

# Bitwise Operators and Buses

*This lecture describes C's bitwise logical operators. It also explains how a grouping of logic-level signals (a bus) can be used to represent or transmit a number or a character.*

*After this lecture you should be able to evaluate expressions that use C's bitwise logical operators. You should also be able to convert between logic levels on a bus and the corresponding numerical or character value.*

## C's Bitwise Logical Operators

These operators operate bit-by-bit on the binary representation of their operands.

The bitwise complement operator, `~`, is a unary operator similar to the logical negation operator and has the same precedence. However, it inverts the values of the bits in the binary representation of the operand. If a bit is 0, the bitwise negation sets that bit in the result to 1 and vice versa. For example, `~ 2` has the value 1 (2 is 10 and 1 is 01 in binary).

The bitwise 'and', 'exclusive-or'<sup>1</sup> and 'or' operators are `&`, `^`, and `|`. They result in the operation being applied to the *bits* in the binary representations of their operands. Both operators have lower precedence than the comparison operators but higher precedence than the logical operators. The bitwise 'and' has a higher precedence than the bitwise 'or'.

Exercise: What are the values of the following expressions?

```
( 7 ^ 5 ) | 5  
0xAA & 15
```

Note that there is an important difference between logical and bitwise logical operators. For example, the expression `5 && 2` is 1 while `5 & 2` is 0.

## Binary Numbers and Logic Levels

Computers represent binary values by using two voltages. For example, one way is to use 0 volts to represent a binary '0' and 5 volts to represent a binary '1'. These voltages, sometimes also called low (L) and high (H), are called logic levels.

A binary number can be represented by a collection of 8 (for a `char`) or 16 (for an `int`) signals<sup>2</sup>.

Each signal represents a particular bit of a binary number. A group of related signals is called a *bus*.

Exercise: The connector used between a PC and a printer has 25 signal pins. Pin numbers 9 to 2<sup>3</sup> carry signals generated by the PC that provide the printer with the ASCII value of the character that should be printed. You measure the following voltages: 0,5,5,5, 0,5,5,0 on the signal pins. What character is the printer trying to print?

## Summary of Operator Precedence

The following table shows the operators that have been studied in this course in order of precedence. If more than one operator of the same precedence could be evaluated, the operator on the left takes precedence except for the unary and assignment operators where the grouping is right to left.

operator	symbol(s)
parentheses, array index, function call	( ) [ ] name ( )
unary operators	! ~
multiplicative	* /
additive	+ -
relational	< > <= >=
equality	== !=
bitwise and	&
bitwise exclusive or	^
bitwise OR	
logical AND	&&
logical OR	
assignment	=

<sup>1</sup>The exclusive or operator gives 0 if the two bits are the same and 1 otherwise.

<sup>2</sup>A signal is a voltage that carries information.

<sup>3</sup>in order from most significant to least significant bit.