CprE 288 – Introduction to Embedded Systems
Exam 1 Review

Overview

- Exam 1: Tuesday 10/2, in class
  - Open textbook, datasheet, 1 page of notes, and calculator allowed
  - 75 minutes
  - Electronic textbook and electronic Datasheet is fine. Nothing else on your electronic device can be used or **you will receive an F for CPRE 288**

Exam Coverage

- Focus
  - Embedded C programming
  - Memory Mapped I/O and Registers
    - General Concept of Memory mapped registers
    - GPIO
- Covers material in lectures
  - No UART questions
  - No ADC questions
  - No Interrupt questions
- Covers material in homework's (HW1 – HW4)
- Cover materials in Labs 1 - 4
- 60 points total (10% of course grade)

Exam Preparation

Suggested preparation steps:

- Review homeworks
- Review lectures
- Review labs
- Make a nice notes sheet
- Note: this set of slides are *not comprehensive*

Keywords

- char
- short
- int
- long
- float
- double

- ~~enum~~
- struct
- union

- break
- case
- ~~continue~~
- default
- do
- else
- for
- ~~goto~~
- if
- return
- switch
- while

- ~~auto~~
- ~~const~~
- ~~extern~~
- ~~register~~
- signed
- static
- unsigned
- volatile

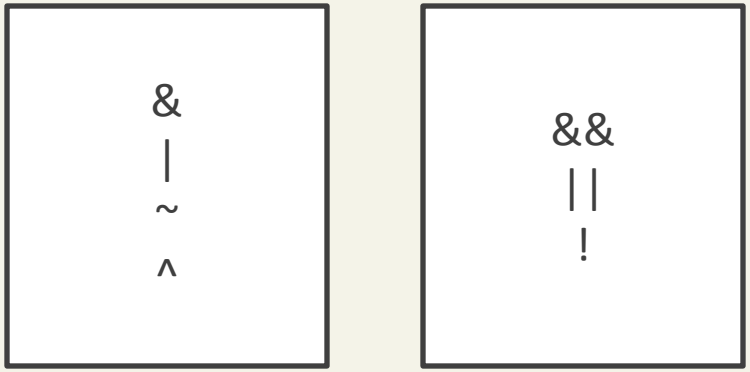
- ~~sizeof~~
- typedef
- void

Syntax

- Could you write the following statements by hand?
  - Loops (for, while, do)
    - Write a **for loop** to sum elements of an array or count characters in a string
    - Do you know the syntax of a **do while loop**, **for loop**, and **while loop**?
  - typedef
    - Could you write a typedef definition
    - Do you know what it means when you see a variable type like **uint8_t**?
  - Switch statements
    - Do you know where the semi-colon and colons go in a switch/case statement?
    - Do you understand how the control flow can fall through a case?
  - Control flow
    - Do you understand the keywords **break** and **continue** and their use?

Know your Operators

- Do you know the difference between these two sets of operators?



Know your Operators

```
char a = 20, b = 10, r = 5;

// math operations
r = a + b;
r = a - b;
r = a * b;
r = a \ b;
r = a % b;

// bitwise operators
r = a & 3;
r = a | b;
r = a ^ 0xFF;
r = ~a;
r = a >> 3;
r = b << r;

// conditional
r = (r) ? a : b;
```

```
// boolean
r = a || b;
r = a && b;
r = !a;
r = a < 20;
r = b <= 15;
r = b > 10;
r = a >= b;

// post and prefix
a++;
++a;
b--;
--b;

// assignments
r = a = b = 42;
r |= a;
r &= b;
```

Know how to use Operator Precedence

- Can you use this table?

