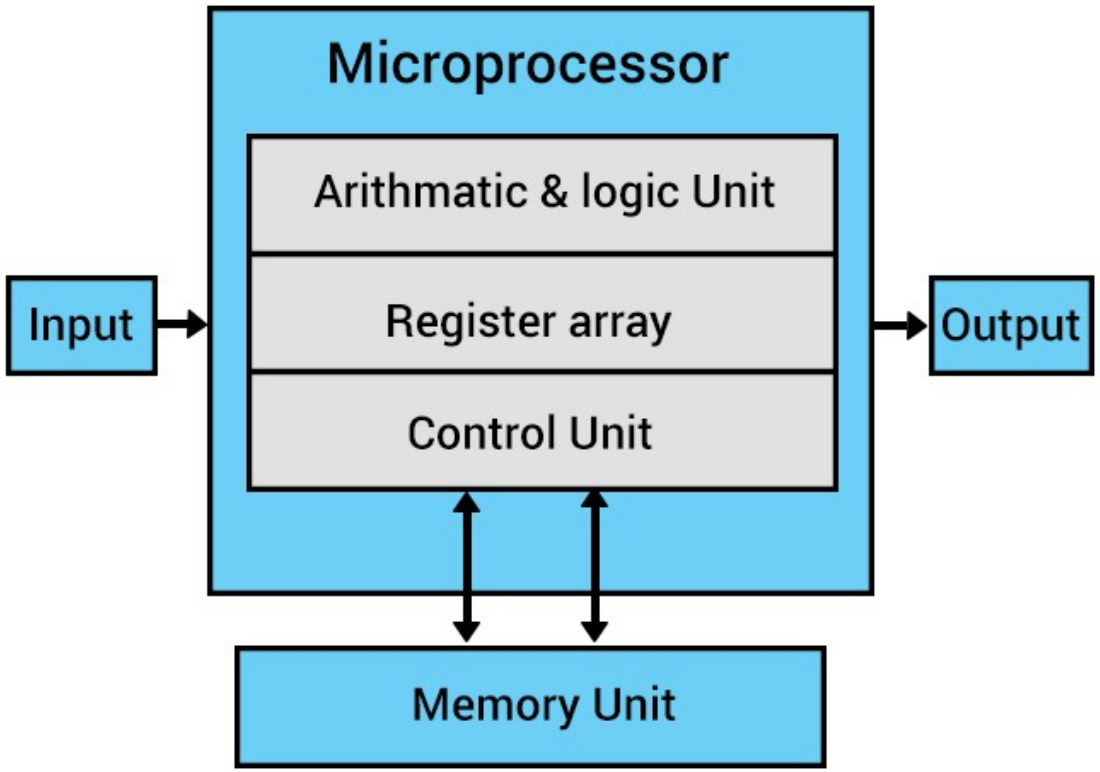
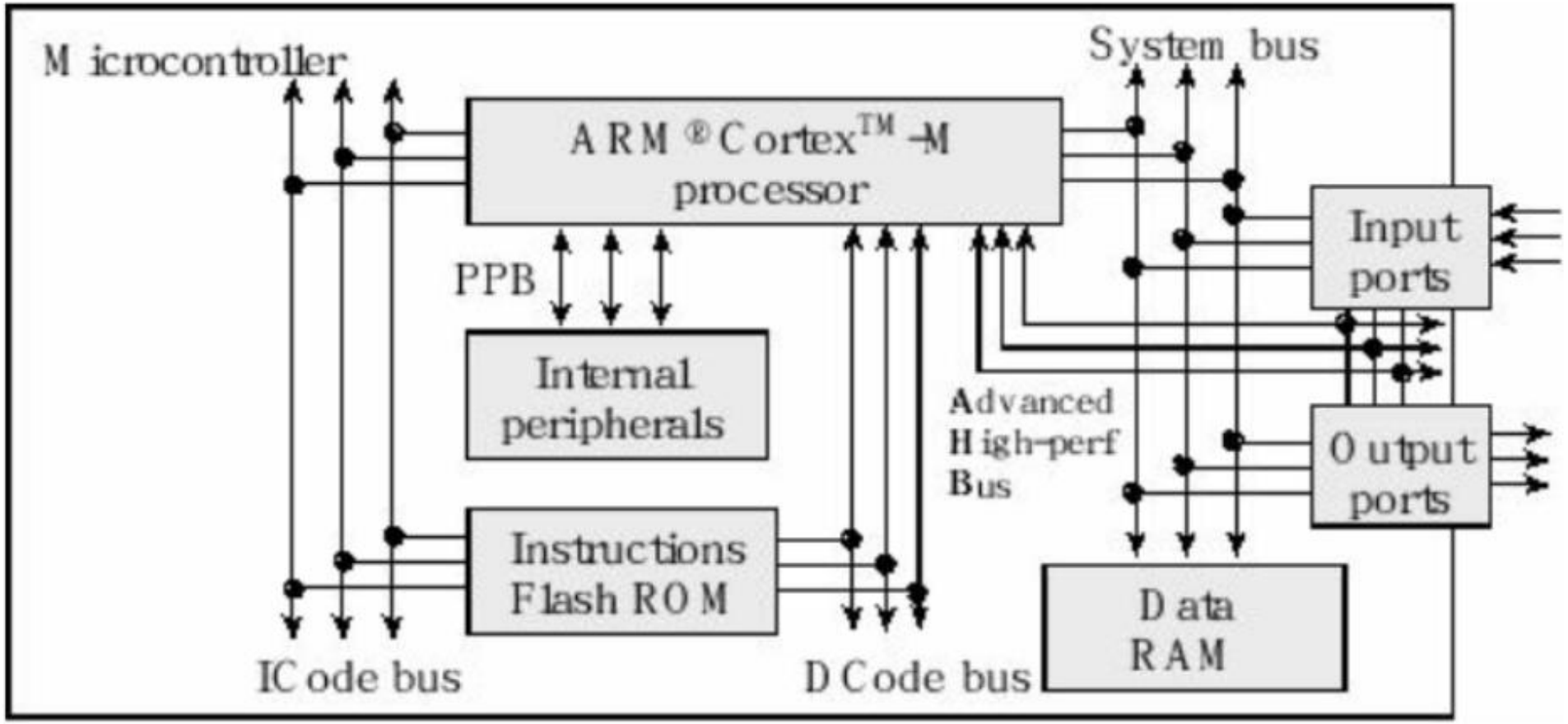
CSE 211: Introduction to Embedded Systems

