Lecture 3: Pointers

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Adapted from material by Blake Hannaford

Administrative

- Lab access- ECE front desk told me everyone should have access, if you can't get in just let them know
- Lab kit pickup
  Mon-Fri: 9am-12pm and 1pm-5pm
- Partner matching form DUE TODAY: https://bit.ly/cse474-24sp-partners
- C Programming Assignment 1 posted

Assignment 1

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C Programming Assignments

C Programming 1

Due Apr 12 by 11:59pm on Canvas
Instructions, Assignment files (zip)

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April

Monday	Tuesday	Wednesday	Thursday	Friday
01 9:30-11:30 OH (Deeksha) ECE 345 11:30-13:30 OH (Alex) ECE 345	02 13:00-15:00 OH (Zach) ECE 345	03 9:30-11:30 OH (Deeksha) ECE 345 12:30-14:20 Lecture MOR 230 *Lecture 3: Pointers in C* 14:00-15:00 OH (Vikram) ECE 345	04 10:00-12:00 OH (Zach) ECE 345 12:30-14:30 OH (Alex) ECE 345	05 12:30-14:20 Lecture MOR 230 *Lecture 4: Number Representation and Bitwise Operators* 14:00-15:00 OH (Vikram) ECE 345
08 9:30-11:30 OH (Deeksha) ECE 345 11:30-13:30 OH (Alex) ECE 345	09 13:00-15:00 OH (Zach) ECE 345	10 9:30-11:30 OH (Deeksha) ECE 345 12:30-14:20 Lecture MOR 230 *Lecture 5: Hardware and Machine Organization* 14:00-15:00 OH (Vikram) ECE 345	11 10:00-12:00 OH (Zach) ECE 345 12:30-14:30 OH (Alex) ECE 345	12 12:30-14:20 Lecture MOR 230 *Lecture 6: Working with Registers and IMU Demo* 14:00-15:00 OH (Vikram) ECE 345 23:59 C Programming 1 due

Last time

- Intro to C programming
  - Splitting code into multiple files
  - main()
  - Function prototypes
  - Header files
  - Hello World in Arduino and C
  - Variable and function scope

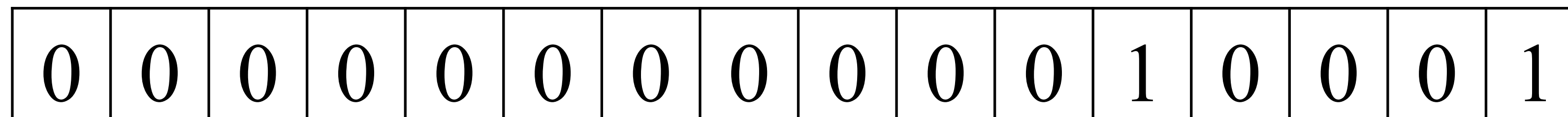
Plan for today

- Pointers and memory
  - How is your data actually stored in memory?
  - Introduction to memory addresses
  - Pointers and pointer operations

Data in memory

- The **key** to understanding C code and writing C code is think about data in the computer memory as 0's and 1's.
- What does our data look like?
  - Assuming that the size of an int is 2 bytes (16 bits), the C compiler sets up our declaration as follows:

```
int c_int_variable = 17;
```



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```

										32	16	8	4	2	1
										2^5	2^4	2^3	2^2	2^1	2^0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1

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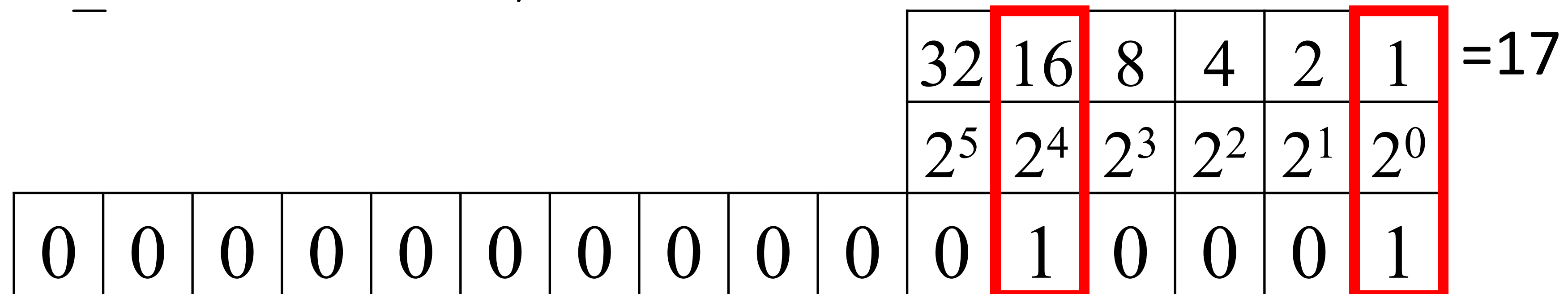