Precedence	Operator	Description	Associativity
1	`++ --`	Suffix/postfix increment and decrement	Left-to-right
	`()`	Function call	
	`[]`	Array subscripting	
	`.`	Element selection by reference	
	`->`	Element selection through pointer	
2	`++ --`	Prefix increment and decrement	Right-to-left
	`+ -`	Unary plus and minus	
	`! ~`	Logical NOT and bitwise NOT	
	`(type)`	Type cast	
	`*`	Indirection (dereference)	
	`&`	Address-of	
	`sizeof`	Size-of	
3	`* / %`	Multiplication, division, and modulus (remainder)	Left-to-right
4	`+ -`	Addition and subtraction	
5	`<< >>`	Bitwise left shift and right shift	
6	`< <=`	For relational operators < and ≤ respectively	
	`> >=`	For relational operators > and ≥ respectively	
7	`== !=`	For relational = and ≠ respectively	
8	`&`		
9	`^`		
10	`|`		
11	`&&`		
12	`||`		
13	`?:`	Ternary conditional	Right-to-Left
14	`=`	Direct assignment	
	`+= -=`	Assignment by sum and difference	
	`*= /= %=`	Assignment by product, quotient, and remainder	
	`<<= >>=`	Assignment by bitwise left shift and right shift	
	`&= ^= |=`	Assignment by bitwise AND, XOR, and OR	
15	`,`	Comma	Left-to-right

Know your Declarations

- Do these declarations make sense?

```
void main() {
    char x = 5, y = 10;
    char z;
    char array1[10];
    char array2[] = {1, 2, 3};
    char array3[5] = {1, 2, 3};
    char *str = "Hello!";

    int i = 7;
    int *ptr = &i;
    int **pp = &ptr;
    char *p;
}
```

Know your Declarations

- Do these declarations make sense?

```
struct House {
    unsigned long value;
    unsigned char baths;
    unsigned char bedrooms;
    unsigned char stories;
    unsigned long footage;
};

void main() {
    struct House my_home;
    struct House *bob_home = &my_home;

    my_home.baths = 1;
    my_home.value = 115000;
    bob_home->baths = 3;
    bob_home->value = 230000;
}
```

Data Structures

- Array access
- Pointers
  - Dereference
  - Address operator
- Access members of structs and unions
- ~~Bit-field defined `struct`~~
- Know the difference between a `struct` and `union`

Pointers

- What are pointers?
- Relationship between
  - pointers
  - array names
- Pointer arithmetic
- Be sure to review class examples and homework problems related to pointers

C-strings

- Review the concept of C-strings
- Relationship between
  - C-strings
  - arrays
- Understand the importance of the NULL byte of a C-string

Bitwise operations

- Forcing bits to 1, Forcing bits to 0, Toggling (i.e. inverting) bits
- Testing if any of a set of bits is set to 1
  1) Decide which bits you want to test
  2) Isolate those bits (i.e. force all other bits to 0)
- Testing if all bits of a set of bits are set to 1
  1) Decide which bits you want to test
  2) Isolate those bits (i.e. force all other bits to 0)
  3) Compare for equality with the Mask
- For the case of testing for bits set to 0. Follow bit(s) set to 1 testing procedure, but invert the variable that you are testing.
- Generic systematic checking example

```
if( (x & MASK_ALL1s) == MASK_ALL1 &&
    (~x & MASK_ALL0s) == MASK_ALL0s &&
    (x & MASK_ANY1s)  &&
    (~x & MASK_ANY0s) )
```

Memory Mapped I/O

- Concept of Memory Mapped I/O
  - Device registers can be accessed from a program as if accessing memory (i.e. devices' registers are "mapped" to memory addresses)
  - Allow sending commands and checking status of a devices by just reading and writing to memory mapped locations.
- Using GPIO
- ~~Polling device status vs. device initiating an interrupt.~~

Pointer Problem

- There will be a pointer problem similar to the one in HW4.

```
typedef struct coord{
  char x;
  char y;
} coord_t;

coord_t  *coord_ptr;
int *num_ptr;
int **p_ptr = &num_ptr;
char a = 0x07;
coord_t my_coord[2];
int num_array[2]={1,4};

int main(){
  coord_ptr = my_coord;
  num_ptr = num_array;
  my_coord[1].x = 0x33;
  coord_ptr++;
  coord_ptr->y = 0x44;
  num_ptr = num_ptr + 2;
  *num_ptr = 0x5040;
  p_ptr++;
  *p_ptr = 0xFEC0;
```

