CSC 209 Review 9 Solution

September 10, 2020

1. a) 0

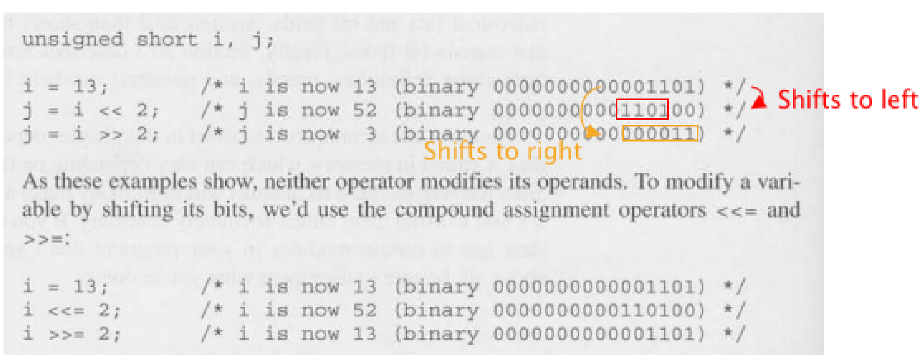
   Notes

   - `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 unsigned numbers for portability

       Example



```
unsigned short i, j;

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

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:

```
    0   1   1   1   //<- this is 7
    --------------
    1   0   0   0   //<- this is 8

    so, ~ 7 = 8
```

- &: Bitwise *and*

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

Example:

```
    0   1   1   1   //<- this is 7
    0   1   0   0   //<- this is 4
    --------------
    0   1   0   0   //<- this is 4

    so, 7 & 4 = 4
```

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

c) 1

<u>Notes</u>

- 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:

```
    0    1    1    1    //<- this is 7
    0    1    0    0    //<- this is 4
    --------------
    0    0    1    1    //<- this is 3

    so, 7 ^ 4 = 3

```

d) 0

Example

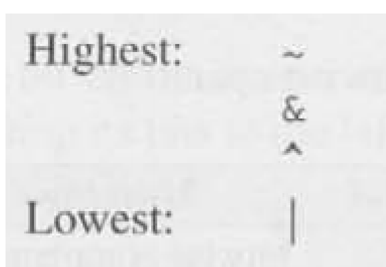
- `i` is 0000000000000111
- `j` is 0000000000001000
- `i ^ j` is 0000000000000000 or 0
- `k` is 0000000000001001
- `i ^ j & k` is 0000000000000000 or 0

Correct Solution

15

Notes

- 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`.

<u>**Notes**</u>

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

1 2 3

```
#define M(x,y)  ((x)^=(y),(y)^=(x),(x)^=(y))
```

New value of x → New value of y, using x from 1 → New value of x, using y from 2, x from 1

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

<u>**Rough Work**</u>

1. store `b` in bit 0

   `b`

2. store `g` in bit 8

   `b | g << 8`

3. store `r` in bit 16

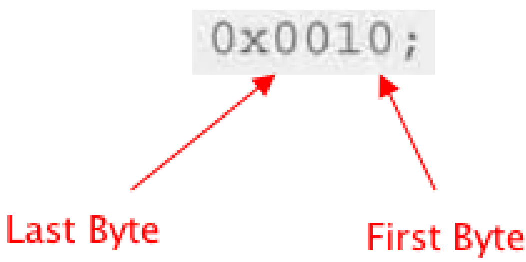
   `b | r << 16`

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

```
#include <stdio.h>
#include <stdlib.h>

#define MK_COLOR(r,g,b) (long) ( (r | (g << 8)) | (r | (b << 16)
))
#define GET_RED(c) (long) (c & 0x007)
#define GET_GREEN(c) (long) ((c >> 8) & 0x007)
#define GET_BLUE(c) (long) ((c >> 16) & 0x007)
```

```c

int main() {
    long i, r = 4, g = 5, b = 6, r2, g2, b2;

    i = MK_COLOR(r,g,b);

    r2 = GET_RED(i);
    g2 = GET_GREEN(i);
    b2 = GET_BLUE(i);

    printf("%ld\n", i);
    printf("%ld\n", r2);
    printf("%ld\n", g2);
    printf("%ld\n", b2);

    return 0;
}
```

6. a)

