



CMSC 131

Object-Oriented Programming I

Bitwise Operations

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Overview

- ▶ Bitwise Operators
- ▶ BitSet class

Operators Revisited

- ▶ **Operators:** We discussed various operators (+, -, *, <, ==, &&, ||) earlier this semester, but omitted some:
Bitwise operators: Operate on values as **binary numbers**
- ▶ **Bitwise Operators:** Recall that all quantities are stored as binary numbers in memory. For example:

```
int x = 1037;    // binary: ...0010000001101 filled out to 32 bits
char c = 'y';    // binary: ...0000001111001 filled out to 16 bits
boolean b = true; // binary: 1
```

- ▶ You are **not** required to know how these conversions are performed. (It is covered in later courses.)
- ▶ Java's bitwise operators act on these binary representations

Bitwise Operators

- ▶ Java supports the standard bit operators:
 - $\sim a$: **complement** of a
 - $a \& b$: **and** (1 if **both** a and b are 1)
 - $a | b$: **or** (1 if **either** a and b are 1)
 - $a \wedge b$: **exclusive or** (1 if **either** a or b is 1, but **not both**)

a	b	$\sim a$	$a \& b$	$a b$	$a \wedge b$
0	0	1	0	0	0
0	1	1	0	1	1
1	0	0	0	1	1
1	1	0	1	1	0

Bitwise Operators

- ▶ Java's bitwise operators can be applied
 - to any **integral type**: **char**, **byte**, **short**, **int**, **long**
 - to **boolean**
- ▶ When applied to integral types, the operations are applied **bitwise**:

```
int a = 45;    // a = ...00101101
```

```
int b = 14;    // b = ...00001110
```

```
int c = a & b; // c = (00101101 & 00001110) = 00001100 (= 12)
```

```
  00101101
  & 00001110
  -----
  00001100
```

```
  00101101
  | 00001110
  -----
  00101111
```

```
  00101101
  ^ 00001110
  -----
  00100011
```

- ▶ **Who uses these**: They are used in often hardware-related tasks (device management) and have other surprising uses. (E.g.: Using exclusive-or you can swap two integers without a temporary.)

Bitwise Operators

▶ **Who uses these:**

- They are used in often hardware-related tasks (device management) and have
- To multiply shift left by powers of two
- To divide shift right by powers of two
- Other surprising uses. (E.g.: Using exclusive-or you can swap to integers without a temporary)

▶ **Using XOR to swap without temporary**

- $A = A \text{ XOR } B$
- $B = A \text{ XOR } B$
- $A = A \text{ XOR } B$

▶ **Example:**

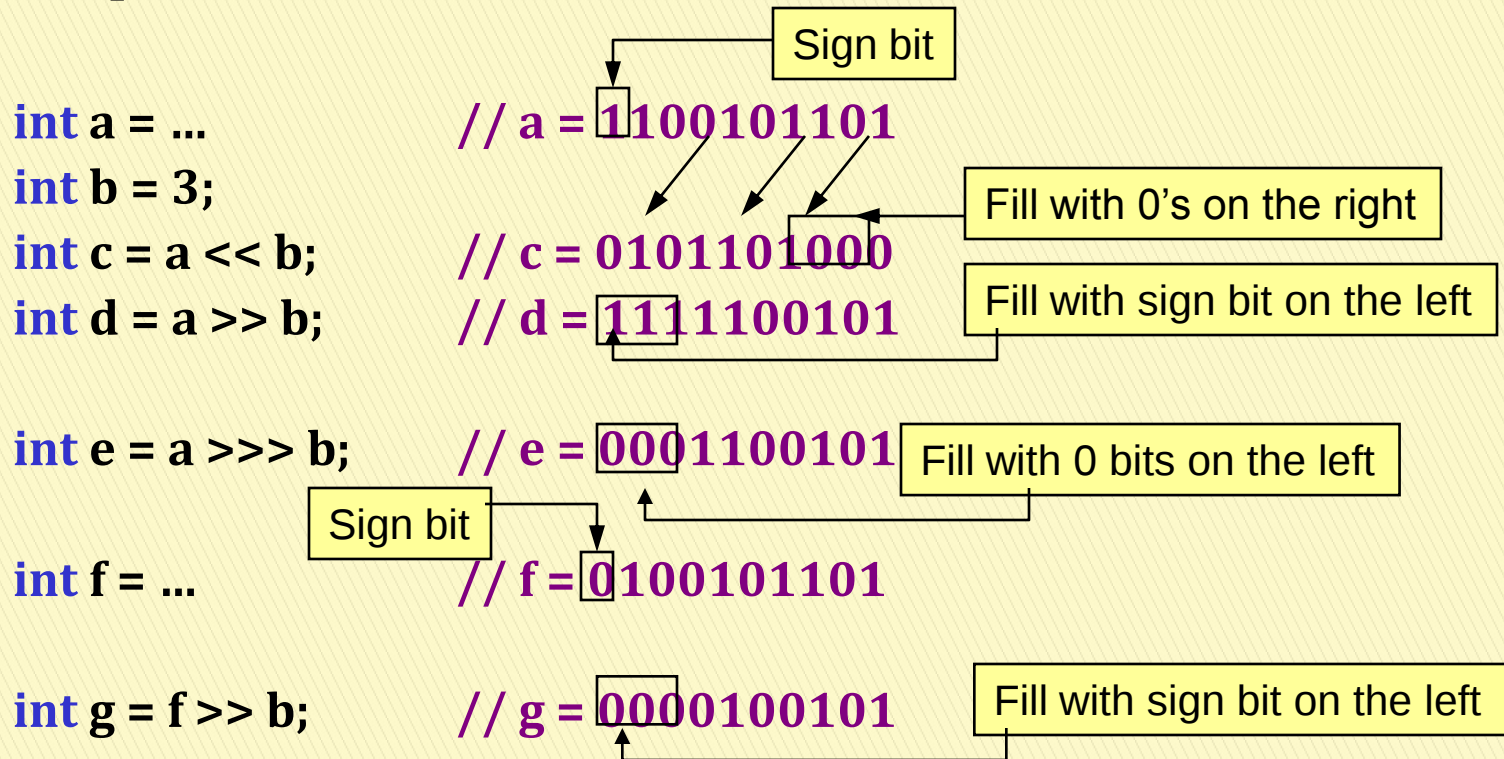
http://en.wikipedia.org/wiki/XOR_swap_algorithm

Shift Operators

- ▶ Another common operation involves **shifting** bits left or right
 - **a << b**: Shift **a** **left** by **b** positions (filling with 0's)
 - **a >> b**: Shift **a** **right** by **b** positions (filling with the **sign bit**)
 - **a >>> b**: Shift **a** **right** by **b** positions (filling with 0's)
- ▶ **Notes:**
 - **a** must be **integral** type (byte, short, ..., long).
 - **b** should be a **nonnegative integral** type
- ▶ **Sign bit**: Because there is no “-” sign in binary, Java encodes negative numbers using a method called **2's-complement representation**. We will not discuss this, but a key element is that the leftmost bit, called the **sign bit**, is:
 - 0 for **positive** numbers
 - 1 for **negative** numbers
- ▶ We often want to keep the sign bit **unchanged** when shifting

Shift Operators

- **Example:** Rather than use 32-bit int's, we use a 10-bit example



BitSet Class

- ▶ The BitSet class implements a vector of bits
<http://download.oracle.com/javase/6/docs/api/java/util/BitSet.html>
- ▶ Let's take a look at the class methods
- ▶ How can we use this class in order to implement a Sudoku validator?