ORACLE

Academy

Java Programming

8-2

Class File

ORACLE
Academy

Objectives

- This lesson covers the following topics:
  - Understand the class file structure
  - Identify the access field
  - Identify the method structure and bytecode
    - Method Info: Code_attribute
    - Code Attribute: LineNumberTable_attribute
    - Class Attribute: SourceFile_attribute

The class File

- Contains one Java type, either a class or an interface
- Described using C like structures
  - Uses types u1, u2, and u4 to represent an unsigned one, two, or four byte quantity
  - No alignment or padding
  - Can be read using readUnsignedByte, readUnsignedShort, and readInt
  - Uses pseudo-array notation, even for varying size records
  - A stream of 8-bit bytes

The class File

- Java class file precisely defines the class file format, which ensures that the Java class file can be loaded and understood by any Java Virtual Machine
- In the Java class file, the size of a variable-length item precedes the actual data for the item which allows the class file to be parsed from beginning to end with no padding

The class File Structure

```
ClassFile {
 u4         magic;
 u2         minor_version;
 u2         major_version;
 u2         constant_pool_count;
 cp_info    constant_pool[constant_pool_count-1];
 u2         access_flags;
 u2         this_class;
 u2         super_class;
 u2         interfaces_count;
 u2         interfaces[interfaces_count];
 u2         fields_count;
 field_info fields[fields_count];
 u2         methods_count;
 method_info methods[methods_count];
 u2         attributes_count;
 attribute_info attributes[attributes_count];
}
```

The Java class definition contains everything a Java Virtual Machine needs to know about one Java class or interface.

The class File Structure

```
ClassFile {
 u4          magic;
 u2          minor_version;
 u2          major_version;
 u2          constant_pool_count;
 cp_info       constant_pool[constant_pool_count-1];
 u2          access_flags;
 u2          this_class;
 u2          super_class;
 u2          interfaces_count;
 u2          interfaces[interfaces_count];
 u2          fields_count;
 field_info     fields[fields_count];
 u2          methods_count;
 method_info    methods[methods_count];
 u2          attributes_count;
 attribute_info attributes[attributes_count];
}
```

A class file consists of a stream of 8-bit bytes.

16-bit and 32-bit quantities are constructed by reading in two and four consecutive 8-bit bytes.

Multibyte data items are always stored in big-endian order, where the high bytes come first

The class File Structure

```
public class SampleClass {
    public int test()
    {
      int x=99999;
      int y=1;
      int z = x + y;
      return z;
    }
}
```

This is a sample Java source code file we will use to show the corresponding Java class file.

The SampleClass class defines only one instance method, test(), and 3 local variables (x,y,z).

The class File Structure

- Sample of Java bytecode for SampleClass:

```
Offset(h)  00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F

00000000   CA FE BA BE 00 00 00 34 00 10 0A 00 04 00 0D 03  Êþº¾...4........
00000010   00 01 86 9F 07 00 0E 07 00 0F 01 00 06 3C 69 6E  ..†Ÿ.........<in
00000020   69 74 3E 01 00 03 28 29 56 01 00 04 43 6F 64 65  it>...()V...Code
00000030   01 00 0F 4C 69 6E 65 4E 75 6D 62 65 72 54 61 62  ...LineNumberTab
00000040   6C 65 01 00 04 74 65 73 74 01 00 03 28 29 49 01  le...test...()I.
00000050   00 0A 53 6F 75 72 63 65 46 69 6C 65 01 00 10 53  ..SourceFile...S
00000060   61 6D 70 6C 65 43 6C 61 73 73 2E 6A 61 76 61 0C  ampleClass.java.
00000070   00 05 00 06 01 00 0B 53 61 6D 70 6C 65 43 6C 61  .......SampleCla
00000080   73 73 01 00 10 6A 61 76 61 2F 6C 61 6E 67 2F 4F  ss...java/lang/O
00000090   62 6A 65 63 74 00 21 00 03 00 04 00 00 00 00 00  bject.!.........
000000A0   02 00 01 00 05 00 06 00 01 00 07 00 00 00 1D 00  ................
000000B0   01 00 01 00 00 00 05 2A B7 00 01 B1 00 00 00 01  .......*·..±....
000000C0   00 08 00 00 00 06 00 01 00 00 00 01 00 01 00 09  ................
000000D0   00 0A 00 01 00 07 00 00 00 2F 00 02 00 04 00 00  .........../......
000000E0   00 0B 12 02 3C 04 3D 1B 1C 60 3E 1D AC 00 00 00  ....<.=..`>.¬...
000000F0   01 00 08 00 00 00 12 00 04 00 00 00 04 00 03 00  ................
00000100   05 00 05 00 06 00 09 00 07 00 01 00 0B 00 00 00  ................
00000110   02 00 0C                                        ...
```

