

URL : <https://github.com/arpit6232/PES-Assignment-1>

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<README.md>

PES-Assignment-1

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Repository Comments

Contains

Code for Assignment 1 for PES, ECEN-5813, Fall 2020

Repository for PES-Assignment 1

- **bit_operations.h** - Header file which contains the function prototypes and enumerators needed for **bit_operations.c**

- **bit_operations.c** - The main script for bit manipulation and data representation styles (decimal, binary and hexadecimal) and code for hexdump from a specific location

Involves Six Functions and Unit Tests and helper functions for the following

1) `uint_to_binstr(char *str, size_t size, uint32_t num, uint8_t nbits)`

- Returns the binary representation of an unsigned integer, as a null-terminated string. On input, `str` is a pointer to a char array of at least `size` bytes, `num` is the value to be converted, and `nbits` is the number of bits in the input. If the operation was successful, the function returns the number of characters written to `str`, not including the terminal `\0`.

2) `int_to_binstr(char *str, size_t size, int32_t num, uint8_t nbits)`

- Returns the binary representation of a signed integer, as a null-terminated string. On input, `str` is a pointer to a char array of at least `size` bytes, `num` is the value to be converted, and `nbits` is the number of bits in the input. If the operation was successful, the function returns the number of characters written to `str`, not including the terminal `\0`. In the case of an error, the function returns a negative value, and `str` is set to the empty string.

3) `uint_to_hexstr(char *str, size_t size, uint32_t num, uint8_t nbits)`

- Returns the hexadecimal representation of an unsigned integer, as a null-terminated string. On input, `str` is a pointer to a char array of at least `size` bytes, `num` is the value to be converted, and `nbits` is the number of bits to be considered. If the operation was successful, the function returns the number of characters written to `str`, not including the terminal `\0`. In the case of an error, the function returns a negative value, and `str` is set to the empty string.

4) `uint32_t twiddle_bit(uint32_t input, int bit, operation_t operation)`

- Changes a single bit of the input value, without changing the other bits. Upon invocation, `bit` is in the range 0 to 31, inclusive. Returns `0xFFFFFFFF` in the case of an error

5) `uint32_t grab_three_bits(uint32_t input, int start_bit)`

- Returns three bits from the input value, shifted down. This function's output is best shown graphically.

..... .XXX.... TO 00000000 00000000 00000000 00000XXX

6) `char *hexdump(char *str, size_t size, const void *loc, size_t nbytes)`

- Returns a string representing a "dump" of the nbytes of memory starting at loc. Bytes are printed up to 16 bytes per line, separated by newlines

Assignment Comments

This assignment demonstrates C Programming from scratch for data representation conversion and basic bit manipulation, it also demonstrates a code for reading a hexdump from a address specified.

Execution

- To run the Program :

1) make

2) ./bit_operations

- TO Use with Debug Mode :

1) gcc bit_operations.h bit_operations.c -o bit_operations

2) ./bit_operations -d

<Header File – bit_operations.h>

```
#ifndef BIT_OPERATIONS_
#define BIT_OPERATIONS_
```

```
#include <stdint.h>
#include <stddef.h>
#include <stdio.h>
#include <string.h>
```

```
/*
 * Copyright (C) 2020 by Arpit Savarkar
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 * forms is permitted as long as the files maintain this copyright. Users are
 * permitted to modify this and use it to learn about the field of embedded
 * software. Arpit Savarkar and the University of Colorado are not liable for
 * any misuse of this material.
 */
/**
 * @file bit_operations.h
 * @brief An headerfile for bit manipulation operations and
 * hexdump from a specific location
 *
 * This file provides functions prototypes and abstractions for bit manipulation
 * decimal to binary, decimal to hex, clearing, Setting and toggling
 * a bit and printing a hex dump from a specific location
 *
 * @author Arpit Savarkar
 * @date August 27 2020
 * @version 1.0
 */
```

Sources of Reference :

Online Links : <https://stackoverflow.com/questions/7775991/how-to-get-hexdump-of-a-structure-data>

Textbooks : Embedded Systems Fundamentals with Arm Cortex-M based MicroControllers

I would like to thank the SA's of the course Rakesh Kumar, Saket Penurkar for their support to debug the hexdump code.

```
*/
```

```
/**
 * @brief Returns a character corresponding to hex table for decimal equivalent
```

```

*
* Given a integer to a char data set, this will return a char
* equivalent in hex
*
* @param num Integer to a data item
*
* @return char.
*/
char convert(int num);

```

```

/**
* @brief Returns a integer set with a specific bit
*
* Given a integer and a bit location, this will return a uint32_t
* Set to a specified bit location
*
* @param num : Integer to a data item
* @param bit : Location of a specific bit on the register corresponding to num
*
* @return uint32_t
*/
int set_bit(uint32_t input, int bit);

```

```

/**
* @brief Returns a integer cleared specific bit
*
* Given a integer and a bit location, this will return a uint32_t
* cleared to a specified bit location
*
* @param num : Integer to a data item
* @param bit : Location of a specific bit on the register corresponding to num
*
* @return uint32_t
*/
int clear_bit(uint32_t input, int bit) ;

```

```

/**
* @brief Returns a integer set with a specific bit
*
* Given a integer and a bit location, this will return a uint32_t
* Toggled to a specified bit location
*
* @param num : Integer to a data item
* @param bit : Location of a specific bit on the register corresponding to num
*
* @return uint32_t
*/