Section 5

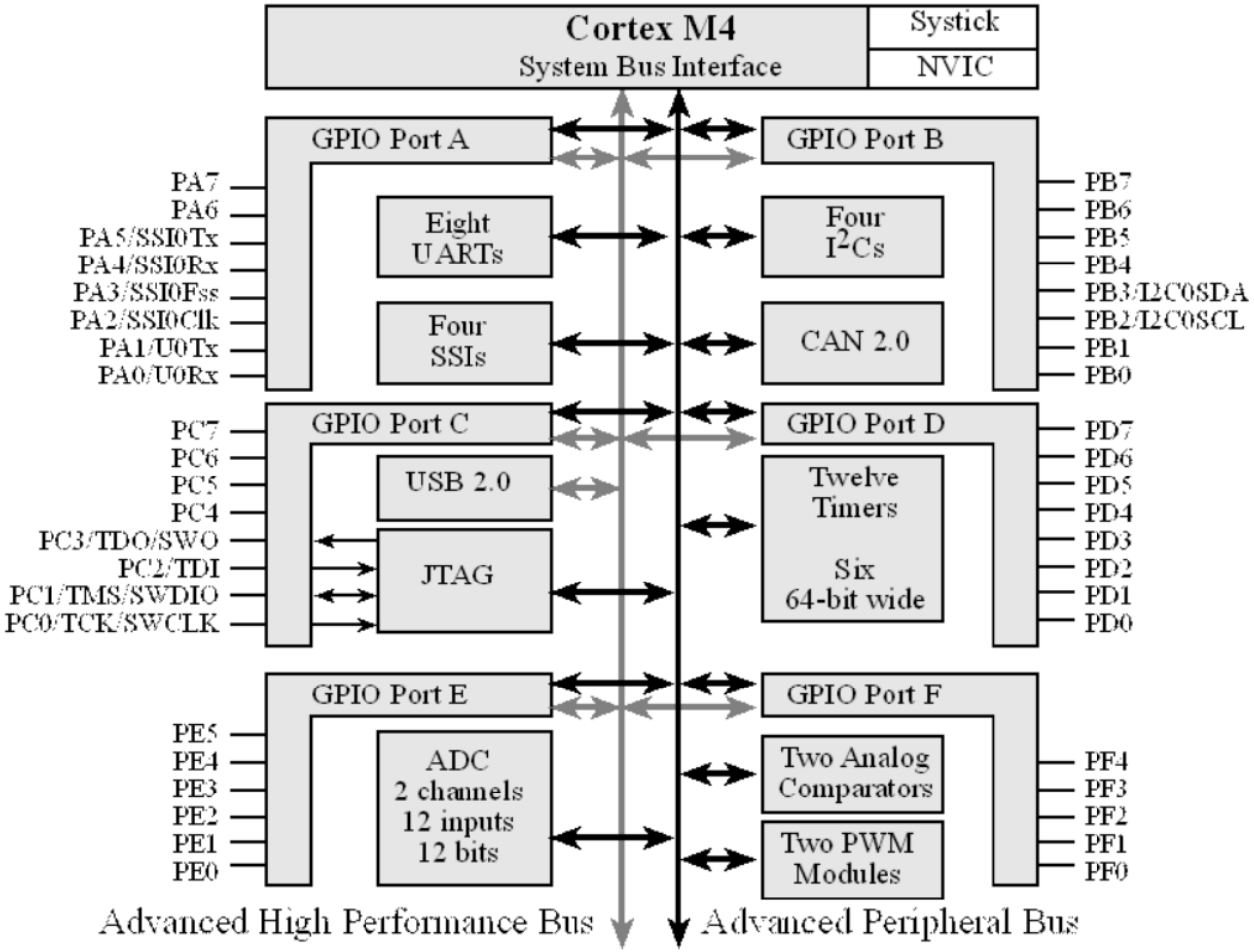
What is a microprocessor?



