and lines
  - CharArrayWriter
    - Similar to ByteArrayOutputStream
    - Characters written to the stream are stored in a buffer.
    - The buffer can be retrieved by calling toCharArray() or toString()
  - FilterWriter
    - An abstract class for writing filtered character streams

Creating a Writer Object

- OutputStreamWriter
  - This class acts as a bridge from character streams to byte streams
  - OutputStreamWriter takes an OutputStream parameter to its constructor
  - Characters written to the OutputStreamWriter are translated to bytes (based on the encoding) and written to the underlying OuputStream.
- PipedWriter
  - Similar to PipedOutputStream
  - Connects to an Instance of PipedReader
  - A pipe represents a one-way stream through which 2 threads may communicate
  - Thread1 writes to a PipedWriter
  - Thread2 reads from the PipedReader
- StringWriter

Creating a Writer Object

- PrintWriter
  - Provides print() and println() methods for standard output
  - both print() and println() are overloaded to take a variety of types
  - When println is used, the stream will output the appropriate sequence (either linefeed, carriage return or carriage return/linefeed) for the current platform
  - System.out and System.err are PrintWriters

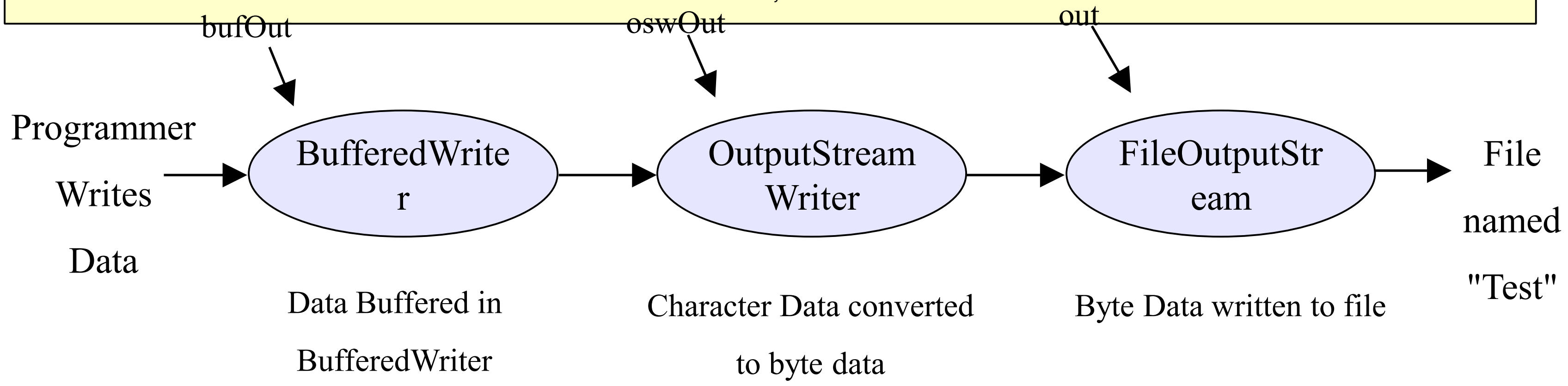
- FileWriter (subclass of OutputStreamWriter)
  - A convenience class for writing characters to file
  - FileWriters assume that the default character encoding is acceptable
  - Alternatively, open the file using a FileOutputStream and then pass that stream to an OutputStreamWriter instance.

Filter Streams

- What are filter streams?
  - Filter streams are similar to filters in Unix
  - The basic idea is that while the data is being read (or written) the data is modified by a filter or series of filters.
  - How the data is modified is depends on which filters are used.
  - Filters can be chained together.
- Example:
  - A programmer creates a FileOuputStream
  - OutputStreams are byte-oriented, but the programmer wishes to use character-oriented streams instead.
  - The programmer knows that the OutputStreamWriter class can convert between character oriented streams and byte oriented streams
  - The programmer creates an OuputStreamWriter and passes the FileOutputStream reference to it

Filter Streams - Example

```
          import java.io.*;

         public class MyClass
                   {
           public void test()
                    {
                      try
                       {
  FileOutputStream out = new FileOutputStream("Test");
OutpuStreamWriter oswOut = new OutputStreamWriter(out);
  BufferedWriter bufOut = new BufferedWriter(oswOut);

             // programmer now uses bufOut
                       }
             catch (IOException x)
                       {
                       }
                    }
                   }
```



bufOut

oswOut

out

Programmer

Writes

Data

BufferedWriter

OutputStream Writer

FileOutputStream

File

named

"Test"

Data Buffered in

BufferedWriter

Character Data converted

to byte data

Byte Data written to file

FileWriter Revisited

- Remember FileWriter?
  - A convenience class for writing characters to file
  - FileWriters assume that the default character encoding and default buffer size are acceptable
  - Alternatively, open the file using a FileOutputStream and then pass that stream to an OutputStreamWriter instance.