```

```
int toggle_bit(uint32_t input, int bit);
```

```
/**  
 * @brief Returns a pointer to a string corresponding to binary representation of  
 * unsigned uint32_t integer  
 *  
 * Given a pointer to string instantiated with a specified size, function returns the  
 * length of the binary equivalent of a number (argument) upto a specified number of  
 * bits (argument)  
 *  
 * @param str : Pointer to a char data set  
 * @param size : char array Instantiated of at 'size' bytes  
 * @param num : Integer to be converted to binary  
 * @param nbits : It is the number of bits of the input  
 *  
 * @return int  
 */
```

```
int uint_to_binstr(char *str, size_t size, uint32_t num, uint8_t nbits);
```

```
/**  
 * @brief Returns a pointer to a string corresponding to binary representation of  
 * signed uint32_t integer  
 *  
 * Given a pointer to string instantiated with a specified size, function returns the  
 * length of the binary equivalent of a number (argument) upto a specified number of  
 * bits (argument)  
 *  
 * @param str : Pointer to a char data set  
 * @param size : char array Instantiated of at 'size' bytes  
 * @param num : Integer to be converted to binary  
 * @param nbits : It is the number of bits of the input  
 *  
 * @return int  
 */
```

```
int int_to_binstr(char *str, size_t size, int32_t num, uint8_t nbits);
```

```
/**  
 * @brief Returns a pointer to a string corresponding to hexadecimal representation of  
 * unsigned uint32_t integer  
 *  
 * Given a pointer to string instantiated with a specified size, function returns the  
 * length of the hex equivalent of a number (argument) upto a specified number of  
 * bits (argument)  
 *  
 * @param str : Pointer to a char data set
```

```
* @param size : char array Instantiated of at 'size' bytes
* @param num : Integer to be converted to binary
* @param nbits : It is the number of bits of the input
```

```
*/
* @return int
*/
```

```
int uint_to_hexstr(char *str, size_t size, uint32_t num, uint8_t nbits);
```

```
/**
```

```
* @brief Bit Manipulation to set/clear/toggle a but at a specified bit location
```

```
*/
```

```
* Changes a single bit of the input value, without changing the other bits. Upon invocation,
bit is in
```

```
* the range 0 to 31, inclusive. Returns 0xFFFFFFFF in the case of an error.
```

```
*/
```

```
* @param input : Integer data of whose bits are to be manipulated
```

```
* @param bit : Specific location upon which bit manipulation is to be carried out
```

```
* @param operation : Object to Enum Operation_t
```

```
* @return uint32_t
```

```
*/
```

```
typedef enum {
```

```
CLEAR,
```

```
SET,
```

```
TOGGLE
```

```
} operation_t;
```

```
uint32_t twiddle_bit(uint32_t input, int bit, operation_t operation);
```

```
/**
```

```
* @brief Bit Manipulation to return three bits from the input value, shifted down.
```

```
*/
```

```
* @param input : Pointer to a integer data over which bits values are to be extracted
```

```
* @param start_bit : Starting bit location from which next 3 bits would be extracted
```

```
*/
```

```
* @return uint32_t
```

```
*/
```

```
uint32_t grab_three_bits(uint32_t input, int start_bit);
```

```
/**
```

```
* @brief Hex Dump of a memory location upto a selected number of bytes at a specified
memory
```

```
* location
```

```
*/
```

```
* Returns a string pointer representing a "dump" of the nbytes of memory starting at loc.
Bytes are
```

```

* printed up to 16 bytes per line, separated by newlines. The function returns the pointer str,
which
* facilitates daisy-chaining this function into other
* string-manipulation functions such as puts.
*
* @param str : Pointer to a char data set where the hex dump would be stored
* @param size : char array Instantiated of at 'size' bytes
* @param num : Address in memory from where hex dump would be recorded
* @param nbytes : Number of bytes upto which the hex values of the memory would be
stored
*
* @return Character Pointer
*/
char *hexdump(char *str, size_t size, const void *loc, size_t nbytes);

```

```

/**
* @brief Helper Function to check or prevent illegal access to memory out of scope
*
* Returns a success or failure check over number of bytes before they are processed
* for decimal to binary and decimal to hex conversion
*
* @param str : Pointer to a char data set where the hex dump would be stored
* @param size : char array Instantiated of at 'size' bytes
* @param num : Address in memory from where hex dump would be recorded
* @param nbits : Number of bits upto which string pointer would be manipulated in memory
* @param base : Base for conversion Decimal -2 , Hexadecimal - 16
*
* @return Integer ( 1 = Success, 0 = Failure )
*/
int check_legality(char *str, size_t size, uint32_t num, uint8_t nbits, int base);

```

```

/**
* @brief Helper Function to convert decimal number to binary representation
*
* Returns a pointer to a string which represents the binary representation of the
* decimal number.
*
* @param str : Pointer to a char data set where the hex dump would be stored
* @param size : char array Instantiated of at 'size' bytes
* @param num : Address in memory from where hex dump would be recorded
* @param nbits : Number of bits upto which string pointer would be manipulated in memory
*
* @return Integer ( 1 = Success, 0 = Failure )
*/
void dec_to_bin(char *str, size_t size, uint32_t num, uint8_t nbits);

```

```

/**
 * @brief Test function to test uint_to_binstr() function with test cases
 *
 * Returns status as integer "1" if all test cases return successful, else "0"
 * Test Cases include
 * - Check on conversion of negative numbers
 * - Check on conversion to binary numbers which require more than specified bytes
 *
 * @return Integer ( 1 = Success, 0 = Failure )
 */
int test_uint_to_binstr(int debug);

```

```

/**
 * @brief Test function to test int_to_binstr() function with test cases
 *
 * Returns status as integer "1" if all test cases return successful, else "0"
 * Test Cases include
 * - Check on conversion to binary which require more than specified bytes
 * - Segmentation Faults Check
 * - Check on conversion to binary numbers which require more than specified bytes
 *
 * @param debug : To Print Debug Status
 *
 * @return Integer ( 1 = Success, 0 = Failure )
 */
int test_int_to_binstr(int debug);