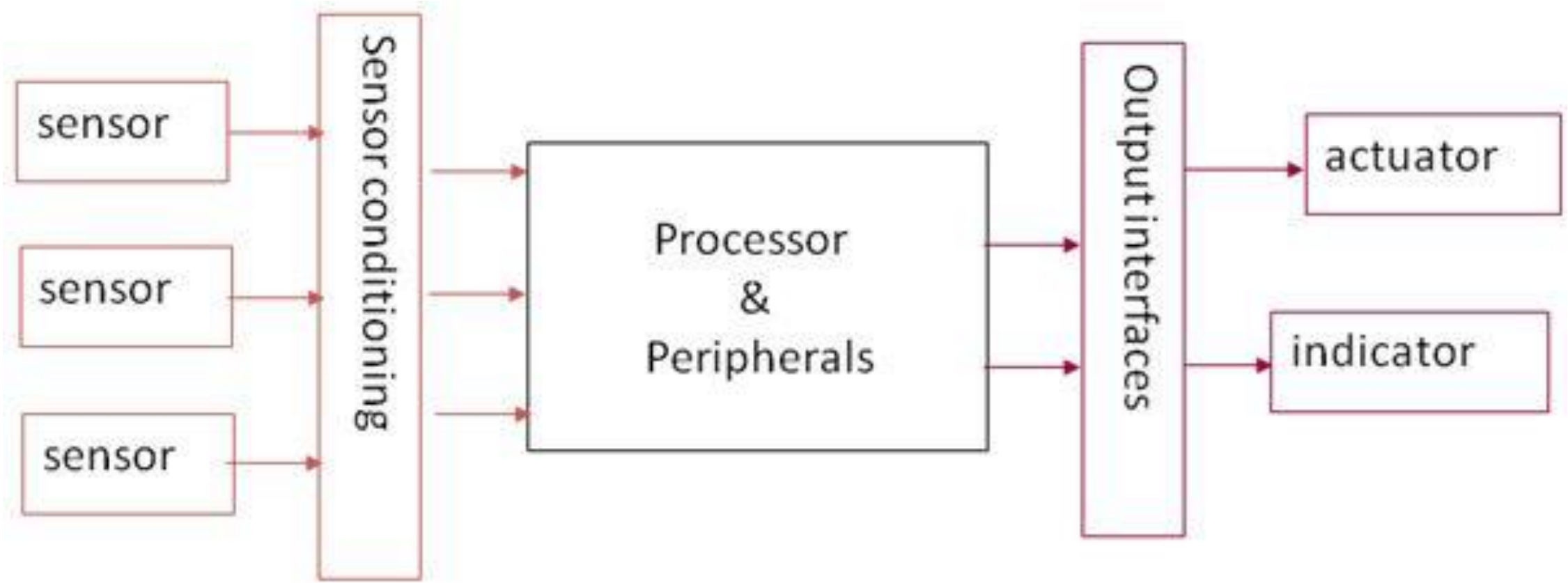
What is a microcontroller?



