

Project 1: Working with Bits. Due date: Feb. 28, 11:55PM EST.

You may discuss any of the assignments with your classmates and tutors (or anyone else) but all work for all assignments must be entirely your own. Any sharing or copying of assignments will be considered cheating.

Things to remember for all of the programs:

- If you are allocating memory using malloc, you need to deallocate it using free. Proper memory management is part of the grade for each problem.
- Do not return dangling pointers (pointer to a local variable that was created in a function) it may take a while before you see the results and these are things that are hard to debug.
- Use sizeof operator to determine sizes of types, do not hardcode the actual numerical values. The only exceptions to this rule if for problems 4 and 5 in which you have to assume that the single precission floating point numbers are represented using 4 bytes (32 bits).
- Use parenthesis to avoid ambiguity of operator precedence (this will save you a lot of debugging time).

The problems below are listed in order of difficulty. You should attempt to solve them in that order.

Problem 1 (20 points): Break a Secret Messages

A beginner programmers was attempting to print text to an output file. Something went wrong and the output file contains numbers instead of the text. Your job is to read the file and figure out the text that your fellow programmer started with.

The numbers in the output file resulted from incorrect type of the pointer that was used to iterate through the data, not by corruption of the data, so all the correct bits are there. You simply need to interpret them using correct types.

You can assume that the text file contains at most 1000 lines of numbers (one number per line). You can also assume that the numbers fit in the integer range.

Your program should work with any file name. The file name should be specified as the command line argument to the program.

You need to define a function with the following signature

```
char * convert_to_string ( int text[] , int size );
```

in a file called projl.c. This function should take an array of integers (these are the values read from your file) and the number of elements in the array. It should return a string that corresponds to the original message.

Problem 2 (20 points): Create a Secret Message

After you solved probelm 1, you decide that it would actually be useful to store secret messages in this fashion (and distribute them to your yournger collegues who did not yet have a pleasure of taking CSO and cannot possibly figure out what they mean).

Write a program that reads regular text (containing ASCII characters) from an input file (provided as argument 1 on the command line) and writes its numberical equivalent to an output file (provided as argument 2 on the command line). The output file should contain numbers (in the range of int type), one per line.

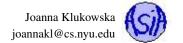
You need to define a function with the following signature

```
int convert_to_int ( char * text );
```

in a file called projl.c. This function should take a c-string as its parameter and convert the first sizeof(int) bytes of the c-string to an integer that is returned. Your function should work even if the c-string passed to it has fewer than sizeof(int) characters (the missing bits should be filled with zeroes.

Problem 3 (20 points): Extract bits and bytes

Implement two functions: one that extracts the most significant byte out of an integer variable and one that extracts the least significant byte out of an integer variable.



You need to define two functions with the following signatures in a file called proj1.c.

```
int get_most_significant_byte ( int x );
```

This function should take an integer as its parameter and return an integer that stores the value of the most significant byte of that number.

```
int get_least_significant_byte ( int x );
```

This function should take an integer as its parameter and return an integer that stores the value of the least significant byte of that number.

For example:

when called with 123 (0x0000007b), the first function should return 0 (0x00) and the second should return 123 (0x7b); when called with -123 (0xffffff85), the first function should return 255 (0xff) and the second should return 133 (0x85); when called with 128974848 (0.07b00000), the first function should return 7 (0x07) and the second should return 0 (0x00).

RESTRICTION: You are not allowed to use any loops or conditional statements in the implementation of this function. Your implementation should use sizeof(int) to determine the number of bytes in an integer, not a hardcoded 4.

Problem 4 (20 points): Split Bits of a Single Precission IEEE Floating Point

Imeplement functions that extract the bits from the single precission IEEE floating point number. Your need to write three different functions: one that extracts the exponent bits (exp in the textbook), one that extracts the fraction bits (frac in the textbook), and one that extracts the sign bit (s in the textbook). Use section 2.4.2 in the textbook as a reference regarding which bits belong to which of the three parts.

You need to define three functions with the following signatures in a file called projl.c

```
unsigned int * get_exp ( float f );
```

This function should take a single precission floating point number and return bits conresponding to the exponennent bits as a pointer to unsigned int. All bits other than the exponent bits should be zeroed in the returned value.

```
unsigned int * get_frac ( float f );
```

This function should take a single precission floating point number and return bits conresponding to the fraction bits as a pointer to unsigned int. All bits other than the fraction bits should be zeroed in the returned value.

```
unsigned int * get_sign ( float f );
```

This function should take a single precission floating point number and return the bit conresponding to the sign bit as a pointer to unsigned int. All bits other than the sign bit should be zeroed in the returned value. (Notice that this means that the returned value will be either or zero bits or a single 1 bit in the most significant position followed by all zero bits.)

Here are sample outputs that your functions should produce (assuming the bits of the values that you are returnding are printed):

value	1.200000e+38	
all bits		01111110101101001000111001010010
exp	2122317824	011111101000000000000000000000000000000
frac	3444306	000000001101001000111001010010
sign	0	000000000000000000000000000000000000000

value	201.0	
all bits		010000110100100100000000000000000000000
exp	1124073472	010000110000000000000000000000000000000
frac	4784128	000000001001001000000000000000000000000
sign	0	000000000000000000000000000000000000000

value	-1024.25	
all bits		1100010010000000000100000000000
exp	1149239296	010001001000000000000000000000000000000
frac	2048	0000000000000000000100000000000
sign	2147483648	100000000000000000000000000000000000000

value	1.399995e-40	
all bits		00000000000011000011001000011
exp	0	000000000000000000000000000000000000000
frac	99907	00000000000011000011001000011
sign	0	000000000000000000000000000000000000000

value inf	
all bits	0111111110000000000000000000000000000



exp	2139095040	011111111000000000000000000000000000000
frac	0	000000000000000000000000000000000000000
sign	0	000000000000000000000000000000000000000

Note that for this problem you are simply writing the functions, not a program that displays the above values (this will come in the next problem).