```

```

/**
 * @brief Test function to test uint_to_hexstr() function with test cases
 *
 * Returns status as integer "1" if all test cases return successful, else "0"
 * Test Cases include
 * - Check on conversion to hexadecimal which require more than specified bytes
 * - Segmentation Faults Check
 * - Check on conversion to binary numbers which require more than specified bytes
 *
 * @param debug : To Print Debug Status
 *
 * @return Integer ( 1 = Success, 0 = Failure )
 */
int test_uint_to_hexstr(int debug);

```

```

/**
 * @brief Test function to test twiddle_bit() function with test cases
 *

```



```

* Returns status as integer "1" if all test cases return successful, else "0"
* Test Cases include
* - Segmentation Faults Check
* - Check on conversion to binary numbers which require more than specified bytes
* - Check which uses any other setups other than SET, TOGGLE, CLEAR
*
* @param debug : To Print Debug Status
*
* @return Integer ( 1 = Success, 0 = Failure )
*/

```

```

int test_twiddle_bit(int debug);

```

```

/**
* @brief Test function to test grab_three_bits() function with test cases
*
* Returns status as integer "1" if all test cases return successful, else "0"
* Test Cases include
* - Segmentation Faults Check
* - Check on bit manipulation over bits which access more than require more than specified
bytes
* - Check to prevent access to bits which are negative and greater than 30
*
* @param debug : To Print Debug Status
*
* @return Integer ( 1 = Success, 0xFFFFFFFF = Failure )
*/

```

```

int test_grab_three_bits(int debug);

```

```

/**
* @brief Test function to test hexdump() function with test cases
*
* Returns status as integer "1" if all test cases return successful, else "0"
* Test Cases include
* - Segmentation Faults Check
* - Check to get the hexdump of a specified string upto the specific bytes
*
* @param debug : To Print Debug Status
*
* @return Integer ( 1 = Success, 0 = Failure )
*/

```

```

int test_hexdump(int debug);

```

```

#endif /* BIT OPERATIONS */

```

<Program file bit_operations.c>

```
/******
```

```
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```

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```

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```

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```

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```

```
*any misuse of this material.
```

```
*
```

```
*****/
```

```
/**
```

```
* @file bit_operations.c
```

```
* @brief An abstraction for bit manipulation operations and
```

```
* hexdump from a specific location
```

```
*
```

```
* This file provides functions and abstractions for bit manipulation
```

```
* decimal to binary, decimal to hex, clearing, Setting and toggling
```

```
* a bit and printing a hex dump from a specific location
```

```
*
```

```
* @author Arpit Savarkar
```

```
* @date August 27 2020
```

```
* @version 1.0
```

```
*
```

```
*
```

```
Sources of Reference :
```

```
Online Links : https://stackoverflow.com/questions/7775991/how-to-get-hexdump-of-a-structure-data
```

```
Textbooks : Embedded Systems Fundamentals with Arm Cortex-M based MicroControllers
```

```
I would like to thank the SA's of the course Rakesh Kumar, Saket Penurkar for their support to debug the hexdump code.
```

```
*/
```

```
#include "bit_operations.h"
```

```
// ***** Helper Functions *****
```

```
/**
```

```
* @brief Returns a character corresponding to hex table for decimal equivalent
```

```
*
```

```
* Given a integer to a char data set, this will return a char
```

```
* equivalent in hex
```

```
*
```

```

* @param num Integer to a data item
*
* @return char.
*/
char convert(int num) {
/*
Conversion Table for reference
Decimal: 0 1 2 3 4 5 6 7
Hex 0 1 2 3 4 5 6 7
Decimal: 8 9 10 11 12 13 14 15
Hex 8 9 A B C D E F
*/
if (num >= 0 && num <= 9)
return (char)(num + '0');
else
return (char)(num - 10 + 'A');
}

/**
* @brief Returns a integer set with a specific bit
*
* Given a integer and a bit location, this will return a uint32_t
* Set to a specified bit location
*
* @param num : Integer to a data item
* @param bit : Location of a specific bit on the register corresponding to num
*
* @return uint32_t
*/
int set_bit(uint32_t input, int bit) {
// Returns Input manipulated to set a bit
// "|" is Bitwise OR
return (input | (1U << (bit)));
}

/**
* @brief Returns a integer cleared specific bit
*
* Given a integer and a bit location, this will return a uint32_t
* cleared to a specified bit location
*
* @param num : Integer to a data item
* @param bit : Location of a specific bit on the register corresponding to num
*
* @return uint32_t
*/
int clear_bit(uint32_t input, int bit) {
// Returns Input manipulated to clear a bit

```

```

// "&" is Bitwise AND
return (input & ~(1U << (bit)));
}
/**
 * @brief Returns a integer set with a specific bit toggled
 *
 * Given a integer and a bit location, this will return a uint32_t
 * Toggled to a specified bit location
 *
 * @param num : Integer to a data item
 * @param bit : Location of a specific bit on the register corresponding to num
 *
 * @return uint32_t
 */
int toggle_bit(uint32_t input, int bit) {
// Returns Input manipulated to toggle a bit
// "^" is Bitwise AND
return (input ^ (1U << (bit)));
}

```