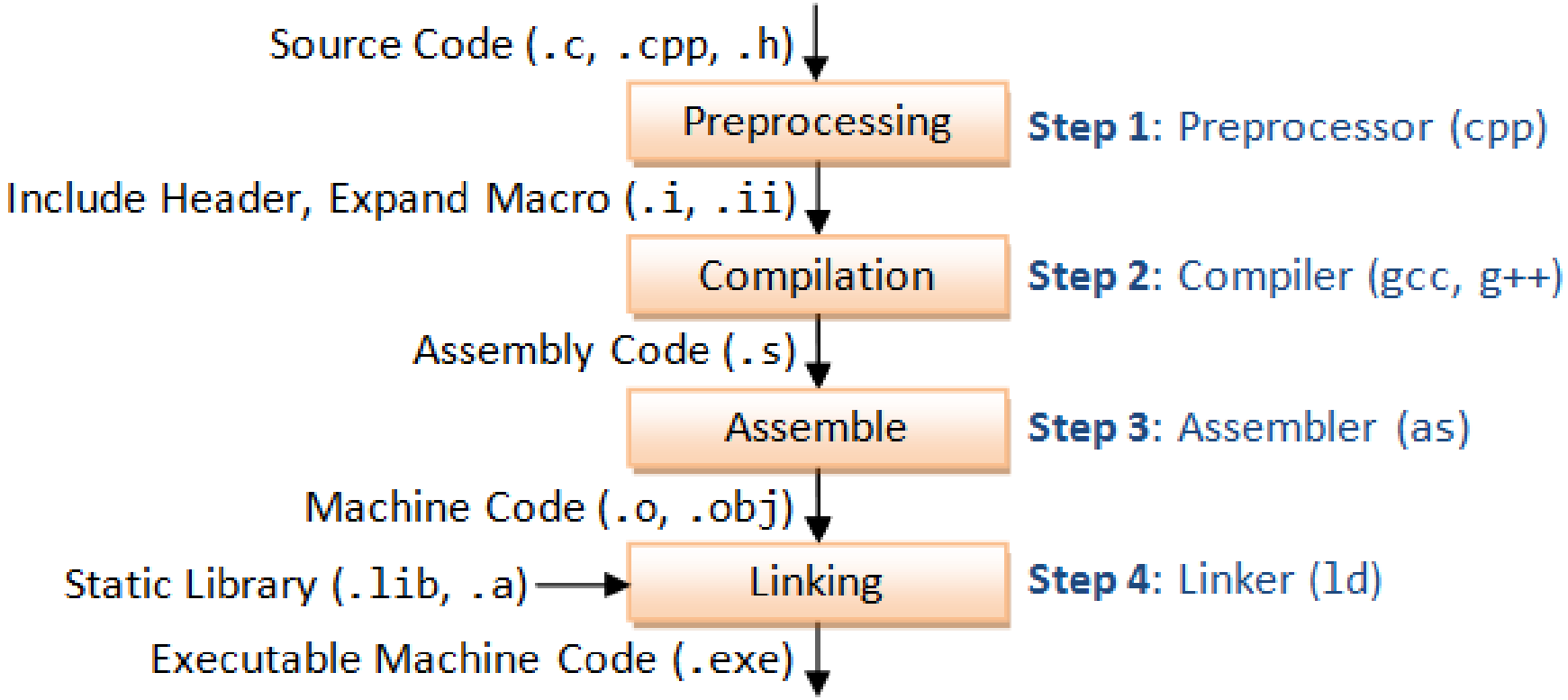
What is a microcontroller?



Embedded System



Software Build Process



Introduction to Embedded C

Review of C programming concepts:

- Preprocessor Directives
- Error Types
- Primitive Data Types
- Type Casting
- Enumeration
- Structures
- Arrays
- Pointers
- Scope and Lifetime of Variables

Preprocessor Directives

- Including files
  - #include “file.h”
- Object-like macro:
  - #define WHEEL_RADIUS 10
- Function-like macro:
  - #define MAX(a,b) (((a)>(b)) ? (a):(b))
- Compiler Instructions
  - #pragma

Preprocessor Directives

- Conditional compilation:

```
#if(FEATURE_LEVEL == 1)
    RunFeatureLvl1();
#else
    RunFeatureLvl2();
#endif
```

Preprocessor Directives

- Header file guard:

```
#ifndef FILE_H
#define FILE_H

/* Code Here */

#endif /* FILE_H */
```

