# CPE 323: Introduction to Embedded Computer Systems
# Homework I

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| 1 (13) | 2 (20) | 3 (15) | 4 (10) | Total (58) |
|---|---|---|---|---|
| | | | | |

**Problem #1 (13 points)**

**(a) (5 points)**

Fill in the following table specifying the ranges of the following data types.

| Type | Minimum | Maximum |
|---|---|---|
| 8-bit unsigned integers | 0 | 255 |
| 16-bit unsigned integers | 0 | 65,535 |
| 8-bit signed integers (2's complement) | 1000 0000 (-128) | 0111 1111 |
| 16-bit signed integers (2's complement) | 1000 0000 0000 0000 | 0111 1111 1111 1111 |
| 12-bit signed integers (2's complement) | 1000 0000 0000 | 0111 1111 1111 |

**(b) (8 points)**

Fill in the following table. For integers find their binary, octal, and hexadecimal representation in a 16-bit computer using 2's complement.

| Number (decimal) | Binary | Hex | Octal |
|---|---|---|---|
| 12,212 | 0010 1111 1011 0100 | 2FB4 | 27664 |
| -3,460 | 1111 0010 0111 1100 | F27C | -6604 |

12,212: Binary 0010 1111 1011 0100
2 F B 4

12212/2 0
6106/2 0
3053/2 1
1526/2 0
763/2 1
381/2 1
190/2 0
95/2 1
47/2 1
23/2 1
11/2 1
5/2 1
2/2 0
1/2 1
0

12212/8 R4
1526/8 R6
190/8 R6
23/8 R7
2/8 R2
0/8 R0

-3460

3460/2 0
1730/2 0
865/2 1
432/2 0
216/2 0
108/2 0
54/2 0
27/2 1
13/2 1
6/2 0
3/2 1
1/2 0

0000 0101 1000 0100
1111 1010 0111 1011
+ 1
1111 0010 0111 1100
F 2 7 C

3460/8 = R4
432/8 = R0
54/8 = R6
6/8 = R6
0/8 = R0

**Problem #2 (20 points)**

Consider the following arithmetic operations. Find the results and set the flags C, V, N, and Z accordingly.
Show your work step-by-step: that means convert the input operands to binary, find the results of arithmetic operations in binary, find the flags, and convert the result back to decimal representation.

(a) 8-bit, two's complement

$20_{10} + 100_{10}$

20/2 = 0
10/2 = 0
5/2 = 1
2/2 = 0
1/2 = 1

100/2 = 0
50/2 = 0
25/2 = 1
12/2 = 0
6/2 = 0
3/2 = 1
1/2 = 1
0/2 = 0

0001 0100
+ 0110 0100
0111 1000

Binary

Z = 0
N = 0
V = 0
C = 0

Back to decimal

$0 \times 2^7 + 1 \times 2^6 + 1 \times 2^5 + 1 \times 2^4 + 1 \times 2^3 + 0 + 0 + 0$

$0 + 64 + 32 + 16 + 8 = 120$ ✓

20+100 ✓

(b) 8-bit, two's complement (hint: implement subtraction through addition and set flags accordingly)

$(-25)_{10} - 69_{10}$

25/2 = 1
12/2 = 0
6/2 = 0
3/2 = 1
1/2 = 1

69/2 = 1
34/2 = 0
17/2 = 1
8/2 = 0
4/2 = 0
2/2 = 0
1/2 = 1
0

0001 1001
1110 0110
+ 1
1110 0111

0100 0101
1011 1010
+ 1
1011 1011

$\boxed{1}$1111 111
1110 0111
+ 1011 1011
1010 0010

Binary

back to decimal

$1 \times 2^7 + 0 \times 2^6 + 1 \times 2^5 + 0 \times 2^4 + 0 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 0 \times 2^0$

$-128 + 32 + 2 = -94$

C = 1
V = 0
Z = 0
N = 1

**Problem #3 (15 points)**

**(a) (10 points)** Convert the following number from decimal to the IEEE 32-bit floating point. Show your work.
$-7.275_{10}$

**(b) (5 points)** Could you convert the decimal number 1048576.125 into a single precision float without using any significant bits of the mantissa? Explain your answer.