```

/**
 * @brief Helper Function to check or prevent illegal access to memory out of scope
 *
 * Returns a success or failure check over number of bytes before they are processed
 * for decimal to binary and decimal to hex conversion
 *
 * @param str : Pointer to a char data set where the hex dump would be stored
 * @param size : char array Instantiated of at 'size' bytes
 * @param num : Address in memory from where hex dump would be recorded
 * @param nbits : Number of bits upto which string pointer would be manipulated in memory
 * @param base : Base for conversion Decimal -2 , Hexadecimal - 16
 *
 * @return Integer ( 1 = Success, 0 = Failure )
 */
int check_legality(char *str, size_t size, uint32_t num, uint8_t nbits,
int base) {

// Functions to check segmentation fault and access to illegal number
// of bits

int len = 0;

if (size <=0) {
str[0] = '\0';
return -1;
}

```

```

// Segmentation Faults Check
if( (nbits/8) > size ) {
str[0] = '\0';
return -1;
}
// Illegal nbits
if (nbits <= 0 ) {
str[0] = '\0';
return -1;
}

int temp = num;
while (temp>0) { // Returns the modulo as binary of specified base
temp /= base;
len++;
}

if (len == 0) {
str[0] = '\0';
return -1;
}
// Seg Fault Check
if (len > nbits) {
str[0] = '\0';
return -1;
}
}

/**
 * @brief Helper Function to convert decimal number to binary representation
 *
 * Returns a pointer to a string which represents the binary representation of the
 * decimal number.
 *
 * @param str : Pointer to a char data set where the hex dump would be stored
 * @param size : char array Instantiated of at 'size' bytes
 * @param num : Address in memory from where hex dump would be recorded
 * @param nbits : Number of bits upto which string pointer would be manipulated in memory
 *
 * @return Integer ( 1 = Success, 0 = Failure )
 */
void dec_to_bin(char *str, size_t size, uint32_t num, uint8_t nbits) {

int base = 2, i =0, len = 0;

// To specify the 0bxxxxxx for the binary

```

```

str[0] = '0';
str[1] = 'b';
// Instantiating string with '0's upto nbytes
for (i = 2; i < nbits+2; i++) {
str[i] = '0';
}
//Demarkating End of string
str[i] = '\0';

// Need to be stored backwards for correctness
while (num>0) {
str[--i] = convert(num % base); // Returns the modulo as binary for base 2
num /= base;
len++;
}

// To prevent Segmentation faults restricted to nbits
if (len > nbits) {
str[0] = '\0';
}
}

```

```

/**
 * @brief Returns a pointer to a string corresponding to binary representation of
 * signed uint32_t integer
 *
 * Given a pointer to string instantiated with a specified size, function returns the
 * length of the binary equivalent of a number (argument) upto a specified number of
 * bits (argument)
 *
 * @param str : Pointer to a char data set
 * @param size : char array Instantiated of at 'size' bytes
 * @param num : Integer to be converted to binary
 * @param nbits : It is the number of bits of the input
 *
 * @return int
 */
int uint_to_binstr(char *str, size_t size, uint32_t num, uint8_t nbits) {
int len = 0;

// Illegal setup
if(num<0)
return -1;

// Seg faults and minimum size setup check
if (check_legality(str, size, num, nbits, 2) == -1)
return -1;

```

```
// Function to convert the input "num" to Binary
dec_to_bin(str, size, num, nbits);
```

```
len = 0;
for (int i = 0; str[i] != '\0'; i++)
len++;
```

```
return (len);
}
```

```
/**
 * @brief Test function to test uint_to_binstr() function with test cases
 *
 * Returns status as integer "1" if all test cases return successful, else "0"
 * Test Cases include
 * - Check on conversion of negative numbers
 * - Check on conversion to binary numbers which require more than specified bytes
 *
 * @return Integer ( 1 = Success, 0 = Failure )
 */
```

```
int test_uint_to_binstr(int debug) {
size_t size = 1024;
char str[size];
int ret, i;
```

```
if(debug)
printf("\n Test Results for Unsigned Integer to Binary Conversion ");
// 8 bit check
```

```
// Valid Number of Bit Check
ret = uint_to_binstr(str, size, UINT8_MAX, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, UINT8_MAX, 8, ret);
if(ret == -1)
return 0;
// Invalid Number of Bits as input
ret = uint_to_binstr(str, size, UINT8_MAX+1, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, UINT8_MAX+1, 8, ret);
if(ret != -1)
return 0;
```

```
// Invalid String Size - Segmentation/Bus Fault Test
ret = uint_to_binstr(str, 0, UINT8_MAX, 8);
if(debug)
printf("\nString Size: %d, Num: %d, nbits: %d, Length: %d", 0, UINT8_MAX, 8, ret);
```

```

if(ret != -1)
return 0;

// 16 Bit Check

// Valid Number of Bit Check
ret = uint_to_binstr(str, size, INT16_MAX, 16);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d",size, INT16_MAX, 16, ret);
if(ret == -1)
return 0;

// InValid Number of Bits as input
ret = uint_to_binstr(str, size, UINT16_MAX+1, 16);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, UINT16_MAX: %d",size, UINT16_MAX+1, 16,
ret);
if(ret != -1)
return 0;

// InValid String Size - Segmentation/Bus Fault Test
ret = uint_to_binstr(str, 0, UINT16_MAX, 16);
if(debug)
printf("\nString Size: %d, Num: %d, nbits: %d, Length: %d",0, UINT16_MAX, 16, ret);
if(ret != -1)
return 0;

// 32 bit
// Compiler interprets UINT32_MAX as -1 when assigned to uint32_t
// which results in legality check to be as negative number

// InValid Number of Bits as input
ret = uint_to_binstr(str, size, UINT32_MAX, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d",size, UINT32_MAX, 8, ret);
if(ret >= 0)
return 0;

// InValid Number of Bits as input
ret = uint_to_binstr(str, size, UINT32_MAX, 16);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, UINT32_MAX, 16, ret);
if(ret >= 0)
return 0;