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0xFFFF_FFFD		
0xFFFF_FFFC		
0xFFFF_FFFB	num_ptr	
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0xFFFF_FFF8		
0xFFFF_FFF7	p_ptr	
0xFFFF_FFF6		
0xFFFF_FFF5		
0xFFFF_FFF4		
0xFFFF_FFF3	a	
0xFFFF_FFF2	my_coord[1].y	
0xFFFF_FFF1	my_coord[1].x	
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0xFFFF_FFEF	my_coord[0].x	
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0xFFFF_FFED		0x00
0xFFFF_FFEC		0x00
0xFFFF_FFEB		0x04
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0xFFFF_FFF5		0xFF
0xFFFF_FFF4		0xF8
0xFFFF_FFF3	a	0x07
0xFFFF_FFF2	my_coord[1].y	~~0x44~~ 00
0xFFFF_FFF1	my_coord[1].x	~~0x33~~ 00
0xFFFF_FFF0	my_coord[0].y	0x50
0xFFFF_FFEF	my_coord[0].x	0x40
0xFFFF_FFEE	num_array[1]	0x00
0xFFFF_FFED		0x00
0xFFFF_FFEC		0x00
0xFFFF_FFEB		0x04
0xFFFF_FFEA	num_array[0]	0x00
0xFFFF_FFE9		0x00
0xFFFF_FFE8		0x00
0xFFFF_FFE7		0x01

```
typedef struct coord{
  char x;
  char y;
} coord_t;

coord_t  *coord_ptr;
int *num_ptr;
int **p_ptr = &num_ptr;
char a = 0x07;
coord_t my_coord[2];
int num_array[2]={1,4};

int main(){
  coord_ptr = my_coord;
  num_ptr = num_array;
  my_coord[1].x = 0x33;
  coord_ptr++;
  coord_ptr->y = 0x44;
  num_ptr = num_ptr + 2;
  *num_ptr = 0x5040;
  p_ptr++;
  *p_ptr = 0xFEC0;
```

Address	Variable Name	Value
0xFFFF_FFFF	coord_ptr	0xFF
0xFFFF_FFFE		0xFF
0xFFFF_FFFD		0xFF
0xFFFF_FFFC		~~0xEF~~ F1
0xFFFF_FFFB	num_ptr	0xFF
0xFFFF_FFFA		0xFF
0xFFFF_FFF9		0xFF
0xFFFF_FFF8		~~0xE7~~ EF
0xFFFF_FFF7	p_ptr	0xFF
0xFFFF_FFF6		0xFF
0xFFFF_FFF5		0xFF
0xFFFF_FFF4		~~0xF8~~ FC
0xFFFF_FFF3	a	0x07
0xFFFF_FFF2	my_coord[1].y	~~0x44~~ 00
0xFFFF_FFF1	my_coord[1].x	~~0x33~~ 00
0xFFFF_FFF0	my_coord[0].y	0x50
0xFFFF_FFEF	my_coord[0].x	0x40
0xFFFF_FFEE	num_array[1]	0x00
0xFFFF_FFED		0x00
0xFFFF_FFEC		0x00
0xFFFF_FFEB		0x04
0xFFFF_FFEA	num_array[0]	0x00
0xFFFF_FFE9		0x00
0xFFFF_FFE8		0x00
0xFFFF_FFE7		0x01

```
typedef struct coord{
  char x;
  char y;
} coord_t;

coord_t  *coord_ptr;
int *num_ptr;
int **p_ptr = &num_ptr;
char a = 0x07;
coord_t my_coord[2];
int num_array[2]={1,4};

int main(){
  coord_ptr = my_coord;

  num_ptr = num_array;

  my_coord[1].x = 0x33;

  coord_ptr++;

  coord_ptr->y = 0x44;

  num_ptr = num_ptr + 2;

  *num_ptr = 0x5040;

  p_ptr++;

  *p_ptr = 0xFEC0;
```

