CSC 209 Review 9 Solution

September 2, 2020

1. a) 0

   ### Notes

   - a) is 0 because (i >> 1 + j >> 1 = i >> 10 >> 1 = 0)
   - **Bitwise Shift Operators**
     - has lower precedence than arithematic operators

     ### Example:

     i << 2 + 1 means i << (2+1) and not (i << 2) + 1

     - << : Left Shift
     - >> : Right Shift
     - *Tip:* Always shift only on <u>unsigned</u> numbers for portability

     ### Example

```
unsigned short i, j;

i = 13;          /* i is now 13 (binary 0000000000001101) */   Shifts to left
j = i << 2;      /* j is now 52 (binary 0000000000110100) */
j = i >> 2;      /* j is now  3 (binary 0000000000000011) */
                      Shifts to right
```

As these examples show, neither operator modifies its operands. To modify a variable by shifting its bits, we'd use the compound assignment operators <<= and >>=:

```
i = 13;          /* i is now 13 (binary 0000000000001101) */
i <<= 2;         /* i is now 52 (binary 0000000000110100) */
i >>= 2;         /* i is now 13 (binary 0000000000001101) */
```

     - >>= / <<= : Are bitwise shift equivalent of + =

   b) 0

   ### Notes

- ~i is 1111111111111111
- i is 0000000000000000
- so ~i & i = 0
- ~ : Bitwise complement (NOT)

a	~ a
0	1
1	0

Example:

```
1     0   1   1   1    //<- this is 7
2     --------------
3     1   0   0   0    //<- this is 8
4
5     so, ~ 7 = 8
```

- &: Bitwise *and*

a	b	a & b
0	0	0
0	1	1
1	0	0
1	1	1

Example:

```
1     0   1   1   1    //<- this is 7
2     0   1   0   0    //<- this is 4
3     --------------
4     0   1   0   0    //<- this is 4
5
6     so, 7 & 4 = 4
```

- ^ : Bitwise *exclusive or*
- |: Bitwise *inclusive or*

c) 1

Notes

- ~i is 1111111111111110
- j is 0000000000000000
- ~i & j is 0000000000000000 or 1
- ~i & j ^ k is 1

- ^: Bitwise XOR

a	b	a ^ b
0	0	0
0	1	1
1	0	1
1	1	0

Example:

```
1      0    1    1    1    //<- this is 7
2      0    1    0    0    //<- this is 4
3      --------------
4      0    0    1    1    //<- this is 3
5
6      so, 7 ^ 4 = 3
7
```

d) 0

<u>Example</u>

- `i` is 0000000000000111
- `j` is 0000000000001000
- `i ^ j` is 0000000000000000 or 0
- `k` is 0000000000001001
- `i ^ j & k` is 0000000000000000 or 0

<u>Correct Solution</u>

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<u>Notes</u>

- There is a precendence to the order of operations

Highest: ~

               &

               ^

Lowest: |

2. • toggling from 0 to 1

```
i = 0x0000;
i |= 0x0001;
```

or

```
i |= 1 << 0; where i = 0x0000;
```
• toggling from 1 to 0

```
i = 0x0001;
i &= ~0x0001;
```

or

```
i &= ~(1 << 0); where i = 0x0001;
```

Correct Solution

• toggling from 0 to 1 of 4th bit

```
i = 0x0010;
i ^= 0x0000;
```

or

```
i ^= 1 << 4; where i = 0x0000;
```
• toggling from 1 to 0 of 4th bit

```
i = 0x0010;
i ^= 0x0010;
```

or

```
i ^= (1 << 4); where i = 0x0010;
```

Notes

• Toggling can be done using bitwise XOR
• **Setting a bit**
  – Is done using | or bitwise OR

```
i = 0x0000;            /* i is now 0000000000000000 */
i |= 0x0010;           /* i is now 0000000000010000 */
```

- – The idiom of above is i |= 1 << j

- **Clearing a bit**
  - – Is done using | or bitwise AND

```
i = 0x00ff;            /* i is now 0000000011111111 */
i &= ~0x0010;          /* i is now 0000000011101111 */
```

  - – The idiom of above is i &= ~(i << j)