// Valid Input Check
ret = uint_to_binstr(str, size, UINT32_MAX, 32);

```



```

if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d",size, UINT32_MAX, 32, ret);
if(ret >= 0)
return 0;

```

```

// InValid String Size - Segmentation/Bus Fault Test
ret = uint_to_binstr(str, 0, UINT32_MAX, 32);
if(debug)
printf("\nString Size: %d, Num: %d, nbits: %d, Length: %d",0, UINT32_MAX, 32, ret);
if(ret >= 0)
return 0;

```

```

return 1;
}

```

```

/**
 * @brief Returns a pointer to a string corresponding to binary representation of
 * signed uint32_t integer
 *
 * Given a pointer to string instantiated with a specified size, function returns the
 * length of the binary equivalent of a number (argument) upto a specified number of
 * bits (argument)
 *
 * @param str : Pointer to a char data set
 * @param size : char array Instantiated of at 'size' bytes
 * @param num : Integer to be converted to binary
 * @param nbits : It is the number of bits of the input
 *
 * @return int
 */
int int_to_binstr(char *str, size_t size, int32_t num, uint8_t nbits) {

```

```

// If Unsigned Integer uint_to_binstr() can be used
if (num>0)
return uint_to_binstr(str, size, num, nbits);

```

```

// Function to Check Segmentation Faults and Illegal Bit Access
if (check_legality(str, size, num*-1, nbits, 2) == -1)
return -1;

```

```

num *= -1;
int i =0, c = 1;

```

```

// Decimal to Binary Conversion
dec_to_bin(str, size, num, nbits);

```

```

// 1's compliment logic

```

```

for(i =2; str[i]!='\0'; i++) {
if(str[i] == '1')
str[i] = '0';

else if(str[i] == '0')
str[i] = '1';
}
int k = i-1;

// 2's compliment logic
for (i = k; i>=0; i--) {
if(str[i] == '1' && c == 1) {
str[i] = '0';
}
else if(str[i] == '0' && c == 1) {
str[i] = '1';
c = 0;
}
}

int len = 0;
for (int i =0; str[i]!='\0'; i++)
len++;

return (len);
}

```

```

/**
 * @brief Test function to test int_to_binstr() function with test cases
 *
 * Returns status as integer "1" if all test cases return successful, else "0"
 * Test Cases include
 * - Check on conversion to binary which require more than specified bytes
 * - Segmentation Faults Check
 * - Check on conversion to binary numbers which require more than specified bytes
 *
 * @param debug : To Print Debug Status
 *
 * @return Integer ( 1 = Success, 0 = Failure )
 */
int test_int_to_binstr(int debug) {
size_t size = 1024;
char str[size];
uint8_t nbits = 16;
int ret,i;

```

```

if(debug)
printf("\n Test Results for signed Integer to Binary Conversion ");
// 8 Bit
// Invalid number of bits as input Test
ret = int_to_binstr(str, size, INT8_MIN*2, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT8_MIN*2, 8, ret);
if(ret != -1)
return 0;
// Valid Input Test
ret = int_to_binstr(str, size, INT8_MIN, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT8_MIN, 8, ret);
if(ret == -1)
return 0;

// Invalid number of bits as input Test
ret = int_to_binstr(str, size, INT8_MAX*2+2, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT8_MAX*2+2, 8, ret);
if(ret != -1)
return 0;

// Valid Input Test
ret = int_to_binstr(str, size, INT8_MAX, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT8_MAX, 8, ret);
if(ret == -1)
return 0;

// Invalid String Size - Segmentation/Bus Fault Test
ret = int_to_binstr(str, 0, INT8_MAX, 8);
if(debug)
printf("\nString Size: %d, Num: %d, nbits: %d, Length: %d", 0, INT8_MAX, 8, ret);
if(ret != -1)
return 0;

// 16 Bit

// Invalid number of bits as input Test
ret = int_to_binstr(str, size, INT16_MIN*2, 16);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT16_MIN*2, 16, ret);
if(ret != -1)
return 0;
// Valid Input Test
ret = int_to_binstr(str, size, INT16_MIN, 16);

```

```

if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT16_MIN, 16, ret);
if(ret == -1)
return 0;

// Invalid number of bits as input Test
ret = int_to_binstr(str, size, INT16_MAX*2+2, 16);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT16_MAX*2+2, 16, ret);
if(ret != -1)
return 0;

// Valid Input Test
ret = int_to_binstr(str, size, INT16_MAX, 16);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT16_MAX, 16, ret);
if(ret == -1)
return 0;
// InValid String Size - Segmentation/Bus Fault Test
ret = int_to_binstr(str, 0, INT16_MAX, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", 0, INT16_MAX, 16, ret);
if(ret != -1)
return 0;

// Compiler interprets UINT32_MAX as -1 when assigned to uint32_t
// which results in legality check to be as negative number

// Invalid number of bits as input Test
ret = int_to_binstr(str, size, INT32_MIN+1, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT32_MIN+1, 8, ret);
if(ret != -1)
return 0;

// Invalid number of bits as input Test
ret = int_to_binstr(str, size, INT32_MIN+1, 16);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT32_MIN+1, 16, ret);
if(ret != -1)
return 0;

// Valid Input test
ret = int_to_binstr(str, size, INT32_MIN+1, 32);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT32_MIN+1, 32, ret);

```

```

if(ret == 0)
return 0;

// Invalid number of bits as input Test
ret = int_to_binstr(str, size, INT32_MAX-1, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT32_MAX-1, 8, ret);
if(ret != -1)
return 0;