Problem 5 (20 points): Deciphering Single Precission IEEE Floating Point

In this problem you will build on the functions that you created for problem 4. The goal is to be able to write a program that determines the values of E, M and s variables in the formula

$$V = (-1)^s \times M \times 2^E$$

used for encoding the floating point numbers. See section 2.4.2 in the textbook for reference.

You need to implement the following functions in a file called proj1.c:

```
int is_normalized ( float f );
```

This function should take a single precission floating point number and return zero (a.k.a., false) when the value of f is not normalized, and any other number (a.k.a., true) when the value of f is normalized.

```
int is_denormalized ( float f );
```

This function should take a single precission floating point number and return zero (a.k.a., false) when the value of f is not denormalized, and any other number (a.k.a., true) when the value of f is denormalized.

```
int is_special ( float f );
```

This function should take a single precission floating point number and return zero (a.k.a., false) when the value of f is not special, and any other number (a.k.a., true) when the value of f is special.

```
int get E ( float f );
```

This function should take a single precission floating point number and return the numerical value of E from the above formula. The value of E is related to the exp bits.

```
char * get_M ( float f )
```

This function should take a single precission floating point number and return the numerical value of M from the above formula. The value of M should be returned as a string with the appropriate leading character and containing the decimal point. The value of M is related to the frac bits.

```
int get_s ( float f );
```

This function should take a single precission floating point number and return the numerical value of s from the above formula, i.e. 0 for positive values of f, 1 for negative values of f. The value of f is related to the exp bits.

Write a program that uses all of the above functions decipher the binary encoding of single precision IEEE floating point numbers. Your program should prompt the user for a floating point number and display the information about that number as shown in the exaples below.

User enters 1.2e+38

```
value
      1.200000e+38
all bits
                 1111110101101001000111001010010
      2122317824
                 exp
         3444306
                 0000000001101001000111001010010
frac
                 sign
1.200000e+38 is normalized
E = 126
M = 1.01101001000111001010010
s = 0
```

User enters 201.0

```
value
   2.010000e+02
all bits
        exp
   1124073472
        4784128
        frac
        sian
       0
2.010000e+02 is normalized
E = 7
```



s = 0

User enters -1024.25

```
value
     -1.024250e+03
              10001001000000000010000000000
all bits
     1149239296
              exp
frac
         2048
              2147483648
              sian
-1.024250e+03 is normalized
E = 10
M =
  1.000000000010000000000
s =
  1
```

User enters 1.4e-45

```
1.401298e-45
value
all bits
        0
        exp
        frac
      1
      0
        sian
1.401298e-45 is denormalized
E = -126
=
```

This one cannot be entered from the keyboard, but you can test your program by setting manually the value of the floating point number of 1.0/0.0

```
value
   inf
        all bits
   2139095040
        exp
frac
       0
        0
        sign
inf is special
E = 255
M =
s =
```

This one cannot be entered from the keyboard either, but you can test your program by setting manually the value of the floating point number of 1.0/0.0 - 1.0/0.0

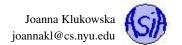
```
value
    -nan
         all bits
    2139095040
         exp
     4194304
         frac
    2147483648
         sign
-nan is special
E = 255
M =
s = 1
```

Accessing and submitting this project

You will be given access to a private repository called YOUR_GITHUB_USERNAME_proj1 on GitHub and, of course, YOUR_GITHUB_USERNAME should be replaced by yout GitHub username). DO NOT FORK THIS REPOSITORY! You should be working directly with that repository.

The repository contains an empty file projl.c file and a corresponging projl.h header file. You need to implement most of your code in projl.c. It also contains empty probl.c, probl.c and probl.c files. You need to implement the programs for these problems in those files.

It contains a textfile message that contains the scrambled message for problem 1. You should try to decipher that input file. You'll know when you get the correct text.



It contains a file called Makefile - you should not need to edit this file, unless you are adding additional source code and header files. You can create executables for programs for problems 1, 2 and 5 by running one of the following from your terminal

make prob1 make prob2 make prob5

This will either produce errors resulting from compilation errors (preprocessing, compilation or linking), or produce an executable files called prob1, prob2 and prob5, respectively. Each of the commands will also produce the object file proj1.o.

If you make any changes to the Makefile make sure that you submit the modified Makefile with your assignment

Do not add and commit the binaries produced by the makefile. You can run

make clean

to remove all the binary files from the directory before committing changes.

To submit the homework, **push** the final version to that repository. You should push intermediate versions as well - this is a way to make sure that you have a backup of the files. We will collect your files from your repository at the due date. (You may make further changes to the code, but they will not be graded.)

NOTE: you should write test code for the functions that you implement for problems 3 and 4. But these files should not be submitted with the assignment.

Questions

Post any questions you have regarding this assignment to Piazza under the "homeworks" topic.