- This is the Binary File format produced from the Java compiler javac

The class File Structure

- Magic number (4 bytes)
  - Class files are identified by the following 4 byte header :
  - CAFEBABE

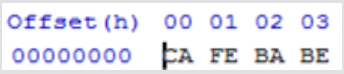
- Version of class file format (4 bytes)
  - Minor version number of the class file format being used (2 bytes), major version number of the class file format being used(2 bytes)

The class File Structure

- Version of class file format (4 bytes) (cont.)
- javase 8.0 = 52(0x 34 hex)
  - J2SE 6.0 = 50 (0x32 hex)
    J2SE 5.0 = 49 (0x31 hex)
    JDK 1.4 = 48 (0x30 hex)
    JDK 1.3 = 47 (0x2F hex)
    JDK 1.2 = 46 (0x2E hex)
    JDK 1.1 = 45 (0x2D hex

The class File Structure

- If a file does not start with 0XCAFEBABE, it definitely is not a valid Java class file



- The second four bytes of a class file contain the minor and major version numbers
- If classes have a version number that is out of the range of major or minor version then the JVM will reject them and not load them

The class File Structure - Constant Pool

- Following the version numbers is the constant pool
- The Constant Pool contains the constants associated with the class or interface, such as literal String, class and interface name, field name and other constants that are referred to within the class
  - u2 constant_pool_count;

The class File Structure - Constant Pool

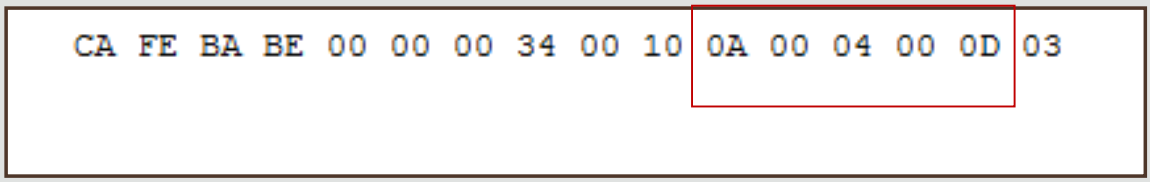
- All constant_pool table entries have the following general format:
  - cp_info
  - {
  - u1 tag;
  - u1 info[];
  - }
- The constant_pool_count precedes the actual constant.
- In this example the value is 00 10, in total there are 16

```
CA FE BA BE 00 00 00 34 00 10 0A 00 04 00 0D 03
```

The class File Structure - Constant Pool

- The javap command displays the constant pool:
  - minor version: 0
  - major version: 52
  - flags: ACC_PUBLIC, ACC_SUPER
  - Constant pool:
  - #1 = Methodref #4.#13 // java/lang/Object."<init>":()V
  - #2 = Integer 99999
  - #3 = Class #14 // SampleClass
  - #4 = Class #15 // java/lang/Object
  - #5 = Utf8 <init>
  - #6 = Utf8 ()V
  - #7 = Utf8 Code
  - #8 = Utf8 LineNumberTable
  - #9 = Utf8 test
  - #10 = Utf8 ()I
  - #11 = Utf8 SourceFile
  - #12 = Utf8 SampleClass.java
  - #13 = NameAndType #5:#6 // "<init>":()V
  - #14 = Utf8 SampleClass
  - #15 = Utf8 java/lang/Object