```c
unsigned short swap_bytes(unsigned short i) {
    unsigned short j, k;

    j = i & 0x007; // extract first byte

    i = i >> 4;
    k = i & 0x007; // extract second byte

    i = i >> 4; // shift down layter two bytes

    i |= j << 8; // add first byte to position of fourth byte
    i |= k << 12; // add second byte to position of third byte

}
```

b)

```c
unsigned short swap_bytes(unsigned short i) {

    i = i >> 8 | i << 8;

    return i;
}
```

Rough Works

1. Extract first two bytes

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

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.
```c
unsigned int rotate_left(unsigned int i, int n) {
    return i >> 28 | i << n;
}

unsigned int rotate_right(unsigned int i, int n) {
    return i << 28 | i >> n;
}
```

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)
```c
unsigned int count_ones(unsigned char *ch)
{
    unsigned char *p;
    unsigned int count;

    for (p = ch; *p != '\0'; p++){
        if (*p == '1') {
            count++;
        }
    }

    return count;
}
```

   b)
```c
unsigned int count_ones(unsigned char ch)
{
    int sum = 0;

    sum += (i >> 0) & 1;
    sum += (i >> 1) & 1;
```

```c
        sum += (i >> 2) & 1;
        sum += (i >> 3) & 1;
        sum += (i >> 4) & 1;
        sum += (i >> 5) & 1;
        sum += (i >> 6) & 1;
        sum += (i >> 7) & 1;
        return count;
    }
```

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.

```c
unsigned int reverse_bits (unsigned int n)
{
    int m = 15, p = 0;
    unsigned int byte_left_end, byte_right_end, res = 0;

    while (m > p) {
        byte_left_end = n >> m & 1;
        byte_right_end = n >> p & 1;

        res |= byte_left_end << (15 - m) | byte_right_end << (15 - p);