3. It swaps the elements between x and y.

   Notes

   - Preprocessor performs operations of statements in order from left to right

4. #define MK_COLOR(r,g,b) (long) ((b | (g << 8)) | (b | (r << 16)))

   Rough Work

   1. store b in bit 0

      b

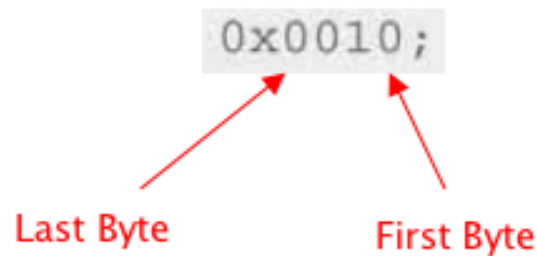   2. store g in bit 8

      b | g << 8

   3. store r in bit 16
      b | r << 16

Correct Solution

```
#define MK_COLOR(r,g,b) (long) ((r| (g << 8)) | (r| (b<< 16)))
```

Notes

- First Byte is furthest from `0x` and first byte is closest to `0x`

5.   - GET_RED

      ```
      #define GET_RED(c) (long) (c & 0x007)
      ```

      - GET_GREEN

      ```
      #define GET_GREEN(c) (long) ((c >> 8) & 0x007)
      ```

      - GET_BLUE

      ```
      #define GET_BLUE(c) (long) ((c >> 16) & 0x007)
      ```

      Notes

      - `0x0007` in binary is `0x0000000000001111`
      - `c >> 4` shifts `c` to right by 4 bits and return overlapping value between `c >> 4` and `0x0000000000001111` (`0x007`)
      - Test code is below

      ```
      1    #include <stdio.h>
      2    #include <stdlib.h>
      3
      4    #define MK_COLOR(r,g,b) (long) ( (r | (g << 8)) | (r | (b << 16)
         ))
      5    #define GET_RED(c) (long) (c & 0x007)
      6    #define GET_GREEN(c) (long) ((c >> 8) & 0x007)
      7    #define GET_BLUE(c) (long) ((c >> 16) & 0x007)
      ```

```
8
9      int main() {
10         long i, r = 4, g = 5, b = 6, r2, g2, b2;
11
12         i = MK_COLOR(r,g,b);
13
14         r2 = GET_RED(i);
15         g2 = GET_GREEN(i);
16         b2 = GET_BLUE(i);
17
18         printf("%ld\n", i);
19         printf("%ld\n", r2);
20         printf("%ld\n", g2);
21         printf("%ld\n", b2);
22
23         return 0;
24      }
```

6. a)
```
1      unsigned short swap_bytes(unsigned short i) {
2          unsigned short j, k;
3
4          j = i & 0x007; // extract first byte
5
6          i = i >> 4;
7          k = i & 0x007; // extract second byte
8
9          i = i >> 4; // shift down layter two bytes
10
11         i |= j << 8; // add first byte to position of fourth byte
12         i |= k << 12; // add second byte to position of third byte
13
14     }
```

b)
```
1      unsigned short swap_bytes(unsigned short i) {
2
3          i = i >> 8 | i << 8;
4
5          return i;
6      }
```

Rough Works

1. Extract first two bytes

   j = i & 0x0007
   i = i >> 4
   k = i & 0x0007

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2. Shift later two bytes down

```
i = i >> 4
```

3. Add first two bytes to last two bytes

```
i |= j << 8;
i |= k << 12;
```

7.
```
1    unsigned int rotate_left(unsigned int i, int n) {
2        return i >> 28 | i << n;
3    }
4
5    unsigned int rotate_right(unsigned int i, int n) {
6        return i << 28 | i >> n;
7    }
```