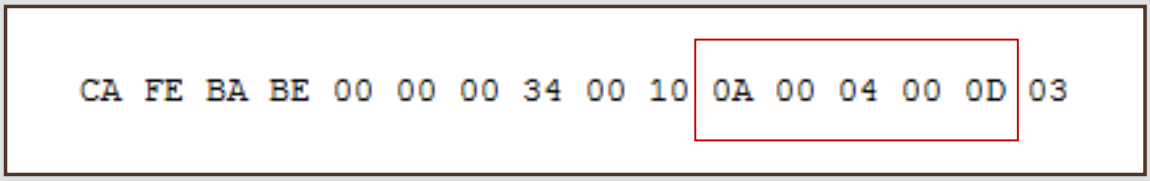
The class File Structure - Constant Pool



- The first constant pool entry is 0A = 10 which represents the CONSTANT_Methodref

```
CONSTANT_Methodref_info {
u1 tag;    0A
u2 class_index;   00 04
 u2 name_and_type_index;   00 0D
}
```

The class File Structure - Constant pool



- The first entry in the constant pool is 0A which indicates the following code is for CONSTANT_Methodref
  - #1 = Methodref #4.#13 // java/lang/Object."<init>":()V
- In this example, the first entry is a constructor of the class ExampleClass
- The name of the constructor is <init> with the ()V as the descriptor

The class File Structure - Constant pool

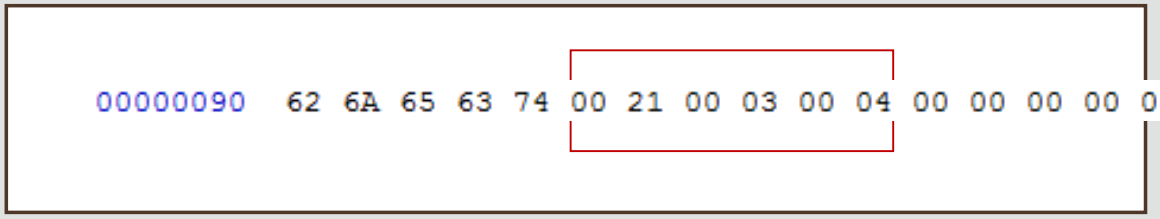
- Some constant pool entries refer to other locations in the class, i.e the 00 04 class_index entry refers to the index which must be a CONSTANT_Class_info structure

```
CA FE BA BE 00 00 00 34 00 10 0A 00 04 00 0D 03
00 01 86 9F 07 00 0E 07 00 0F 01 00 06 3C 69 6E
```

- The second constant pool entry is 03 which represents the CONSTANT_Integer_info
  - CONSTANT_Integer_info {
  - u1 tag; 03
  - u4 bytes; 00 01 86 9F
  - }

```
#2 = Integer            99999
In this example the 00 01 86 9F is the
hex value of integer 99999.
```