        m--;
        p++;
    }
    return res;
}
```

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 &, ^, 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.
```
struct float {
    unsigned int sign: 1;
    unsigned int exponent: 8;
    unsigned int : 0;
    unsigned int fraction: 23;
}
```

Correct Solution

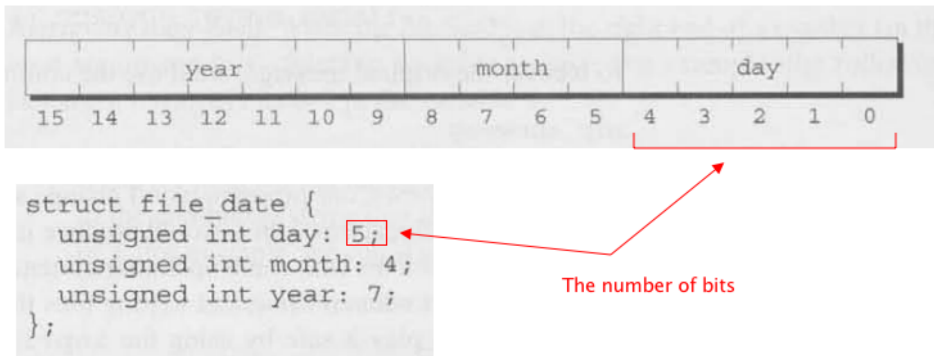
```
struct float {
    unsigned int fraction: 23;
    unsigned int exponent: 8;
    unsigned int sign: 1;
}
```

Notes

- **Bit-Fields in Structures**

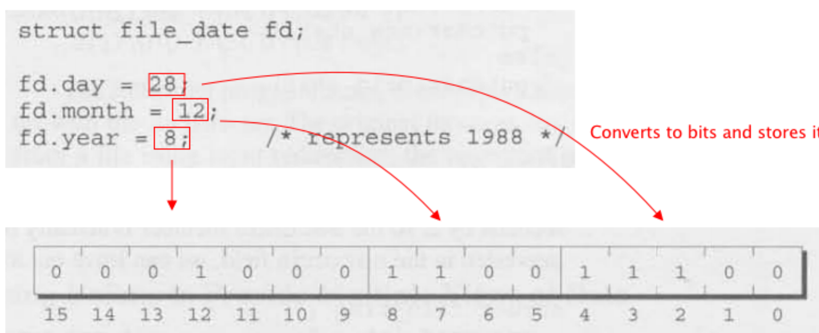
– Bit-fields are tricky and potentially confusing

Example



– 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`

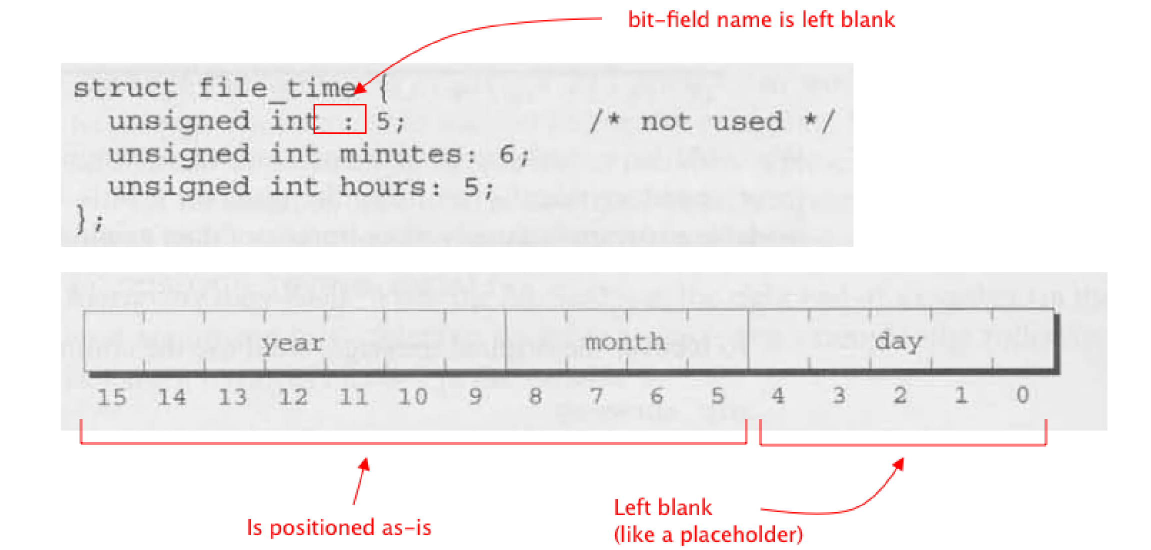
– Assignment of bit-field in structure



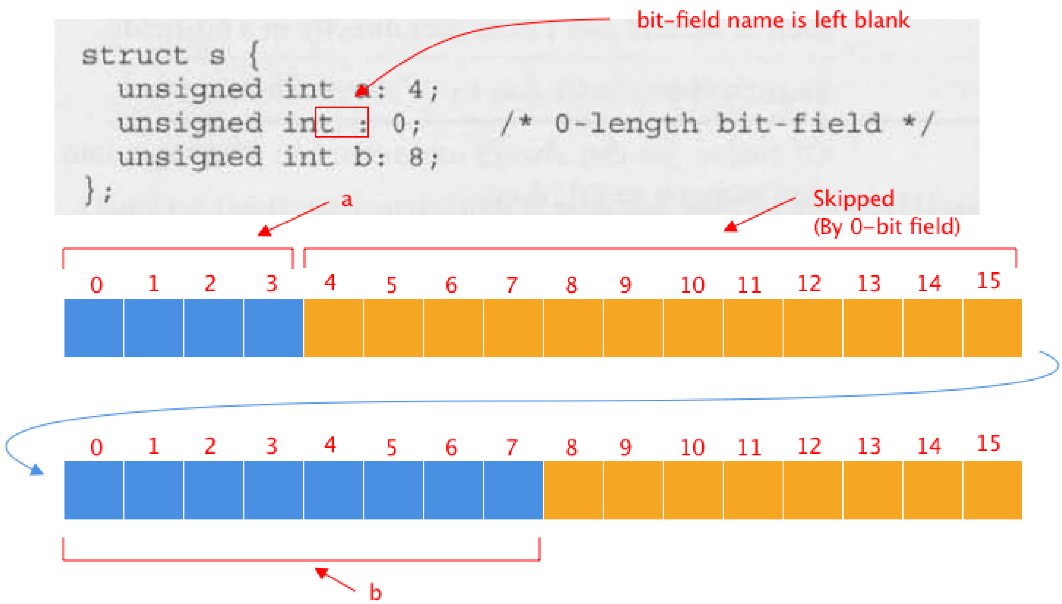
WARNING bit-fields don't have addresses

- ∗ 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



- 0 bit-field padding cause the next field to be aligned on the next container boundary
- 0 bit-field must be unnamed



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`.

Correct Solution

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:

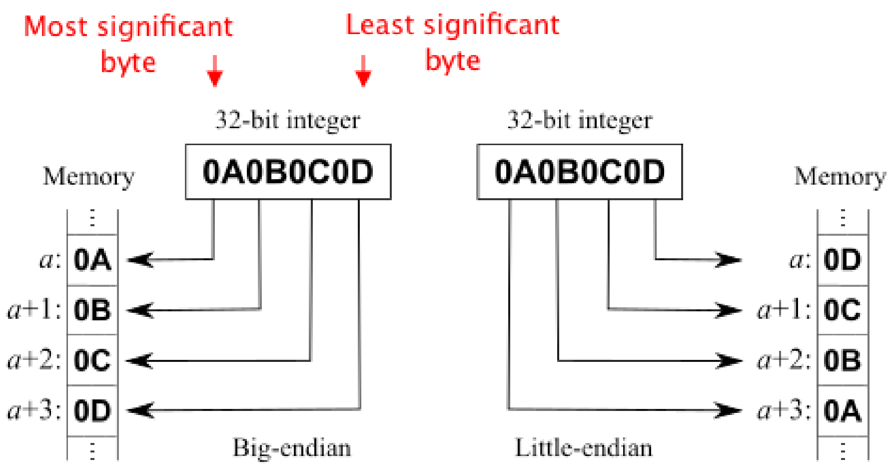
```
    typedef unsigned short WORD;
    typedef unsigned long DWORD;
    typedef unsigned char BYTE;

