# BITWISE OPERATIONS IN EMBEDDED PROGRAMMING

The bitwise or bit-level operator lay's foundation for bitwise operations in embedded programming. We hope you already have sound knowledge of binary number systems in order to follow this tutorial. Many newbies found themselves confuse with **Bitwise Vs. Boolean** operations. A **bitwise expression** is used when we want to modify a variable by changing some or any of the individual bits of the variable. **&** and **|** are bitwise operators for **AND** & **OR** respectively. We'll see in later part of this post, how it will be used to set, clear and extract a bit using bitwise operations. A **Boolean expression** is used when we want to know something about a variable is it equal to 12, is it greater than 12 or is it less than 5 etc. Boolean operators are: **&&** (logical and), **||** (logical or), **!** (logical not). **X** && **Y** returns TRUE only if both **X** and **Y** are TRUE. **X** || **Y** returns TRUE if either **X** or **Y** are TRUE.

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## Basics of Bitwise Operations

Now let's concentrate only on bitwise operations. We'll learn how these bitwise operations allow's us for Setting, Inverting, Toggling, Clearing, Extracting and Inserting bits in embedded programming. Here is a table which summarizes operations with 2-operands.

| A | B | A \| B | A & B | A ^ B |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 | 0 |

Let's take variable **A** and **B**. We'll perform bitwise operation on these two variables. This example will help you understand their operation. Let's first declare these two variables:

```
uint8_t A = 0x3B
 //00111011;
```

```
uint8_t B = 0x96
 //10010110;
```



### AND (& in C)

AND compares each bit and returns 1 if the two bits are 1 (TRUE) otherwise 0 (FALSE). So: **C = A & B**;

| | |
|---|---|
| | **00111011**……………….. (A=0x3B) |
| **&** | **10010110**……………….. (B=0x96) |
| | **00010010** |

The value of **C** will be 0x12 or in binary **00010010**. That is where there is a 1 in each bit for both values.

### OR (| in C)

OR will return a **1** if there is a **1** in either value at that bit. So: **C = A | B**;

| | |
|---|---|
| | **00111011**……………….. (A=0x3B) |
| **\|** | **10010110**……………….. (B=0x96) |
| | **10111111** |

The value of C will be 0xBF or in binary 10111111

### XOR (^ in C – Exclusive OR)

XOR will return a **1** if there is a **1** at that bit for either value but not both.  For example, if bit position **5** for both values has a **1** then XOr returns a **0**. But if only one has a **1** and the other has a **0** XOR returns a **1**. So: **C = A^B**;

| | |
|---|---|
| | **00111011**……………….. (A=0x3B) |
| **^** | **10010110**……………….. |

| | |
|---|---|
| | (B=0x96) |
| | **10101101** |

The value of **C** will be 0xAD or in binary **10101101.**

### NOT (! in C)

This returns the compliment of a value. This mean where there was a **0** there will now be a **1** and vice versa. So: **C = ~(A);**

| | |
|---|---|
| **!** | **00111011**………………..<br>(A=0x3B) |
| | **11000100**………………..<br>(C=0xC4) |

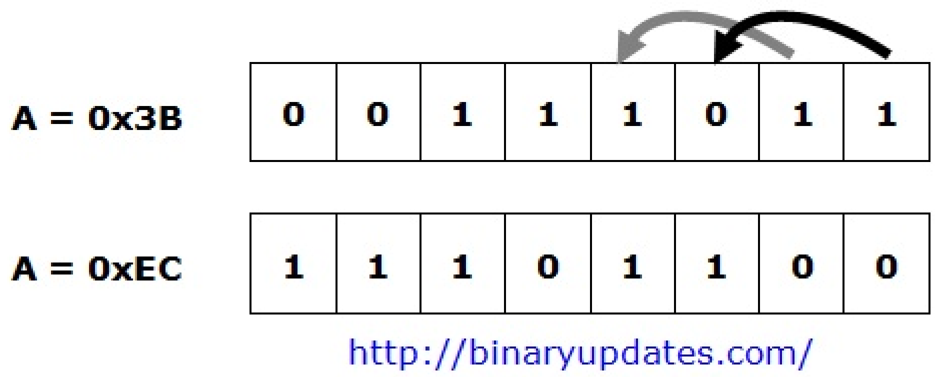
The value of **C** will be 0xC4 or in binary **11000100**

### Bitwise Shift Operators (<<, >>)

And then there are two shift operators – **Left shift** and **Right shift**. These operators shift the bits by the corresponding value, in other word's move the bits.