Data in memory: characters

```
char * c_char_array = "OK";
```

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C converts the two characters ‘O’ and ‘K’ to 8-bit binary versions in the ASCI (UTF-8) code:

character	numerical ASCII code
‘O’	79 (dec), 1001111(bin)
‘K’	75 (dec), 1001011(bin)

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character	numerical ASCII code
‘O’	79 (dec), 1001111(bin)
‘K’	75 (dec), 1001011(bin)

‘O’								‘K’							
0	1	0	0	1	1	1	1	0	1	0	0	1	0	1	1

Where does the data get stored?

Example memory location for `c_int_variable`:

2457568: →

0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1

Example memory location for `c_char_array`:

4200984 : →

0	1	0	0	1	1	1	1	0	1	0	0	1	0	1	1

Where does the data get stored?

- Another layout with sequential locations

Address	Byte 1								Byte 0							
2457568	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
2457570	0	1	0	0	1	1	1	1	0	1	0	0	1	0	1	1

- Same thing in HEX

Address	Byte 1								Byte 0							
257FE0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
257FE2	0	1	0	0	1	1	1	1	0	1	0	0	1	0	1	1

Where does the data get stored?

- C keeps a table of your variable names (it's called the "symbol table") which for our examples would be:

name	address(hex)	type
c_int_variable	0x257FE0	int
c_char_array	0x257FE2	char
c_int_01	0x<some hex addr>	int
c_int_02	0x<some hex addr>	int

Where does the data get stored?

What is a pointer?

A variable whose value is the memory address of another variable

- `// my_int_pointer is a pointer to an int`

```
int * my_int_pointer;
```

`my_int_pointer` is set up to hold the *address of* an int

Address	Byte 1								Byte 0							
257FE0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
257FE2	0	1	0	0	1	1	1	1	0	1	0	0	1	0	1	1

Assigning value of a pointer

The ampersand (&) symbol refers to the memory address of a variables

```
// make my_int_pointer point to c_int_variable
int* my_int_pointer = &c_int_variable ;
```

Stored value

257FE0	→	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1

```
// the pointer now points to c_int_01 instead!
my_int_pointer = &c_int_01 ;
```

Stored value

257FE2	→	0	1	0	0	1	1	1	1	0	1	0	0	1	0	1	1

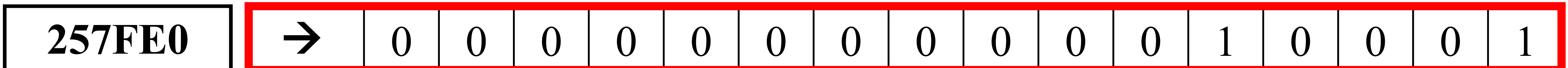
Dereferencing a pointer

Dereferencing = getting the value stored in that address with *

When not used in a declaration (e.g. int * x = 0x2457854), asterisk (*) is known as the "dereferencing operator".

```
// my_int_pointer "points to" c_int_variable
my_int_pointer = & c_int_variable;
int x = *my_int_pointer;
if (x == 17) printf(" I understand pointers!\n");
```

Stored value



Examples

```
int *pa = 0x3000;  // starting address is 0x3000
*pa = 0x000B;
*(pa++) = 0x0010;
*(pa+1) = 0x00C0;
```

What does memory look like? What are the values of

```
*pa + 1 == ??
```

```
(int)pa == ??
```

Examples

Name	Addr				
	3000	0	0	1	0
pa→	3004	0	0	0	0
	3008	0	0	C	0
	300C	0	0	0	0

```
*pa + 1 == 0001
(int)pa == 3004
```

Pointer Types and increments

Pointers are typed so that they "know" how big the thing is they point to. Example:

address	byte	byte	byte	byte	
0x257FE0				0x01	=1
0x257FE4				0x02	=2
0x257FE8			0x00	0x10	=16
0x257FEC			0x02	0x01	=513

Pointer Types and increments

```
int * p1 = 0x257FE0
printf("%d", *p1); // prints 1

printf("%d", *(p1+1) );
// prints 2
//(added 4 to byte address)

printf("%d", *(p1+2) );
// prints 16
//(added 8 to byte address)
```

address	byte	byte	byte	byte
0x257FE0				0x01
0x257FE4				0x02
0x257FE8			0x00	0x10
0x257FEC			0x02	0x01

C Pointers advance in increments of the thing they point to.