8. a) Is a binary with n many 1s from the first bit

   b) Extracts last n bits in i

   Correct Solution

   a) Is a binary with n many 1s from the first bit

   b) Extracts last n bits starting from position m in i
   ---

9. a)
```
1    unsigned int count_ones(unsigned char *ch)
2    {
3        unsigned char *p;
4        unsigned int count;
5
6        for (p = ch; *p != '\0'; p++){
7            if (*p == '1') {
8                count++;
9            }
10       }
11
12       return count;
13   }
```

   b)
```
1    unsigned int count_ones(unsigned char ch)
2    {
3        int sum = 0;
4
5        sum += (i >> 0) & 1;
6        sum += (i >> 1) & 1;
```

```
 7            sum += (i >> 2) & 1;
 8            sum += (i >> 3) & 1;
 9            sum += (i >> 4) & 1;
10            sum += (i >> 5) & 1;
11            sum += (i >> 6) & 1;
12            sum += (i >> 7) & 1;
13            return count;
14        }
```

Notes

- Unsigned char goes from 0 (00000000) to 255 (11111111)
- I am having trouble how to convert from loop to without loop :'(. I need help
- Example

  100010101 - Here there are 4 1s.

```
10  1     unsigned int reverse_bits (unsigned int n)
 2        {
 3            int m = 15, p = 0;
 4            unsigned int byte_left_end, byte_right_end, res = 0;
 5
 6            while (m > p) {
 7                byte_left_end = n >> m & 1;
 8                byte_right_end = n >> p & 1;
 9
10                res |= byte_left_end << (15 - m) | byte_right_end << (15 - p
    );
11
12                m--;
13                p++;
14            }
15            return res;
16        }
```

Rough Work

- Start at n = 15, m = 0
- Swap bit at n with m
- Repeat until m > n

Notes

- unsigned int has 4 bytes or (0x0000) or (0000000000000000, 16 bits)

11. The precedence of &, ˆ, and — is lower than the precedence of the relational and equality operators.

    As a result, the expression will first evaluate

    `(SHIFT_BIT | CTRL_BIT | ALT_BIT) == 0`

    first.

    The work around is to put parenthesis around `key_code & (SHIFT_BIT | CTRL_BIT | ALT_BIT)`.

12. The function tries to insert `low_byte` to `high_byte` after shifting `high_byte` by 8 bits to left.

    It doesn't work because `+` sign takes precedence over `<<`.

    To fix this issue, a parenthesis is required around `high_byte << 8`.

13. It reduces the value of `n` by 1, then uses bitwise operator (&) to extract the common bits between `n` and `n-1`.

Correct Solution

14.
```
1    struct float {
2        unsigned int sign: 1;
3        unsigned int exponent: 8;
4        unsigned int : 0;
5        unsigned int fraction: 23;
6    }
```

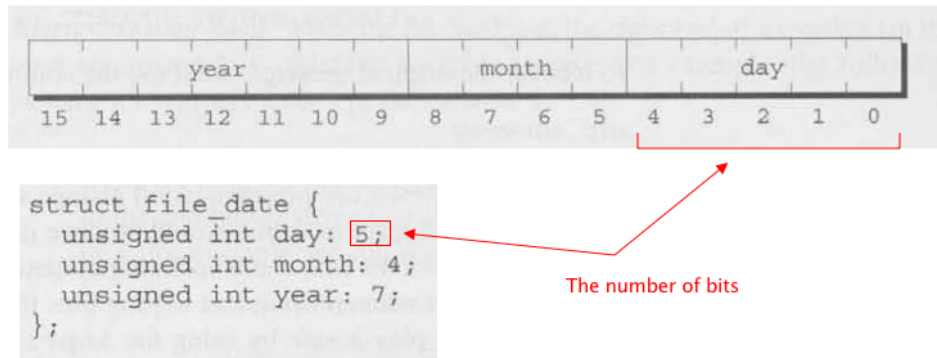**Correct Solution**

```
1    struct float {
2        unsigned int fraction: 23;
3        unsigned int exponent: 8;
4        unsigned int sign: 1;
5    }
```
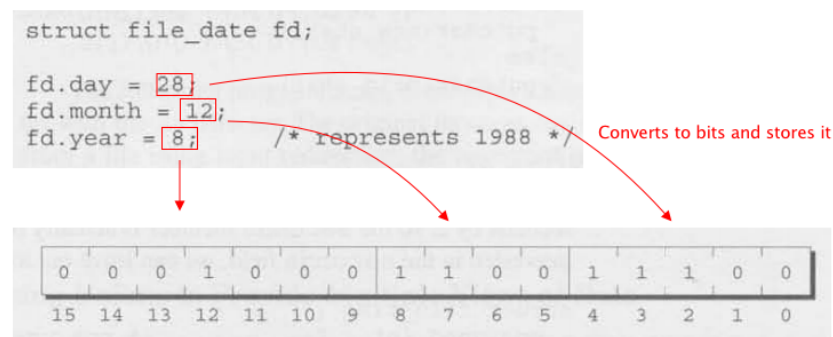