The sign **<<** for left shift and **>>** for right shift. Here is an example:

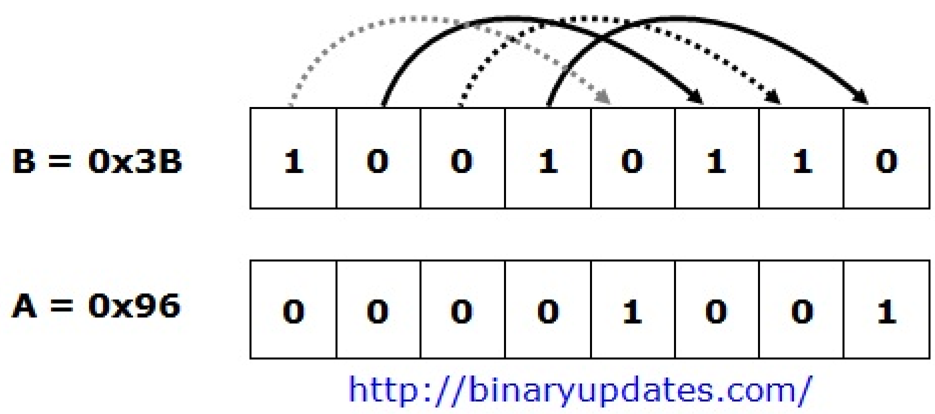
```
C = A << 2;  // left shift A by 2
```




*Bit Shift Operator (Left)*

The value of **C** becomes **0xEC** or in binary 1110**11**00 after shifting 2-bits to the left.

```
D = B >> 4;  // right shift B by 4
```



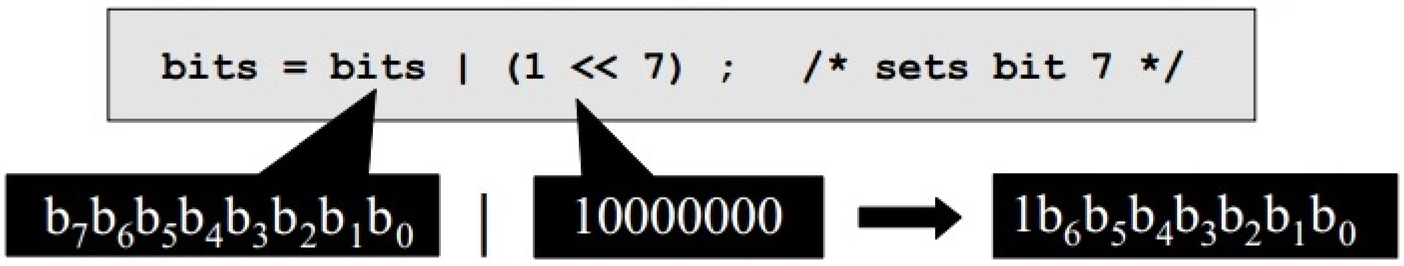

*Bit Shift Operator (Right)*

The value of **D** becomes **0x03** or in binary 0000**1001** after shifting 4-bits to right.

## Setting bits, Inverting bits

Let's say we have variable called **bits** and we have asked to set the bit-7. This can be achieved by writing this single line of code.

When we assign value directly to any register. This may change the value of other bits which might be used to control other hardware feature. To avoid such scenario best practice is to use bit **masking**. This is why we must know bit masking while using *bitwise operations in embedded programming*.




*Setting Bits using Bitwise Operators*

```
bits = bits | (1 << 7) ; /* sets bit 7 */
```

This would usually be written more succinctly as:

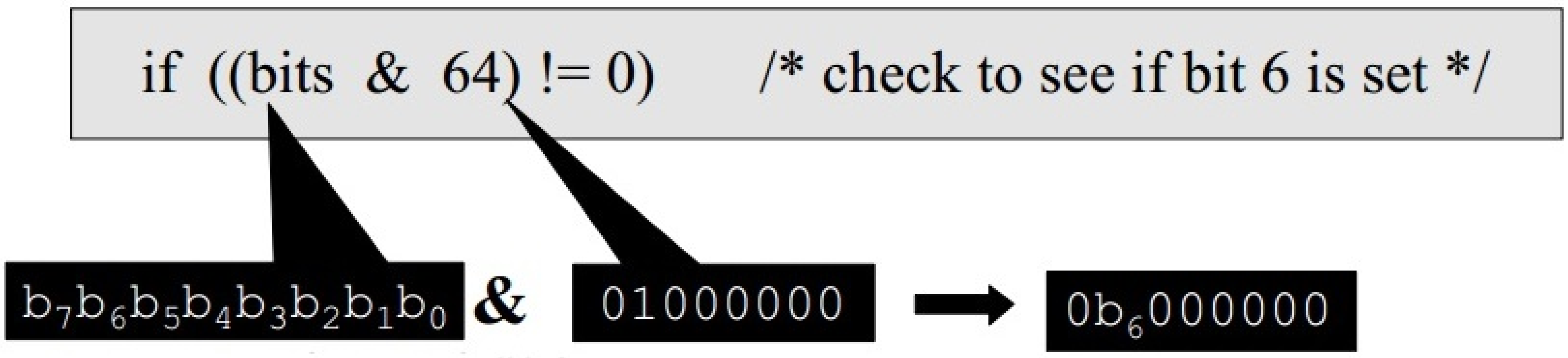
```
bits |= (1 << 7) ; /* sets bit 7 */
```

Inverting (toggling) is accomplished with bitwise-XOR. In following, example we'll toggle bit-6.

```
bits ^= (1 << 6) ; /* toggle bit 6 */
```

