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 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) */
```

Shifts to left

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:

```
    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

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:

```
    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

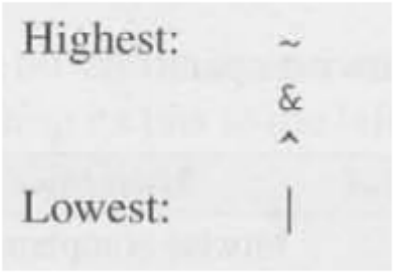
- `i` is `0000000000000111`
- `j` is `0000000000001000`
- `i ^ j` is `0000000000000000` or 0
- `k` is `0000000000001001`
- `i ^ j & k` is `0000000000000000` or 0

Correct Solution

15

Notes

- There is a precendence to the order of operations



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

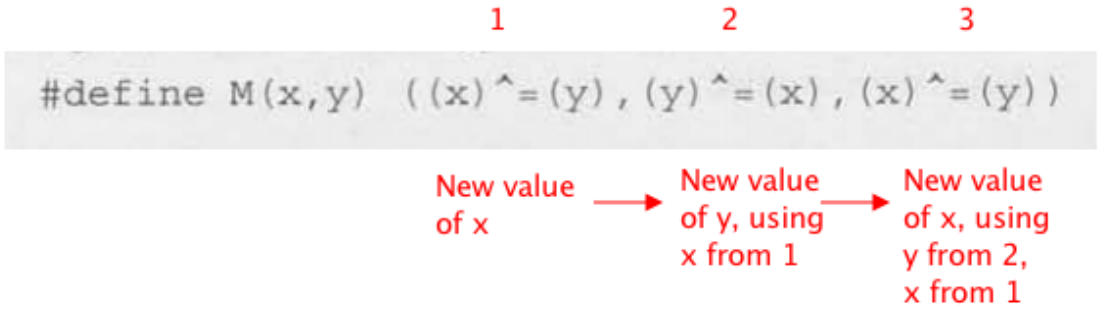
```
i = 0x00ff;          /* i is now 0000000011111111 */
i &= ~0x0010;        /* i is now 0000000011101111 */
```

  - 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

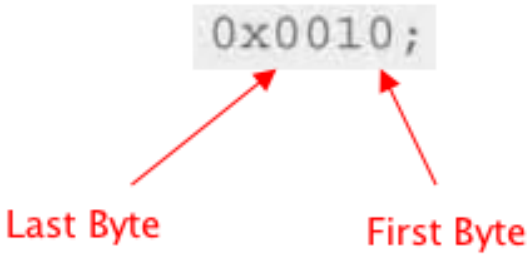
      `b | r << 16`

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

```
#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.
```
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)
```
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)
```
unsigned int count_ones(unsigned char ch)
{
    int sum = 0;

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

```
        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  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

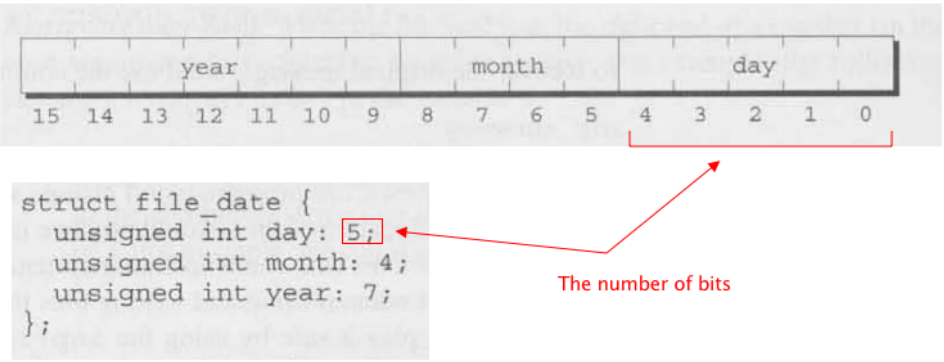
```
struct float {
    unsigned int fraction: 23;
    unsigned int exponent: 8;
    unsigned int sign: 1;
}
```

