

# EECS 370 - Introduction to Computer Organization

## An introduction to binary numbers and 2's complement notation

### Binary/Hexadecimal/Decimal Conversion

Binary, hexadecimal and decimal are all different ways to express numbers. You are all familiar from gradeschool with decimal notation, which uses base 10. Binary and hexadecimal work exactly the same way, except they are base 2 and base 16, respectively.

Here's a table to get you started on how to think about the different notations:

decimal	hex	binary
0	0	0
1	1	1
2	2	10
3	3	11
4	4	100
5	5	101
6	6	110
7	7	111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111
16	10	10000
17	11	10001
18	12	10010
19	13	10011
20	14	10100
.	.	.
.	.	.
.	.	.

### Decimal to binary conversion:

To do decimal to binary conversion, one algorithm you can use is to simply divide the decimal number by two and continue recording the remainder until you get to a quotient of zero. For example, suppose I began with the number 11:

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11/2 = 5 Remainder: 1
 5/2 = 2 Remainder: 1
 2/2 = 1 Remainder: 0
 1/2 = 0 Remainder: 1

```

The binary number you get out of this is simply 1011. You can verify that this is the right number by converting the binary back to decimal as follows:

$2^3$	$2^2$	$2^1$	$2^0$
8	4	2	1
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1	0	1	1

$$8 + 0 + 2 + 1 = 11!$$

### Hex conversions:

Given a binary number, you can easily convert to the hexadecimal representation by grouping the binary number into groups of 4 digits. The possible values for the hex number are up in the table above. Given a decimal number, you can use a similar algorithm to the one above for binary conversions, repeatedly dividing by 16, remembering that the remainder can be represented by the digits 0 -> 9 and the letters A -> F as shown in the table above.

Example Conversion:

$$73289 \text{ (decimal)} = 0001\ 0001\ 1110\ 0100\ 1001 \text{ (binary)} = 0x11E49 \text{ (hex)}$$

**Note:** hexadecimal numbers are often expressed beginning with a 0x

### Questions:

Convert the following decimal numbers to both binary and hex:

- 1) 32
- 2) 5236
- 3) 21387

Convert the following hex numbers to binary and decimal:

- 1) 0x67A0
- 2) 0x002AC
- 3) 0x70AFF

Convert the following binary numbers to hex and decimal:

- 1) 000111010
- 2) 100100101
- 3) 001001111

### Two's Complement

Two's complement is the way computers use to express integers. Positive integers are expressed exactly as the binary numbers above are expressed. Two's complement makes it easy for computers to express negative integers. Suppose we wanted to express the number -34 in 8-bits (for simplicity's sake -- we could just as easily be working with 32 or 128-bits)

Step 1: Begin by writing out 34 in binary form:

$$00100010$$

Step 2: Invert all of the digits:

11011101

Step 3: Add 1:

11011110

Presto! You have your negative number. So -34 is expressed as 11011110. That means any number with a 1 in its most significant bit (leftmost) is negative. Likewise, given a two's complement number, you can easily find out what it represents by inverting the digits back and adding a 1.

### Questions:

1. Convert the following decimal numbers into 32-bit two's complement:

- a) 145
- b) -23
- c) -8132

2. Convert the following 32-bit two's complement numbers into decimal:

- a) 1000 0000 0000 0100 0000 0000 0010 0000
- b) 1111 1111 1111 1111 1111 1111 1111 1001
- c) 1111 1111 1101 1111 1111 1111 1000 0110