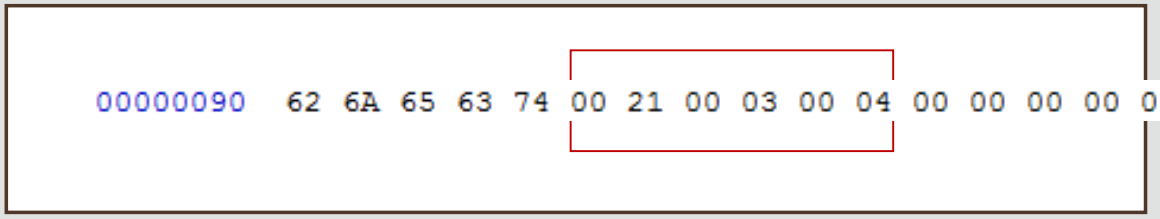
The class File Structure – access_flags



- u2 access_flags; ACC_PUBLIC 00 21

- Declared public; may be accessed from outside its package

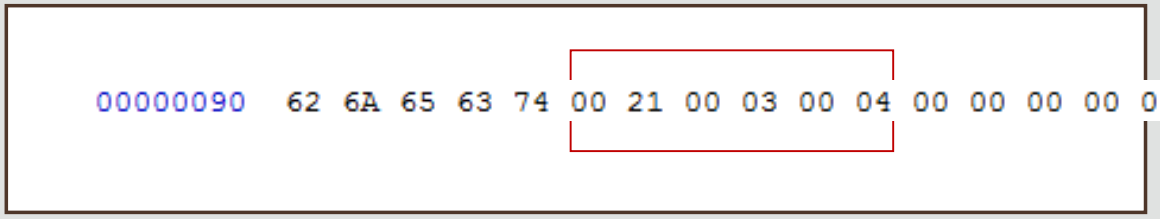
The class File Structure – this_class



- u2; 00 03

- The value of the this_class item must be a valid index into the constant_pool table.
  - #3 = Class #14 // SampleClass

The class File Structure – super_class



- u2 super_class; 00 04

- The value of the super_class item either must be zero or must be a valid index into the constant_pool table
  - #4 = Class #15 // java/lang/Object

The class File Structure - method info

```
000000A0  02 00 01 00 05 00 06 00 01 00 07 00 00 00 1D 00
```

- u2 methods_count; 02

- The method_info structures represent all methods declared by this class or interface type, including instance methods, class methods, instance initialization methods, and any class or interface initialization method

The class File Structure - method info

```
000000A0  02 00 01 00 05 00 06 00 01 00 07 00 00 00 1D 00
```

- There are two method definitions in this SampleClass class file
- The first method – Constructor

```
02 00 01 00 05 00 06 00 01 00 07 00 00 00 1D 00
```

- The Second method – test()

```
00 08 00 00 00 06 00 01 00 00 00 01 00 01 00 09
00 0A 00 01 00 07 00 00 00 2F 00 02 00 04 00 00
```

The class File Structure - method info

- The first method – Constructor

```
02 00 01 00 05 00 06 00 01 00 07 00 00 00 1D 00
```

method_info {
u2 access_flags; 00 01
u2 name_index; 00 05
u2 descriptor_index; 00 06
u2 attributes_count; 00 01
attribute_info attributes[attributes_count];
}
ACC_PUBLIC 0x0001

- Declared public; may be accessed from outside its package.

The class File Structure - method info

- The first method – Constructor

- name_index 00 05
- The value of the name_index item must be a valid index into the constant_pool table
- `#5 = Utf8 <init>`
- This method is the instance initialization method which has special name <init>

The class File Structure - method info

- The first method – Constructor

- The name is supplied by a compiler
- Because the name <init> is not a valid identifier, it cannot be used directly in a program written in the Java programming language

The class File Structure - method info

- The first method – Constructor

```
02 00 01 00 05 00 06 00 01 00 07 00 00 00 1D 00
```

method_info {
u2 access_flags; 00 01
u2 name_index; 00 05
u2 descriptor_index; 00 06
u2 attributes_count; 00 01
attribute_info attributes[attributes_count];
}
descriptor_index 00 06

- The value of the descriptor_index item must be a valid index into the constant_pool table. #6 = Utf8 ()V

The class File Structure - method info

- The first method – Constructor

  - attributes_count 00 01

- The value of the attributes_count item indicates the number of additional attributes of this method
- In this example, there is only one attribute for this constructor

The class File Structure - method info

- The first method – Constructor Attribute

```
02 00 01 00 05 00 06 00 01 00 07 00 00 00 1D 00
01 00 01 00 00 00 05 2A B7 00 01 B1 00 00 00 01
```