Notes

- **Bit-Fields in Structures**

– Bit-fields are tricky and potentially confusing

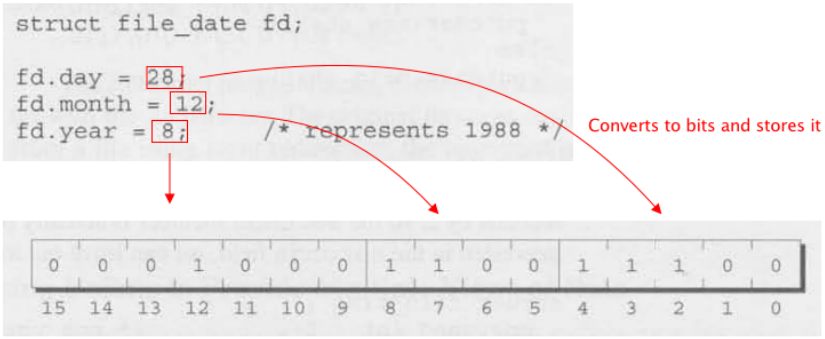
Example



– 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`

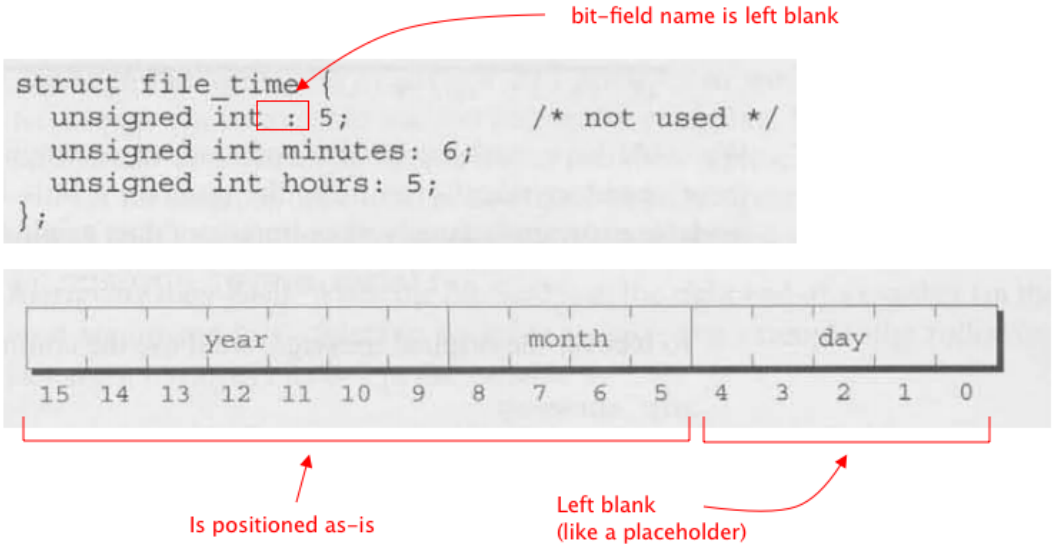
– Assignment of bit-field in structure



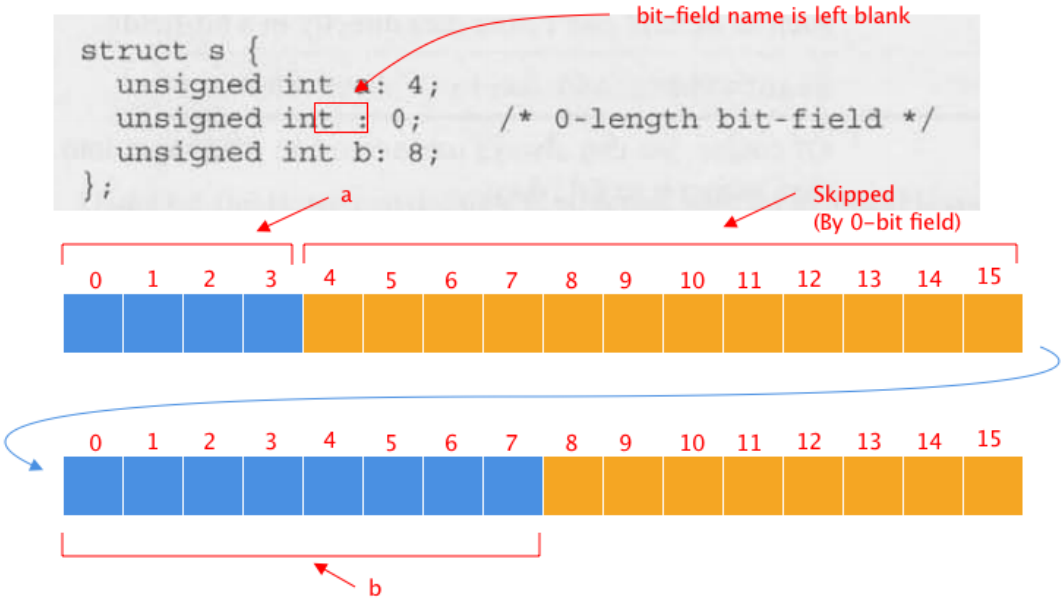
WARNING bit-fields don't have addresses

* 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;
    }