    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

- **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

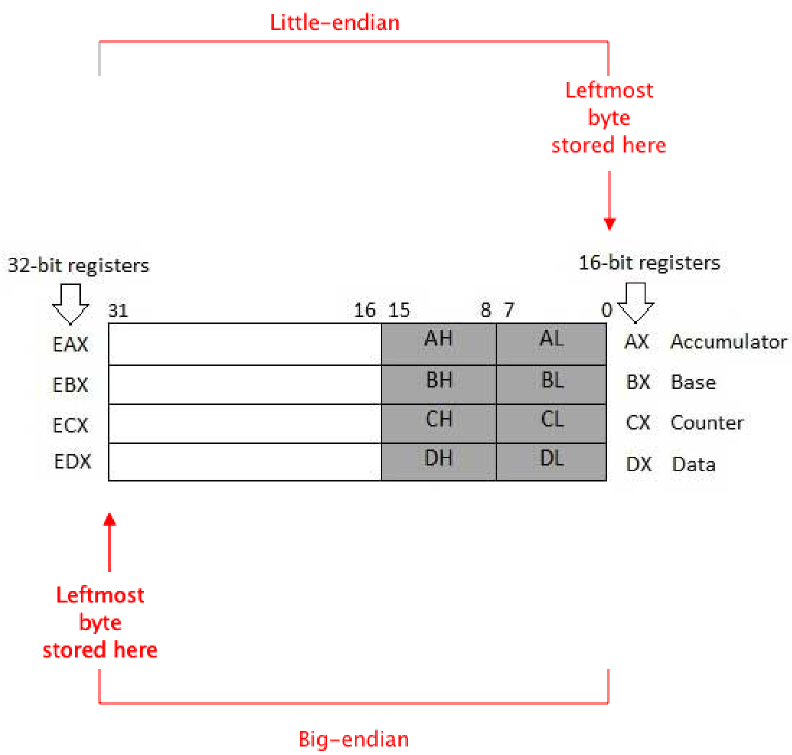
    BX (Base Register):
      - Used in indexed addressing

    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.

```
#include <stdio.h>

union {
    float value;
```

```c
        struct {
            unsigned int fraction: 23;
            unsigned int exponent: 8;
            unsigned int sign: 1;
        }p;
    } float_struc;

    int main(void)
    {
        float_struc.p.fraction = 0;
        float_struc.p.exponent = 128;
        float_struc.p.sign = 1;

        printf("%f\n", float_struc.value);
        return 0;
    }
```