Notes

- **Bit-Fields in Structures**

– Bit-fields are tricky and potentially confusing

Example

struct file_date {
    unsigned int day: 5;
    unsigned int month: 4;
    unsigned int year: 7;
};

The number of bits

– Type of bit-field must be either `int`, `unsigned int`, `signed int`
  * `int` is ambiguous
  * Author suggests to declare all bit-fields to be either `unsigned int` or `signed int`
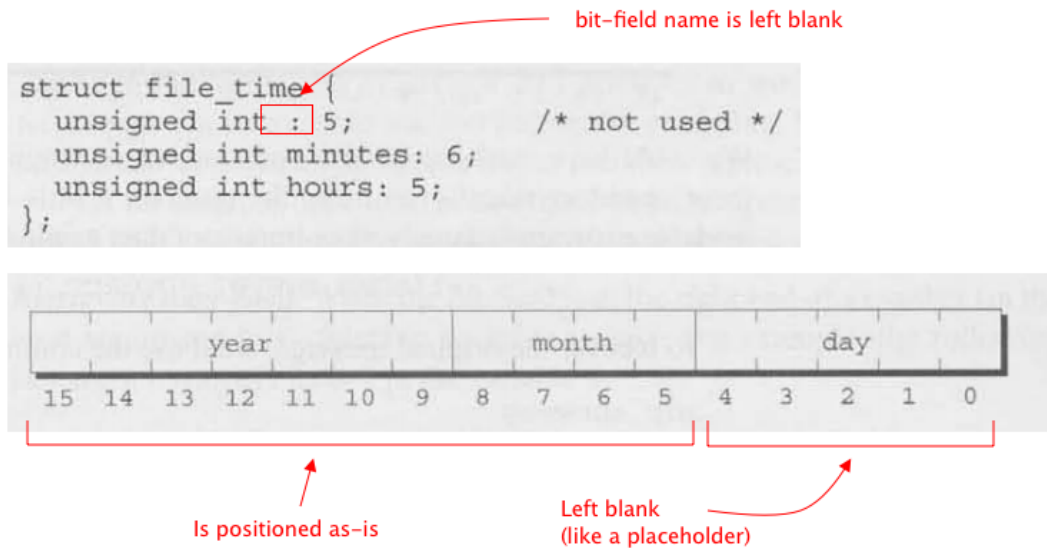– Assignment of bit-field in structure

struct file_date fd;