Error Types

- Preproccesor Error
- Compilation Error
- Linking Error
- Logic Error

Primitive Data Types

Data Type	Size	Range
char	*at least* 1 byte	-128 to 127
unsigned char	*at least* 1 byte	0 to 255
short	*at least* 2 bytes	-32768 to 32767
unsigned short	*at least* 2 bytes	0 to 65535
int	*at least* 2 bytes	-32768 to 32767
unsigned int	*at least* 2 bytes	0 to 65535
long	*at least* 4 bytes	-2,147,483,648 to 2,147,483,647
unsigned long	*at least* 4 bytes	0 to 4,294,967,295
float	*at least* 2 bytes	3.4e-038 to 3.4e+038
double	*at least* 8 bytes	1.7e-308 to 1.7e+308
long double	*at least* 10 bytes	1.7e-4932 to 1.7e+4932

Primitive Data Types

- Standard Integer types can be included from <stdint.h>
  - int8_t
  - uint8_t
  - int16_t
  - uint16_t
  - int32_t
  - uint32_t

Type Casting

- Implicit Casting Example (should be avoided)

```
uint16_t x = 50;
// If x was bigger than 255 then truncation will occur
uint8_t  y = x;
uint32_t z = x;
```

- Explicit Casting Example

```
uint16_t x = 50;
uint8_t  y = (uint8_t) x;
uint32_t z = (uint32_t) x;
```

```
int x = 3, y = 6;
float avg = (float) (x + y) / 2;
//avg = 4 or 4.5 ?
```

Enumeration

```
typedef enum {
    COLOR_RED,
    COLOR_BLUE
} ColorType;
```

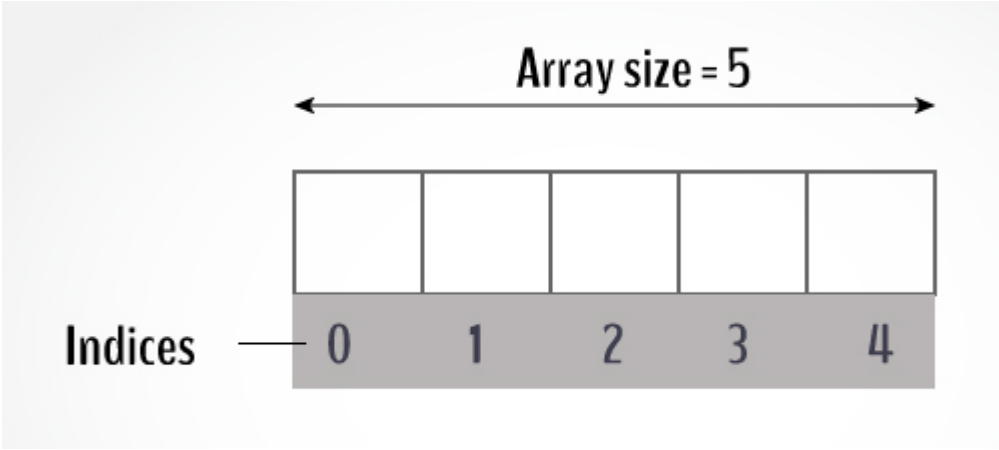
Structures

```
typedef struct {
    uint8_t id;
    uint16_t totalMarks;
} StudentType;
```