Code_attribute { u2 attribute_name_index; 00 07 (code)
u4 attribute_length; 00 00 00 1D (29)
u2 max_stack; 00 01
u2 max_locals; 00 01
u4 code_length; 00 00 00 05
u1 code[code_length]; 2A B7 00 01 B1
u2 exception_table_length; { u2 start_pc; u2 end_pc; u2 handler_pc; u2 catch_type; } exception_table[exception_table_length]; 00
u2 attributes_count; 01
attribute_info attributes[attributes_count]; }

The class File Structure - method info

- The first method – Constructor Attribute

```
02 00 01 00 05 00 06 00 01 00 07 00 00 00 1D 00
01 00 01 00 00 00 05 2A B7 00 01 B1 00 00 00 01
```

- A Code attribute contains the Java Virtual Machine instructions and auxiliary information for a method
  - attribute_name_index
- The value of the attribute_name_index item must be a valid index into the constant_pool table
- In this example, 00 07 indicates a Code constant
  - #7 = Utf8 Code

The class File Structure - method info

- The first method – Constructor Attribute

  - u2 max_stack; 00 01
- The maximum depth of the operand stack of this method is 1
  - u2 max_locals; 00 01
- The number of local variables is 1

The class File Structure - method info

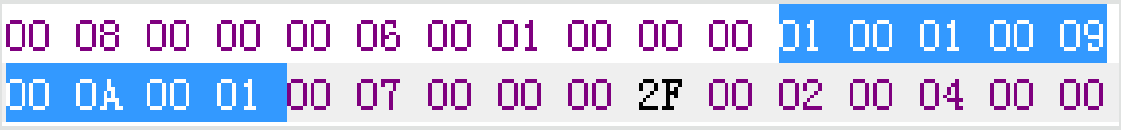
- The first method – Constructor Attribute

```
02 00 01 00 05 00 06 00 01 00 07 00 00 00 1D 00
01 00 01 00 00 00 05 2A B7 00 01 B1 00 00 00 01
```

  - u4 code_length; 00 00 00 05
- The number of bytes in the code array
  - u1 code[5]; 2A B7 00 01 B1
  - 0: aload_0
  - 1: invokespecial #1 // Method java/lang/Object."<init>":()V
  - 4: return

The class File Structure - method info

- The Second method – test()

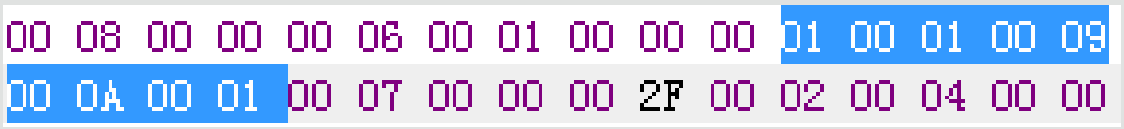


method_info {
u2 access_flags; 00 01
u2 name_index; 00 09
u2 descriptor_index; 00 0A
u2 attributes_count; 00 01
attribute_info attributes[attributes_count];
 }

ORACLE Academy

The class File Structure - method info

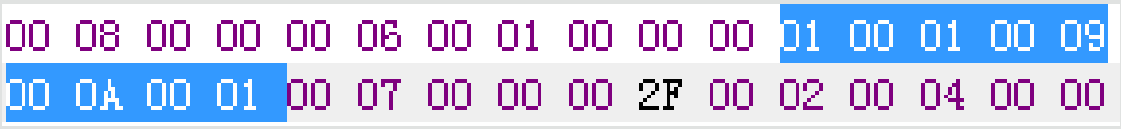
- The Second method – test()



  - ACC_PUBLIC0x0001
- Declared public; may be accessed from outside its package
  - name_index 00 09
- The value of the name_index item must be a valid index into the constant_pool table

The class File Structure - method info

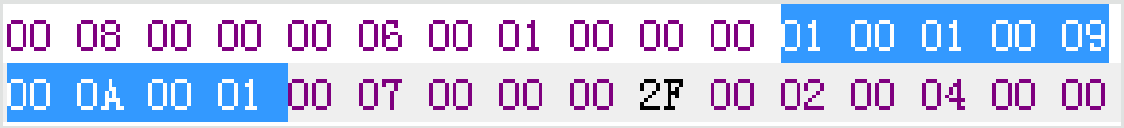
- The Second method – test()