fd.day = 28;
fd.month = 12;
fd.year = 8;   /* represents 1988 */

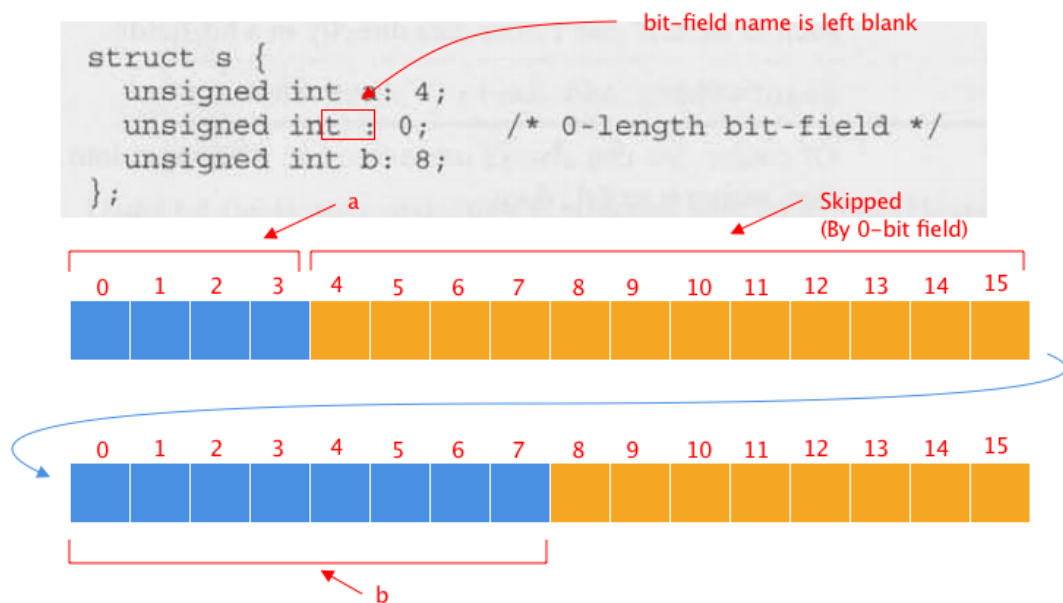Converts to bits and stores it

WARNING bit-fields don't have addresses
  * C doesn't allow address operator `&` to a bit field

• **How Bit-Fields Are Stored**

– C allows to omit the name of bit-field.
– Bit-field without name acts as a padding

bit–field name is left blank

```
struct file_time {
  unsigned int  : 5;            /* not used */
  unsigned int minutes: 6;
  unsigned int hours: 5;
};
```


Is positioned as–is

Left blank
(like a placeholder)

– 0 bit-field padding cause the next field to be aligned on the <u>next container boundary</u>
– 0 bit-field must be unnamed

bit–field name is left blank

```
struct s {
  unsigned int a: 4;
  unsigned int  : 0;      /* 0-length bit-field */
  unsigned int b: 8;
};
```

Skipped
(By 0–bit field)

15. a) Some compilers print -1 instead of 1 because it's value of sign is set at different value.

   b) To avoid the problem, use `unsigned int` instead of `int` in `struct`.

<u>Correct Solution</u>

a) Some compilers print -1 instead of 1 because it's value of sign is set at different
   value.

---

b) To avoid the problem, use `unsigned int` instead of `int` in `struct`. This will allow flag to have value 0 and 1.

Another way is by adding an extra member `sign` of size 1 to `struct`. This will aloow flag to have value -1, 0 and 1.

```
struct float {
    int sign: 1;
    int flag: 1;
}
```

16.
```
typedef unsigned long DWORD;

/* order switched because x86 processor is little endian */
union {
    struct {
        BYTE al, ah, bl, bh, cl, ch, dl, dh;
    } byte;
    struct {
        WORD ax, bx, cx, dx;
    } word;
    struct {
        DWORD eax, ebx, ecx, edx;
    } dword;
}
```

Correct Solution:
```
typedef unsigned short WORD;
typedef unsigned long DWORD;
typedef unsigned char BYTE;

union {
    // located furthest from 0x (stored closest to 0x)
    struct {
        DWORD eax, ebx, ecx, edx;
    } dword;
    struct {
        WORD ax, axe, bx, bxe, cx, cxe, dxe;
    } word;

    // located closest to 0x (stored furthest from 0x)
    struct {
        BYTE al, ah, ale, ahe, bl, bh, ble, bhe, cl, ch,
             cle, che, dl, dh, dle, dhe;
    } byte;
}
```

