**Bitwise Operators in C**

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**1. Introduction to Bitwise Operators**

Bitwise operators are a core part of the C programming language, allowing manipulation of individual bits within data types. Understanding bitwise operations is crucial for low-level programming, embedded systems, and situations where performance and memory efficiency are paramount.

Bitwise operators operate directly on the binary representations of numbers. Instead of dealing with the entire value as a whole, they manipulate the individual bits that make up the value. This allows for fine-grained control over data, making it possible to perform tasks like bit masking, setting or clearing specific bits, and performing operations more efficiently than their arithmetic counterparts.

**Types of Bitwise Operators:**

1. **AND (&)**: Performs a logical AND operation on each pair of corresponding bits of two numbers.
    - **Example**:

a. int a = 5; // Binary: 0101

b. int b = 3; // Binary: 0011

c. int result = a & b; // Result: 0001 (Binary), 1 (Decimal)

2. **OR (|)**: Performs a logical OR operation on each pair of corresponding bits of two numbers.
    - **Example**:

a. int a = 5; // Binary: 0101

b. int b = 3; // Binary: 0011

c. int result = a | b; // Result: 0111 (Binary), 7 (Decimal)

3. **XOR (^)**: Performs a logical XOR (exclusive OR) operation on each pair of corresponding bits.
    - **Example**:

a. int a = 5; // Binary: 0101

b. int b = 3;  // Binary: 0011

c. int result = a ^ b;  // Result: 0110 (Binary), 6 (Decimal)

4. **NOT (~)**: Performs a logical NOT operation on each bit, flipping all the bits in the number.
    - **Example**:

a. int a = 5;  // Binary: 0101

b. int result = ~a;  // Result: 1010 (Binary), -6 (Decimal, Two's Complement)

5. **Left Shift (<<)**: Shifts the bits of the left-hand operand to the left by the number of positions specified by the right-hand operand.
    - **Example**:

a. int a = 5;  // Binary: 0101

b. int result = a << 1;  // Result: 1010 (Binary), 10 (Decimal)

6. **Right Shift (>>)**: Shifts the bits of the left-hand operand to the right by the number of positions specified by the right-hand operand.
    - **Example**:

a. int a = 5;  // Binary: 0101

b. int result = a >> 1;  // Result: 0010 (Binary), 2 (Decimal)

**2. Practical Example: Bitwise Operations in Action**

**Problem Statement:**
Let's write a C program that uses bitwise operators to determine whether a number is even or odd.

**Solution Explanation:** We can use the AND operator (&) with 1 to check if the least significant bit (LSB) of a number is 0 (even) or 1 (odd). This is because even numbers have their LSB as 0, and odd numbers have their LSB as 1.

**Code Implementation:**

```
1. #include <stdio.h>
2.
3. int main() {
4.     int num;
```

```
5.
6.      // Input a number from the user
7.      printf("Enter an integer: ");
8.      scanf("%d", &num);
9.
10.     // Use bitwise AND to check if the number is even or odd
11.     if (num & 1) {
12.         printf("%d is odd.\n", num);
13.     } else {
14.         printf("%d is even.\n", num);
15.     }
16.
17.     return 0;
18. }
```

**Explanation:**

- The expression num & 1 checks the LSB of the number.
- If the LSB is 1, the number is odd.
- If the LSB is 0, the number is even.

**3. Question:**

**Test Your Understanding:**

- **Q1**: Write a C program that toggles the 3rd bit (from the right) of a given integer. Explain how the XOR (^) operator is used in your solution.
- **Q2**: Given an integer x, write a C function that clears (sets to 0) the 4th bit from the right. Provide both the theoretical explanation and the code.
- **Q3**: How would you use bitwise operators to efficiently multiply a number by 4? Write the C code for this operation.

**Conclusion:**

Bitwise operators are powerful tools in C programming that provide fine control over data at the bit level. By mastering these operators, you can write more efficient and concise code, especially in embedded systems and hardware-related programming.