// Invalid Number of bits as input test
ret = int_to_binstr(str, size, INT32_MAX-1, 16);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT32_MAX-1, 16, ret);
if(ret != -1)
return 0;

// Valid input test
ret = int_to_binstr(str, size, INT32_MAX-1, 32);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, INT32_MAX-1, 32, ret);
if(ret == 0)
return 0;

ret = int_to_binstr(str, 0, INT32_MAX-1, 32);
if(debug)
printf("\nString Size: %d, Num: %d, nbits: %d, Length: %d", 0, INT32_MAX-1, 32, ret);
if(ret != -1)
return 0;

return 1;

}

```

```

/**
 * @brief Returns a pointer to a string corresponding to hexadecimal representation of
 * unsigned uint32_t integer
 *
 *
 * Given a pointer to string instantiated with a specified size, function returns the
 * length of the hex equivalent of a number (argument) upto a specified number of
 * bits (argument)
 *
 *
 * @param str : Pointer to a char data set
 * @param size : char array Instantiated of at 'size' bytes
 * @param num : Integer to be converted to binary
 * @param nbits : It is the number of bits of the input

```

```

*
* @return int
*/
int uint_to_hexstr(char *str, size_t size, uint32_t num, uint8_t nbits) {

    int base = 16, len = 0, i = 0;
    int k = 2;

    // Illegal Num size
    if(num < 0)
        return -1;

    // Illegal Num Bit setup
    if (size <= 0 ) {
        str[0] = '\0';
        return -1;
    }

    // Illegal Num Bit setup
    if (nbits <= 0 ) {
        str[0] = '\0';
        return -1;
    }

    // Illegal Length of bit setup
    int temp = num;
    while (temp>0) { // Returns the modulo as binary for base
        temp /= base;
        len++;
    }

    if (len == 0) {
        str[0] = '\0';
        return -1;
    }

    if (len > nbits/4) {
        str[0] = '\0';
        return -1;
    }

    str[0] = '0';
    str[1] = 'x';

    // Initalizing with '0's for required nbits in hex
    for (i=0; i < nbits/4; i++) {
        str[k++] = '0';
    }
}

```

```
}
```

```
// Marking Enf of string
```

```
str[k] = '\0';
```

```
// Conversion of Decimal to Hex
```

```
while(num>0) {
```

```
str[--k] = convert(num % base);
```

```
num /= base;
```

```
len++;
```

```
}
```

```
// Length Calculation
```

```
len = 0;
```

```
for(i=0; str[i]!='\0'; i++) {
```

```
len++;
```

```
}
```

```
return len;
```

```
}
```

```
/**
```

```
 * @brief Test function to test uint_to_hexstr() function with test cases
```

```
 *
```

```
 * Returns status as integer "1" if all test cases return successful, else "0"
```

```
 * Test Cases include
```

```
 * - Check on conversion to hexadecimal which require more than specified bytes
```

```
 * - Segmentation Faults Check
```

```
 * - Check on conversion to binary numbers which require more than specified bytes
```

```
 *
```

```
 * @param debug : To Print Debug Status
```

```
 *
```

```
 * @return Integer ( 1 = Success, 0 = Failure )
```

```
 */
```

```
int test_uint_to_hexstr(int debug) {
```

```
size_t size = 1024;
```

```
char str[size];
```

```
int ret;
```

```
if(debug)
```

```
printf("\n Test Results for signed Integer to Hex Conversion ");
```

```
// 8 bit
```

```
// Valid Check Input
```

```
ret = uint_to_hexstr(str, size, UINT8_MAX, 8);
```

```

if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, UINT8_MAX, 8, ret);
if(ret == -1)
return 0;
ret = uint_to_hexstr(str, 0, UINT8_MAX, 8);
if(debug)
printf("\nString Size: %d, Num: %d, nbits: %d, Length: %d",0, INT8_MAX, 8, ret);
if(ret != -1)
return 0;


// 16 bit

// Valid Check Input
ret = uint_to_hexstr(str, size, UINT16_MAX, 16);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d", size, UINT16_MAX, 16, ret);
if(ret == -1)
return 0;
ret = uint_to_hexstr(str, 0, UINT16_MAX, 8);
if(debug)
printf("\nString Size: %d, Num: %d, nbits: %d, Length: %d",0, UINT16_MAX, 8, ret);
if(ret != -1)
return 0;


// Compiler interprets UINT32_MAX as -1 when assigned to uint32_t
// which results in legality check to be as negative number


// Invalid Check input
ret = uint_to_hexstr(str, size, UINT32_MAX, 8);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d",size, UINT32_MAX, 8, ret);
if(ret != -1)
return 0;


// Invalid Check input
ret = uint_to_hexstr(str, size, UINT32_MAX, 16);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d",size, UINT32_MAX, 16, ret);
if(ret != -1)
return 0;


// Valid Check Output
ret = uint_to_hexstr(str, size, UINT32_MAX, 32);
if(debug)
printf("\nString Size: %ld, Num: %d, nbits: %d, Length: %d",size, UINT32_MAX, 32, ret);

```



```
if(ret != -1)
return 0;
```

```
return 1;
```

```
}
```

```
/**
```

```
 * @brief Bit Manipulation to return three bits from the input value, shifted down.
```

```
 *
```

```
 * @param input : Pointer to a integer data over which bits values are to be extracted
```

```
 * @param start_bit : Starting bit location from which next 3 bits would be extracted
```