- FileWriter is a filter class.
  - When it is created, it constructs a FileOutputStream, an OutputStreamWriter (with the default encoding) and a BufferedWriter with the default buffer size.
  - It is a considered a convenience class because it goes through the process of setting up the filter chain using default encoding and buffer sizes.
  - If the default values are not acceptable, the programmer will have to set up their own filters as outlined in the previous example.

FilterStreams Provided with the JSDK

- Standard Byte-oriented Filter Streams:
  - ObjectInputStream, ObjectOutputStream
  - BufferedInputStream, BufferedOutputStream
  - DataInputStream, DataOutputStream
  - PushbackInputStream

- Compression filter Streams
  - GZIPInputStream, GZIPOutputStream
  - ZipInputStream, ZipOutputStream
  - InflatorInputStream, DeflatorOutputStream

- Character-oriented Filter Streams:
  - PushbackReader
  - FileWriter

Object Serialization

- When an object is instantiated, the system reserves enough memory to hold all of the object's instance variables
  - The space includes inherited instance variables.
- The object exists in memory.
  - Instance methods read and update the memory for a given object.
- The memory which represents an object can be written to an ObjectOutputStream.
  - Objects are serialized to an ObjectOutputStream
- Any other objects referred to by the Serialized object are also serialized to the stream

Example - Serialize an Object

```
                     import java.io.*;

                     public class Test
                             {
public void saveObject(String outputFilename, Object anObject)
                              {
                                try
                                 {
      FileOutputStream fpout = new FileOutputStream(outputFilename);
         ObjectOutputStream obOut = new ObjectOutputStream(fpout);
                       obOut.writeObject(anObject);
                              obOut.flush();
                              obOut.close();
                                 }
                       catch (IOException x)
                                 {
                     System.out.println("Error:" + x);
                                 }
                              }
                             }
```

Example - Read in a Serialized Object

```
import java.io.*;

public class Test
{
public Object readObject(String inputFilename)
{
try
{
FileInputStream fpin = new FileInputStream(inputFilename);
ObjectInputStream obIn = new ObjectInputStream(fpin);
Object anObject = obIn.readObject();
obIn.close();
return anObject;
}
catch (IOException x)
{
System.out.println("Error:" + x);
}
}
}
```

Example - Serialize an Object and Compress

```
                      import java.io.*;
                   import java.util.zip.*;

                      public class Test
                              {
public void saveObject(String outputFilename, Object anObject)
                               {
                                try
                                  {
      FileOutputStream fpout = new FileOutputStream(outputFilename);
       DeflaterOutputStream dOut = new DeflaterOutputStream(fpout);
         ObjectOutputStream obOut = new ObjectOutputStream(dOut);
                       obOut.writeObject(anObject);
                              obOut.flush();
                              obOut.close();
                                  }
                       catch (IOException x)
                                  {
                     System.out.println("Error:" + x);
                                  }
                               }
                              }
```

Example - Read in a Compressed Serialized Object

```
import java.io.*;

public class Test
{
public Object readObject(String inputFilename)
{
try
{
FileInputStream fpin = new FileInputStream(inputFilename);
InflaterInputStream inflateIn = new InflaterInputStream(fpin);
ObjectInputStream obIn = new ObjectInputStream(inflateIn);
Object anObject = obIn.readObject();
obIn.close();
return anObject;
}
catch (IOException x)
{
System.out.println("Error:" + x);
}
}
}
```

The File Class

- Java IO provides a class which is an abstract representation of a file or directory within the file system.

- The File class has 2 constructors:

```
File(String pathName)
File(File parent, String child)
```

- The File class provides several query methods:
  - canRead(), canWrite(), exists(), getAbsolutePath(), getName(), getParent(), getPath(), isAbsolute(), isDirectory(), isHidden(), lastModified(), length(), and list()

- The File class also provides several methods which act on the file system:
  - createTempFile(), delete(), deleteOnExit(), mkdir(), mkdirs(), renameTo(),