Typecasting

You can change variables from one type to another by “casting”

```
// "cast" my_int_pointer to instead BE an int
int x = (int) my_int_pointer;
print(x);
```

Creates an `int` with the address in it and prints it like any other integer.

Arrays

An array is an ordered set of memory elements.

`int j[3]` sets up memory for three ints :

`j[0], j[1], j[2]`

```
int a[5]=0; // array of 5 ints
            // each int is 2 bytes
```

Element name	a[0]	a[1]	a[2]	a[3]	a[4]
Address	3000	3002	3004	3006	3008

Initializing Arrays

```
int a[5]; // Declaring an array
```

Enough storage is allocated for 5 integers (typically 5×32 bits or 40 bytes). But you should not count on any initial value.

Initializing an array:

Method 1: `int q[3] = {0,1,2};`

Method 2:

```
int i, q[3];
for (i=0;i<3;i++) q[i] = 0;
```

Arrays and pointers

Arrays are implemented inside C just like pointers.

Example:

```
int a[10], *p;
p = &a[0];

a[3]<----->*(p+3) are exactly the same

a <-------> &a[0]
are exactly the same
```

Generic (`void`) Pointers

Sometimes we want a pointer which is not locked to a specific type and can potentially point to anything.

```
void *name ;   // declare a generic pointer called name
```

- `name` can point to anything in the computer.
- `name` cannot be dereferenced with *
- Must instead assign value of `void` pointer to a pointer of the type you want.

Generic (void) Pointers

Example:

```
void* myGenericPtr;
int t, *ip, myvalue = 3;
myGenericPtr = &myvalue; // OK
t = *myGenericPtr;   // NO!!

//*****************

ip = nyGenericPtr;
t = *ip; // OK!!
```

Null pointers

If a pointer has the value NULL, it points to nothing. NULL is a predefined constant in <stddef.h> or use #define NULL 0

- NULL is illegal to dereference.
- NULL can be tested for:
- int i,*ip = NULL;

```
if(ip == NULL) {
    // I haven't defined ip yet
   }
   else { // OK, now I   can use it!
```

Function pointers

C can have pointers to functions.

```
type (* functionpointer)(arg list)
```

Examples

```
int(*IntFuncPtr)();
\\  IntFuncPtr is a pointer to a function with
\\   no arguments which returns an int

double(*doubleFuncPtr)(int arg1, char arg2)
\\  doubleFuncPtr is a pointer to a function with
\\    an int and a char arg which returns a double.
```

Function pointers

Assignment to function pointers:

```
int (* IFP)(int x) = NULL; // empty function pointer
int realfunction( int x); // an actual function

IFP = &realfunction;
IFP = realfunction;    // can skip &
```

Dereferencing function pointers:

```
(*IFP)(5)    // call function realfunction with arg 5

IFP(5)       // can also use function pointer just like
             // original function name
```

Pointer arithmetic

A powerful feature of pointers is the ability to compute with them like ints, but only some operations are allowed with pointers.

Allowed:

- Add a scalar to a pointer
- Subtract pointers

Not Allowed

- Adding two pointers
- Multiplying or dividing
- Multiplying /dividing by scalar

Pointer arithmetic

Example: Find the midpoint in an array.

```
#define SIZE 100
int  length, buffer[SIZE]; int *ptr1,
*ptr2, *ptr3;
ptr1 = buffer;            // points to start of array
ptr2 = ptr1 + 100;        // points to end of array
length = ptr2 - ptr1;     // length = 100
ptr3 = ptr1 + length/2    // ptr3 points to mid-point of array
```

Pointer comparisons

`==, !=` Determine if two pointers are equal or not.

`<, <=, >=, >` Which pointer points to a higher address in memory?
Which way will subtraction come out?