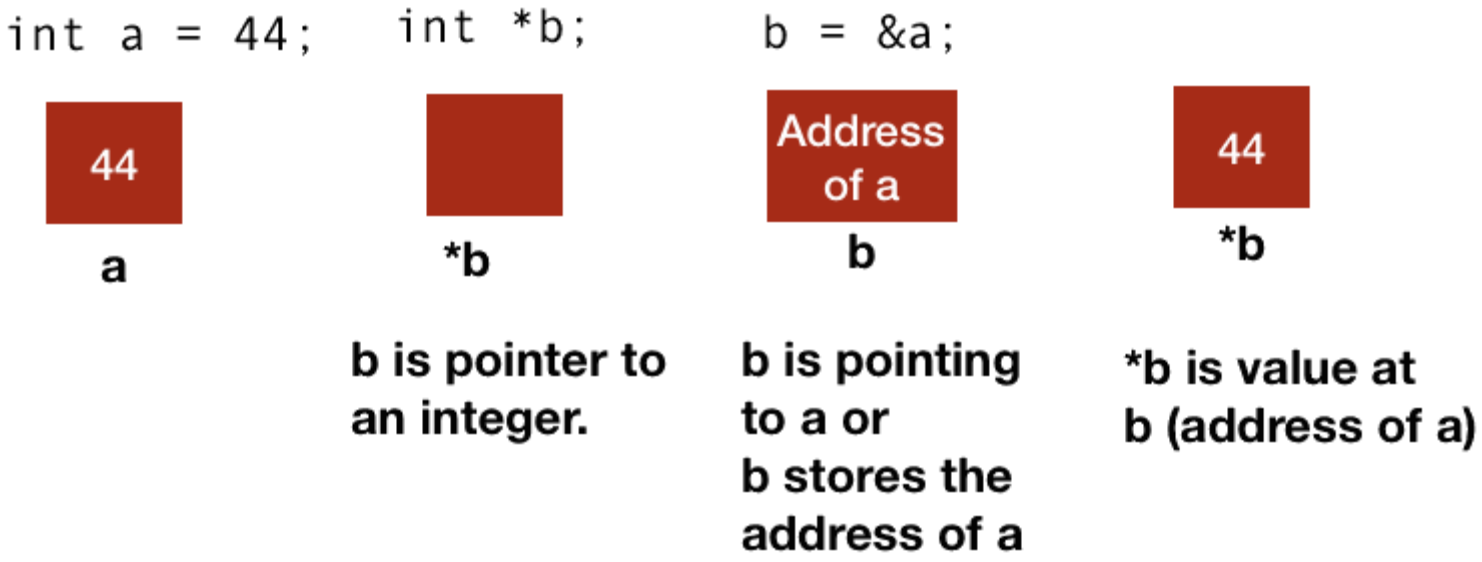
Arrays

```
uint8_t arr1[5];

arr[0] = 10;
```



Pointers


int a = 44;
int *b;
b = &a;
44
a
*b
Address of a
b
44
*b
b is pointer to an integer.
b is pointing to a or b stores the address of a
*b is value at b (address of a)

Arrays and Pointers

```
short x, *pt, arr[5] = {10,20,30,40,50};

x = arr[0];      // x = item_0
x = *arr;        // x = item_0
pt = arr;        // pt points to the array now
pt = &arr[0];    // equivalent to the above statement
x = arr[3];      // x = item_3 (4th item)
x = *(arr + 3); // x = item_3
x = *(pt + 3);  // x = item_3
x = *pt + 3;     // x = item_0 + 3
```

Scope and Lifetime of Variables

- Scope:
  - **Local:** Local variable can only be accessed in the code block where it is defined
  - **File:** Global variable declared/defined with static keyword. It can only be accessed in the file where it is declared/defined.
  - **Global:** Global variable that can be accessed from all files of the project. Only one file must define the variable while other files just declare it using extern keyword

Scope and Lifetime of Variables

- Lifetime:
  - **Automatic:** lifetime ends when the block where the variable is defined ends. Automatic variables are stored in the stack.
  - **Static:** program lifetime. Static variables are stored in data memory.

Scope and Lifetime of Variables

- Example on scope and lifetime

```
uint8 globalVar = 0;                    /* This variable has global scope and static lifetime */
static uint8 fileVar = 1;               /* This variable has file scope and static lifetime */

void function(void)
{
    uint8 localVar = 2;                     /* This variable has local scope and automatic lifetime */
    static uint8 staticLocalVar = 3;        /* This variable has local scope and static lifetime */
}
```

Volatile Qualifier

- A variable qualified by volatile means that its
  - value can be changed outside the program (e.g., external device)
- In practice, volatile makes the compiler not to optimize the code and
  - place this variable in memory (rather than a register)
  - read it from memory every time it s referenced

Volatile Qualifier

- We usually use volatile in the following cases:
  - Memory mapped peripheral registers

```
#define GPIO_PORTF_DATA_R   (*((volatile uint32_t
*)0x400253FC))
```

  - Global variables modified by an ISR

ISR --> Interrupt SubRoutine

```
volatile char trigger_rcvd = 0;
void ISR() {
    trigger_rcvd = 1;
}
int main() {
    while (trigger_rcvd == 0);
    // now, trigger occured }
```

Storage class

- extern: declared here, defined elsewhere
  - Scope: multiple files
  - Lifetime: program lifetime
  - Example: extern int x;
- auto: default for local variables
  - Scope: block
  - Lifetime: from definition to the block end
  - Example: auto int x;

Storage class

- static: keeps local variables allocated
  - Scope: local scope → file if global/function if local variable
  - Lifetime: program lifetime