### Testing Bits

Form a mask with **1** in the bit position of interest, in this case bit-**6**. Then bitwise AND the mask with the operand. The result is non-zero if and only if the bit of interest was 1:




*Test Bits using Bitwise Operators*

```
if ((bits & 64) != 0) /* check to see if bit 6 is set */
```

Same as:

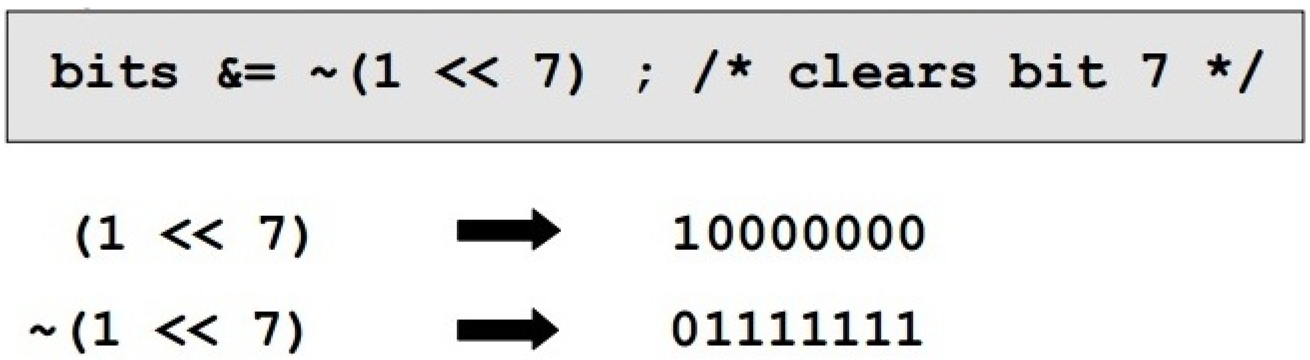
```
if (bits & 0x64) /* check to see if bit 6 is set */
```

Same as:

```
if (bits & (1 << 6)) /* check to see if bit 6 is set */
```

### Clearing Bits

Let's say if we want to clear bit-7. This can be accomplished using bitwise-AND operator




*Clear Bits using Bitwise Operators*

Mask must be as wide as the operand! if bits is a 32-bit data type, the assignment must be 32-bit:

```
bits &= ~(1L << 7) ; /* clears bit 7 */
```

### Extracting Bits

Let's say we have given a 32-bit number and we asked to extract bits from it. Assume that 32-bit number in hex is **0xD7448EAB**. In binary= **1101 01***11 0100 0100 1000 11***10 1010 1011. Now we have asked to extract 16-bits from** bit number **10** through **25.**

HINT: The lower 10 bits (Decimal) are ignored. i.e. **10 1010 1011** are ignored. And the upper 6 bits (Overflow) are ignored. i.e. **1101 01** are ignored. For this example you would output **1101 0001 0010 0011**, which is **0xD123**.

To extract the bits first we have to use bitwise operator in combination with a bit mask to extract bits 10 through 25. The masking value will be **0x3FFFC00**. Now we have two ways we can achieve result.

**Method-I**

```
unsigned int number = 0xD7448EAB;
unsigned int value = (number & 0x3FFFC00) >> 10;
```

**Method-II**

```
unsigned int number = 0xD7448EAB;
unsigned int value = (number >> 10) & 0xFFFF;
```

| | | |
|---|---|---|
| 0xD7448EAB | | 1101 0111 0100 0100 1000 1110 1010 1011 |
| 0x3FFFC00 | & | 0000 0011 1111 1111 1111 1100 0000 0000 |
| 0x3448C00 | | 11 0100 0100 1000 1100 0000 0000 |

*Extracting Bits using Bitwise Operators*

Now if we follow Method-I and after equating. We've got **0x3448C00** (In binary **11010001001000110000000000**). When we shift 10 bits to right, we'll get **0xD123** i.e. in binary **1101000100100011**.

### Monitoring Specific Bit

Monitoring specific bit in register is very important. In Embedded programming, very often we need to read status of flag bit in hardware register. These flag bit controls or indicate hardware feature. Also they are every useful while reading, writing data to and from microchip. So we continuously monitor these bits in register to carry out desired function by microchip. Let's say if we want to monitor $4^{th}$ bit for any change, we'll write function as below:

```
while( bits & (1<<4) ) // monitor for 4th bit changing from 0 to 1
{
        .......
        .......
}
```

The $4^{th}$ bit of register bits is '1' the result of **(bits & (1<<4))** will always be zero. When $4^{th}$ bit is '**1**' then **(bits & (1<<4))** will be equal to **(1<<4)** which is greater than 0 and so this evaluates as **TRUE** condition and code inside while loop get executed.

Now let's say if we want to monitor $4^{th}$ bit state from 1 to 0. In this case, we only need to negate the condition inside of while statement.

```
while( ~(bits & (1<<4)) ) // monitor for 4th bit changing from 1 to 0
{
        .......
        .......
}
```

Bitwise operators save memory and it is fast. This all leads to improve performance. I hope now you know that why **bitwise operations in embedded programming** used such a widely. If you have any questions or suggestions then feel free to leave a comment.