```

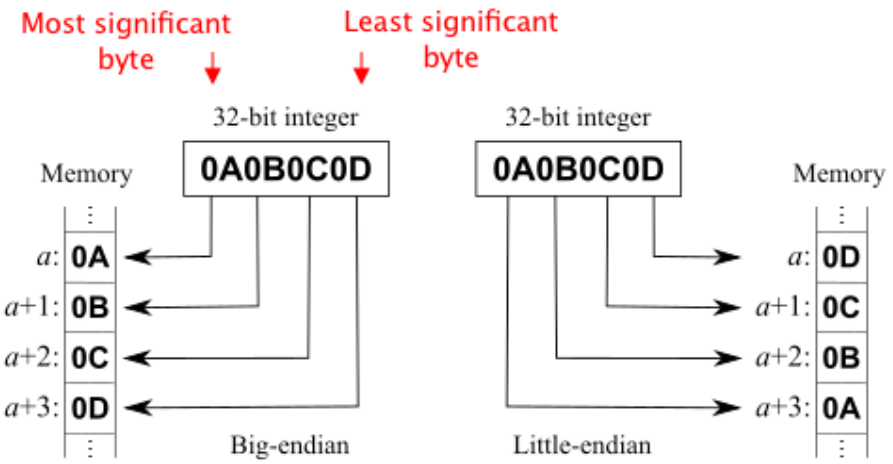
16.

```
typedef unsigned long DWORD;

/* order switched because x86 processor is little endian */
/* we want eax, ebx, ecx, edx to be stored first */
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;
}
```

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

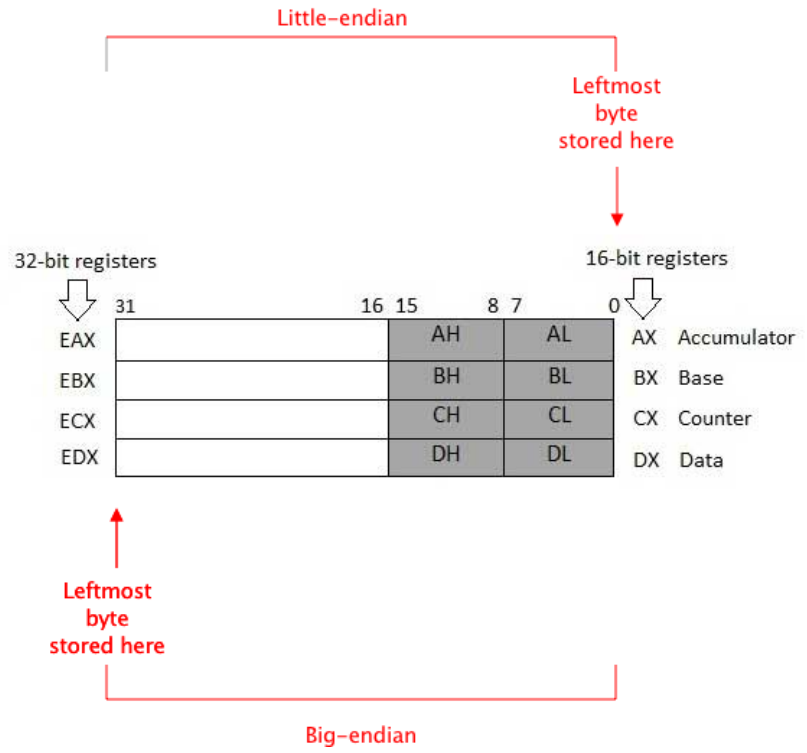
CX (Count Register):

· 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