Notes

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- **Other Low Level Technique**
  - **Using Unions to Provide Multiple Views of Data**
    * Unions are used in C for an entirely different purpose: viewing a block of memory in two or more different ways
      · This is useful for **registers**
  - **Little Endian / Big Endian**
    * **Little Endian** stores most significant byte (closest to 0x) of a word at the smallest memory address (address closest to 0)
    * **Big Endian** stores he least-significant byte at the smallest address (address closest to 0)
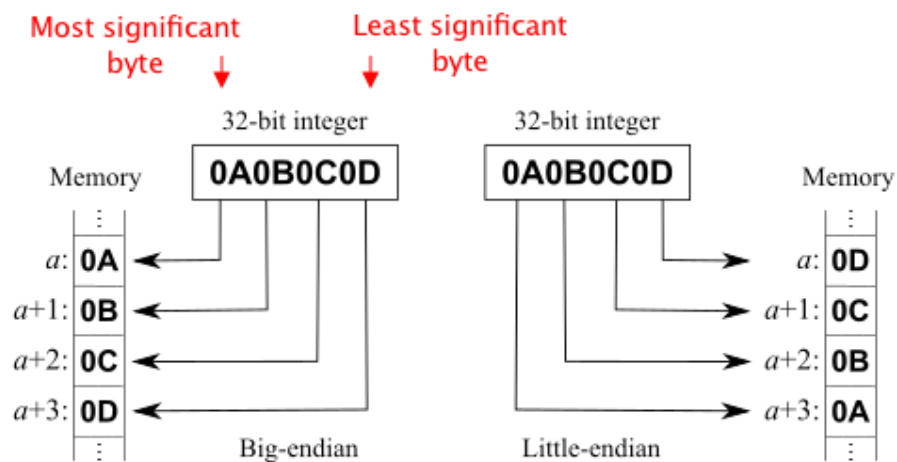
  - **AX / BX / CX / DX**
    * Are called **Data registers**
      · Stores data for processing without access to memory
    * Are used to speed up processor operations [1]
      · Brute force method reads data from and storing data into memory
      · Brute force method sends data to control bus & memory storage unit
      · Brute focre method slows down the processor

    AX (Primary Accumulator):
      · Is used in input/output and most arithmetic instructions

    BX (Base Register):
      · Used in indexed addressing
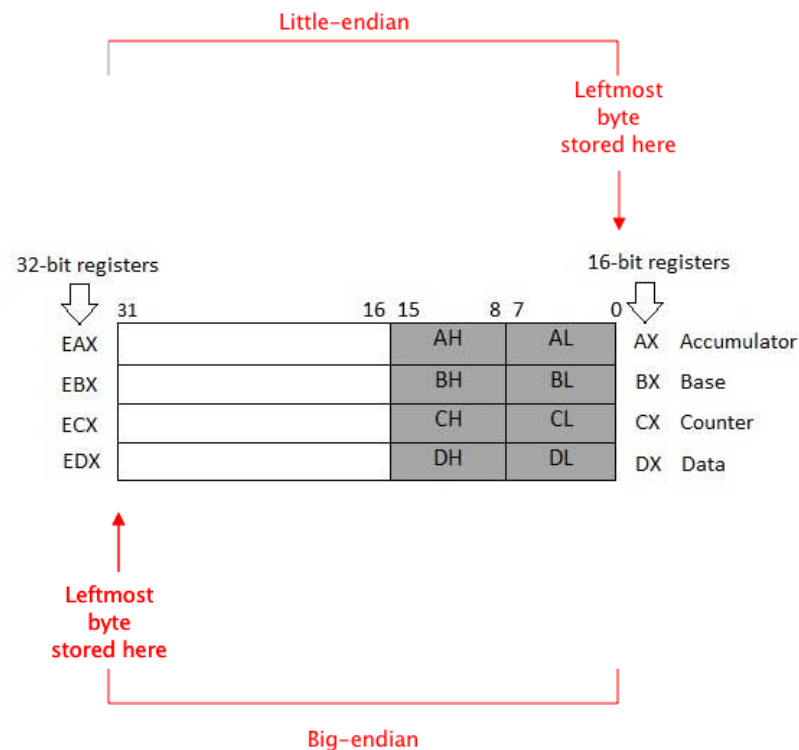
    CX (Count Register):
      · Stores loop count in iterative operations

DX (Data Register):

· Is also used for Input/Output operations.

· Is used with AX register for multiply and divide operations involving large values

```
union {
  struct {
    WORD ax, bx, cx, dx;
  } word;
  struct {
    BYTE al, ah, bl, bh, cl, ch, dl, dh;
  } byte;
} regs;
```


References

1) TutorialsPoint, Asssembly - Registers, link

2) All About Circuits, Union in C Language for Packing and Unpacking Data, link

```
17 1    union {
   2        float value;
   3        struct float {
   4            unsigned int fraction: 23;
```

```
5                unsigned int exponent: 8;
6                unsigned int sign: 1;
7           }
8       }
```