- The entry to the constant pool is 9.
  - #9 = Utf8 test
- This is a normal Java instance method with the name of test()

The class File Structure - method info

- The Second method – test()



  - descriptor_index 00 06A
- The value of the descriptor_index item must be a valid index in the constant_pool table
  - #10 = Utf8 ()V

The class File Structure - method info

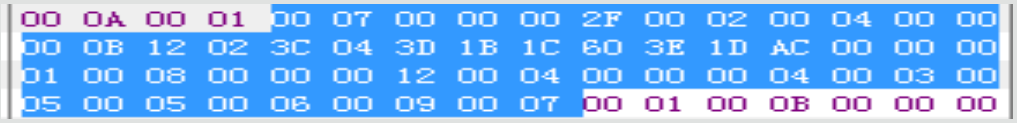
- The Second method – test()

```
00 08 00 00 00 06 00 01 00 00 00 01 00 01 00 09
00 0A 00 01 00 07 00 00 00 2F 00 02 00 04 00 00
```

  - attributes_count 00 01
- The value of the attributes_count item indicates the number of additional attributes of this method
- In this example, there is only one attribute information for the test() method

The class File Structure - method info

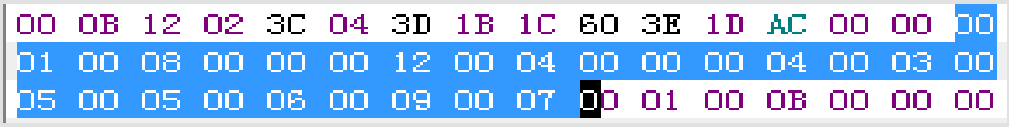
- The Second method – test() method Attribute



Code_attribute { u2 attribute_name_index; 00 07 (code)
u4 attribute_length; 00 00 00 2F (47 bytes)
u2 max_stack; 00 02
u2 max_locals; 00 04
u4 code_length; 00 00 00 0B
u1 code[11]; 12 02 3B 04 3C 1A 1B 60 3D 1C Ac
u2 exception_table_length; { u2 start_pc; u2 end_pc; u2 handler_pc; u2 catch_type; } exception_table[exception_table_length]; 00
u2 attributes_count; 01
attribute_info attributes[attributes_count]; }

The class File Structure - method info

- The Second method – test() method Attribute




```
LineNumberTable_attribute {
    u2 attribute_name_index;
    u4 attribute_length;
    u2 line_number_table_length;
    {   u2 start_pc;
        u2 line_number;
    } line_number_table[line_number_table_length];
}
```

The class File Structure - method info

- The Second method – test() method Attribute

```
00 0B 12 02 3C 04 3D 1B 1C 60 3E 1D AC 00 00 00
01 00 08 00 00 00 12 00 04 00 00 00 04 00 03 00
05 00 05 00 06 00 09 00 07 00 01 00 0B 00 00 00
```

- attribute_name_index : 00 08
- #8 = Utf8 LineNumberTable

- attribute_length: 00 00 00 12

The class File Structure - method info

- SampleClass class Attribute


```
SourceFile_attribute {
  u2 attribute_name_index;
  u4 attribute_length;
  u2 sourcefile_index;
}
```

The class File Structure - method info

- SampleClass class Attribute

attribute_name_index: 00 0B

#11 = Utf8 SourceFile

attribute_length 00 00 00 02

sourcefile_index : 00 0C

The value of the sourcefile_index item must be a valid index in the constant_pool table

- #12 = Utf8 SampleClass.java

Summary

- In this lesson, you should have learned:
  - Understand the class file structure
  - Identify the access field
  - Identify the method structure and bytecode
    - Method Info: Code_attribute
    - Code Attribute: LineNumberTable_attribute
    - Class Attribute: SourceFile_attribute


ORACLE
Academy