Address	Variable Name	Value
0xFFFF_FFFF	coord_ptr	~~0xFF~~ 00
0xFFFF_FFFE		~~0xFF~~ 00
0xFFFF_FFFD		~~0xFF~~ FE
0xFFFF_FFFC		~~0xEF~~ ~~F1~~ C0
0xFFFF_FFFB	num_ptr	0xFF
0xFFFF_FFFA		0xFF
0xFFFF_FFF9		0xFF
0xFFFF_FFF8		~~0xE7~~ EF
0xFFFF_FFF7	p_ptr	0xFF
0xFFFF_FFF6		0xFF
0xFFFF_FFF5		0xFF
0xFFFF_FFF4		~~0xF8~~ FC
0xFFFF_FFF3	a	0x07
0xFFFF_FFF2	my_coord[1].y	~~0x44~~ 00
0xFFFF_FFF1	my_coord[1].x	~~0x33~~ 00
0xFFFF_FFF0	my_coord[0].y	0x50
0xFFFF_FFEF	my_coord[0].x	0x40
0xFFFF_FFEE	num_array[1]	0x00
0xFFFF_FFED		0x00
0xFFFF_FFEC		0x00
0xFFFF_FFEB		0x04
0xFFFF_FFEA	num_array[0]	0x00
0xFFFF_FFE9		0x00
0xFFFF_FFE8		0x00
0xFFFF_FFE7		0x01

Writing the Body of a function

- There will be 1 or 2 problems where you will be asked to write the body of a function to implement a defined computation.

Show your work

- Show intermediate steps. This will help us give partial credit

- Write down assumptions. In general Profs/TAs will not answer questions during the Exam.
  - They will just tell you to write down your assumptions
  - The exception will be if a major typo is found by a student.

QUESTIONS

Question 1

A. How many bytes are each of the following types (on the TMC123)?
   - char, short, int, long, float, double

B. What range of values can be stored in an unsigned char?

C. What range of values can be stored in a signed char?

D. What is the value stored in **x** after this code runs?

```
int x, y, z;
x = y = z = 10;
```

Question 1 (answer)

Name	Number of Bytes sizeof()	Range
char	1	-128 to 127
signed char	1	-128 to 127
unsigned char	1	0 to 255
short	2	-32,768 to 32,767
unsigned short	2	0 to 65,535
int (on TMC4123)	4	-2147483648 to 2147483647
unsigned int (on TMC4123)	4	0 to 4294967295
(pointer on TMC4123)	4	Address Space
long	4	-2147483648 to 2147483647
signed long	4	-2147483648 to 2147483647
unsigned long	4	0 to 4294967295
float	4	±1.175e-38 to ±3.402e38

Question 2a

- When is the condition of the following **if** statement true?

```
if ((x = 3) || (x & 1)) {
   // do something
}
```

Question 2a (answer)

- When is the condition of the following **if** statement true?

```
if ((x = 3) || (x & 1)) {
   // do something
}
```

- The statement is always true. Know the difference between the assignment operator (=) and the equality operator (==).
  - The value on the left (x = 3) is always true, as the value of an assignment is the value that was assigned. This allows programmers to have compound assignments.

Question 2b

- When is the condition of the following **if** statement true?

```
if ((x == 3) || (x & 1)) {
   // do something
}
```

Question 2b (answer)

- When is the condition of the following **if** statement true?

```
if ((x == 3) || (x & 1)) {
   // do something
}
```

- The statement is true if x is either equal to 3 or bit 0 is set.

Question 3

- When is the condition of the following **if** statement true?

```
if ((x & 0x08) == 0x08) {
   // do something
}
```

Question 3 (answer)

- When is the condition of the following **if** statement true?

```
if ((x & 0x08) == 0x08) {
   // do something
}
```

- The statement is true if bit3 of x is set.
  - x = 0b00001000; condition is TRUE
  - x = 0b01001110; condition is TRUE
  - x = 0b00101001; condition is TRUE
  - x = 0b00000000; condition is FALSE
  - x = 0b11100000; condition is FALSE

Review Homework Problems and Answers