```
 *
```

```
 * @return uint32_t
```

```
 */
```

```
uint32_t twiddle_bit(uint32_t input, int bit, operation_t operation) {
```

```
 // Invalid bit check
```

```
if ( bit < 0 || bit > 31)
```

```
return 0xFFFFFFFF;
```

```
 // Function call to clear specific bit
```

```
if (operation == CLEAR) {
```

```
return clear_bit(input, bit);
```

```
}
```

```
 // Function call to set specific bit
```

```
else if (operation == SET) {
```

```
return set_bit(input, bit);
```

```
}
```

```
 // Function call to toggle specific bit
```

```
else if (operation == TOGGLE) {
```

```
return toggle_bit(input, bit);
```

```
}
```

```
else {
```

```
 // Invalid Operation
```

```
return 0xFFFFFFFF;
```

```
}
```

```
}
```

```
/**
```

```
 * @brief Test function to test twiddle_bit() function with test cases
```

```
 *
```

```
 * Returns status as integer "1" if all test cases return successful, else "0"
```

```
 * Test Cases include
```

```
* - Segmentation Faults Check
```

```
* - Check on conversion to binary numbers which require more than specified bytes
```

```
* - Check which uses any other setups other than SET, TOGGLE, CLEAR
```

```
*
```

```
* @param debug : To Print Debug Status
```

```
*
```

```
* @return Integer ( 1 = Success, 0 = Failure )
```

```
*/
```

```
int test_twiddle_bit(int debug) {
```

```
uint32_t input = 0;
```

```
uint32_t output;
```

```
if(debug)
```

```
printf("\n Test Results for Twiddling particular bits of an input 32 bit number ");
```

```
// Validity Check to clear bit 0
```

```
output = twiddle_bit(input, 0, CLEAR);
```

```
if(debug)
```

```
printf("\nInput Number: %d, Bit manipulated: %d, Operation: %d, Result: %d",input, 0, CLEAR,
```

```
output);
```

```
if(output == 0xFFFFFFFF)
```

```
return 0;
```

```
// Validity Check to set bit 0
```

```
output = twiddle_bit(input, 0, SET);
```

```
if(debug)
```

```
printf("\nInput Number: %d, Bit manipulated: %d, Operation: %d, Result: %d",input, 0, SET,
```

```
output);
```

```
if(output == 0xFFFFFFFF)
```

```
return 0;
```

```
// Validity Check to toggle bit 0
```

```
output = twiddle_bit(input, 0, TOGGLE);
```

```
if(debug)
```

```
printf("\nInput Number: %d, Bit manipulated: %d, Operation: %d, Result: %d",input, 0,
```

```
TOGGLE, output);
```

```
if(output == 0xFFFFFFFF)
```

```
return 0;
```

```
// bit size restricted 0 - 31
```

```
output = twiddle_bit(input, 32, CLEAR);
```

```
if(debug)
```

```
printf("\nInput Number: %d, Bit manipulated: %d, Operation: %d, Result: %d",input, 32,
```

```
CLEAR, output);
```

```
if(output != 0xFFFFFFFF)
```

```
return 0;
```

```

// bit size restricted 0 - 31
output = twiggle_bit(input, 32, SET);
if(debug)
printf("\nInput Number: %d, Bit manipulated: %d, Operation: %d, Result: %d",input, 32, SET,
output);
if(output != 0xFFFFFFFF)
return 0;

// bit size restricted 0 - 31
output = twiggle_bit(input, 32, TOGGLE);
if(debug)
printf("\nInput Number: %d, Bit manipulated: %d, Operation: %d, Result: %d",input, 32,
TOGGLE, output);
if(output != 0xFFFFFFFF)
return 0;

// Invalid Bit Test
output = twiggle_bit(input, -1, CLEAR);
if(debug)
printf("\nInput Number: %d, Bit manipulated: %d, Operation: %d, Result: %d",input, -1,
CLEAR, output);
if(output != 0xFFFFFFFF)
return 0;

// Invalid Bit Test
output = twiggle_bit(input, -1, SET);
if(debug)
printf("\nInput Number: %d, Bit manipulated: %d, Operation: %d, Result: %d",input, -1, SET,
output);
if(output != 0xFFFFFFFF)
return 0;

// Invalid Bit Test
output = twiggle_bit(input, -1, TOGGLE);
if(debug)
printf("\nInput Number: %d, Bit manipulated: %d, Operation: %d, Result: %d",input, -1,
TOGGLE, output);
if(output != 0xFFFFFFFF)
return 0;

return 1;

}

```

```

/**
 * @brief Bit Manipulation to return three bits from the input value, shifted down.
 *
 * @param input : Pointer to a integer data over which bits values are to be extracted
 * @param start_bit : Starting bit location from which next 3 bits would be extracted
 *
 * @return uint32_t
 */
uint32_t grab_three_bits(uint32_t input, int start_bit) {

```

```

    uint32_t output;
    int num_elem = 3;
    if (start_bit < 0 || start_bit >= 30)
        return 0xFFFFFFFF;
    // Logic to set the 3 bits from start_bit left to right direction
    output = (((1 << num_elem) - 1) & (input >> (start_bit)));
    return output;
}

```

```

/**
 * @brief Test function to test grab_three_bits() function with test cases
 *
 * Returns status as integer "1" if all test cases return successful, else "0"
 * Test Cases include
 * - Segmentation Faults Check
 * - Check on bit manipulation over bits which access more than require more than specified
   bytes
 * - Check to prevent access to bits which are negative and greater than 30
 *
 * @param debug : To Print Debug Status
 *
 * @return Integer ( 1 = Success, 0xFFFFFFFF = Failure )
 */
int test_grab_three_bits(int debug) {

```

```

    uint32_t input = UINT32_MAX-2;
    uint32_t output;

    if(debug)
        printf("\n Test Results for Extracting 3 bits from a particular start_bit ");