Solutions:

a) 7/2 = 1
3/2 = 1
1/2 = 1
0/2 = 0

= -111

| | | |
|---|---|---|
| .275 x 2 | 0.55 | 0 |
| .55 x 2 | 1.1 | 1 |
| .1 x 2 | 0.2 | 0 |
| .2 x 2 | 0.4 | 0 |
| 0.4 x 2 | 0.8 | 0 |
| 0.8 x 2 | 1.6 | 1 |
| 0.6 x 2 | 1.2 | 1 |
| .2 x 2 | 0.4 | 0 |
| 0.4 x 2 | 0.8 | 0 |
| 0.8 x 2 | 1.6 | 1 |
| 0.6 x 2 | 1.2 | 1 |
| 0.2 x 2 | 0.4 | 0 |
| | | 0 |

| | |
|---|---|
| 129/2 | 1 |
| 64/2 | 0 |
| 32/2 | 0 |
| 16/2 | 0 |
| 8/2 | 0 |
| 4/2 | 0 |
| 2/2 | 0 |
| 1/2 | 1 |

-7: -111

0.275: 01.00 0110 0110 0110 11

I] $-7.275_{10}$

= -111 . 01 00 0110 0110 0110....

II] $1.1101\ 0001\ 1001\ 1001 \ldots \times 2^2$ (Scientific notation)

III] $\underbrace{X}_{\text{1 sign bit}}$ $\underbrace{XXXX\ XXXX}_{\text{exponential}}$ $\underbrace{XXX\ldots XXX}_{\text{23 fraction bits}}$

127+2=129

1 + 1000 0001 + 1101 0001 1001 1001 1001 1001

1100 0000 1001 0110 0110 0110 0110 0110

$\boxed{1100\ 0000\ 1110\ 1000\ 1100\ 1100\ 1100\ 1101}$

b) As shown below, the Mantissa is used in the final representation of 1048576.125 in IEEE Floating point. Since the exponent is not all zeroes, the MSB of the mantissa is 1. Which means we used a significant bit of the mantissa, and therefor 1048576.125 cannot be represented without a mantissa sig fig.

$1048576_{10} = 1000\ 0000\ 0000\ 0000\ 0000_2$

$0.125_{10} = 0.001$

1000 0000 0000 0000 0000. 001

$1.0000\ 0000\ 0000\ 0000\ 0000\ 01 \times 10^{19}$

Start of Mantissa

$127 + 19 = 146_{10} = 1001\ 0010_2 =$ $\boxed{0100\ 1001\ 1000\ 0000\ 0000\ 0000\ 0000\ 0001}$

**Problem #4 (10 points)**

A string variable is initialized to "Welcome to CPE 323, Fall 2020!". The first character in the string is upper case letter 'W'. Assume the string is terminated by a NULL ASCII character (0x00). How many bytes does this string take in memory (include the terminating NULL character)? Using the ASCII table, fill in the following table by entering hexadecimal values of the characters in the string. How many bytes are needed to store this string in memory?

| String | HEX value |
|---|---|
| Welcome to CPE 323, Fall 2020! | W e l c o m e t o C P E<br>57 65 6C 63 6F 6D 65 74 6F 43 50 45<br>3 5 3 , F a l l 2 0 2 0<br>33 35 33 2C 46 61 6C 6C 32 30 32 30<br>!<br>21 |

57 65 6C 63 6F 6D 65 74 6F 43 50 45 33 35 33
2C 46 61 6C 6C 32 30 32 30 21

30 bytes for the string, 1 byte for NULL character,
So total is 31 bytes.