    // Valid Bit Test
    output = grab_three_bits(input, 0);
    if(debug)
        printf("\nInput Number: %d, Start_bit: %d, Result: %d",input, 0, output);
    if(output == 0xFFFFFFFF)

```

```

return 0;

// Invalid Bit Test
output = grab_three_bits(input, 30);
if(debug)
printf("\nInput Number: %d, Start_bit: %d, Result: %d",input, 30, output);
if(output != 0xFFFFFFFF)
return 0;

// Illegal Bit Test
output = grab_three_bits(input, -1);
if(debug)
printf("\nInput Number: %d, Start_bit: %d, Result: %d",input, -1, output);
if(output != 0xFFFFFFFF)
return 0;

return 1;
}

```

```

/**
 * @brief Hex Dump of a memory location upto a selected number of bytes at a specified
memory
 * location
 *
 * Returns a string pointer representing a "dump" of the nbytes of memory starting at loc.
Bytes are
 * printed up to 16 bytes per line, separated by newlines. The function returns the pointer str,
which
 * facilitates daisy-chaining this function into other
 * string-manipulation functions such as puts.
 *
 * @param str : Pointer to a char data set where the hex dump would be stored
 * @param size : char array Instantiated of at 'size' bytes
 * @param num : Address in memory from where hex dump would be recorded
 * @param nbytes : Number of bytes upto which the hex values of the memory would be
stored
 *
 * @return Character Pointer
 */
char *hexdump(char *str, size_t size, const void *loc, size_t nbytes) {
// Segmentation Fault Check
if (size <= 0) {
str[0] = '\0';
return str;
}
// Segmentation Fault Check

```

```

if (nbytes > size) {
str[0] = '\0';
return str;
}

// Length checks.

if (nbytes <= 0) {
str[0] = '\0';
return str;
}

int i, j;
char temp[3]; // Required to restrict compiler from using 2 bytes for special characters
uint8_t rem = 0, num;
unsigned char buff[17]; // String of 17
const unsigned char *pc = (const unsigned char *)loc;
int k = 0;

for (i = 0; i < nbytes; i++) {
// Newline after 16 bytes check with necessary space/offset.

if ((i % 16) == 0) {
// Preventing newline before "zeroth" line buffer.
if (i != 0) {
str[k++] = '\n';
}

// Output the offset.
str[k++] = '0';
str[k++] = 'x';

// 0x0 "0" requires an extra character zero
if(i == 0)
str[k++] = '0';
// Initial Delta from location Decimal to Hex Manipulation
num = i;
do
{
rem = num % 16;
str[k++] = (rem > 9)? rem - 10 + 'A' : rem + '0';
num = num/16;
} while (num != 0);
// 2 Spaces between Address and Buffer Values
for (int s = 0; s < 2; s++)
str[k++] = ' ';
}

```

```

// Now the hex code for the specific character.
str[k++] = '0';
str[k++] = '0';

// Hexadecimal equivalent of buffer
num = pc[i];
for(j=0; temp[j]!='\0'; j++)
temp[j] = '0';
j = 0;
while (num != 0)
{
rem = num % 16;
temp[j++] = (rem > 9)? (rem-10) + 'A' : rem + '0' ;
num = num/16;
}

// Manipulation Reversing the hex string to get the right order
j = 0;
for(j = 0; j<=1; j++)
str[--k] = temp[j];
k+=2;

// Space after the hexdump of memory after every address read
str[k++] = ' ';

if ((pc[i] > 0x20) || (pc[i] < 0x7e))
buff[i % 16] = '.';
else
buff[i % 16] = pc[i];
buff[(i % 16) + 1] = '\n';
}

// Padding out last line if not exactly 16 characters.
while ((i % 16) != 0) {
str[k++] = ' ';
i++;
}
str[k] = '\0';
return str;
}

/**
 * @brief Test function to test hexdump() function with test cases
 *
 * Returns status as integer "1" if all test cases return successful, else "0"

```

```

* Test Cases include
* - Segmentation Faults Check
* - Check to get the hexdump of a specified string upto the specific bytes
*
* @param debug : To Print Debug Status
*
* @return Integer ( 1 = Success, 0 = Failure )
*/
int test_hexdump(int debug) {

```

```

const char *buf= "To achieve great things, two things are needed:\n a plan, and not quite
enough time.";
size_t size = 1024;
char str[size];

```

```

if(debug)
printf("\n HexDump from a particular given address \n");

```

```

// Valid Input Test
hexdump(str, size, buf, strlen(buf)+1);
if(debug) {
printf("\n Hex dump for string %s \n", buf);
puts(str);
}
if (str[0] == '\0')
return 0;

```

```

if(debug)
printf("\n HexDump from a particular given address \n");
// Invalid Input Test
size = 0;
hexdump(str, size, buf, strlen(buf)+1);
if(debug) {
printf("\n Size is %ld \n", size);
puts(str);
}
if (str[0] != '\0')
return 0;
return 1;

```

```

}

```

```

// MAIN
int main(int argc, char* argv[]) {
int status[6] = {0};
int debug;

```



```

if(argc > 1)
debug = 1;
printf("\n DEBUG Status : %d \n", debug);

status[0] = test_uint_to_binstr(debug);
status[1] = test_int_to_binstr(debug);
status[2] = test_uint_to_hexstr(debug);
status[3] = test_twiddle_bit(debug);
status[4] = test_grab_three_bits(debug);
status[5] = test_hexdump(debug);

for(int i=0; i<6; i++)
printf("\nTest: %d, Result: %d\n", i, status[i]);

return 0;
}

```

<Makefile>

```

# -*- MakeFile -*-

bit_operations: bit_operations.h bit_operations.c
gcc bit_operations.h bit_operations.c -o bit_operations

```