C: A High Level Programming Language

• Gives symbolic names to values
  – Don’t need to know which register or memory location

• Provides abstraction of underlying hardware
  – operations do not depend on instruction set
  – example: can write “a = b * c”, even though underlying hardware may not have a multiply instruction

\[ a = 6 / 143; \]
C: A High Level Programming Language

- Provides expressiveness
  - use meaningful symbols that convey meaning
  - simple expressions for common control patterns (if-then-else)
- Enhances code readability
- Safeguards against bugs
  - can enforce rules or conditions at compile-time or run-time
Compilation vs. Interpretation

- Different ways of translating high-level language

- **Interpretation**
  - interpreter = program that executes program statements
  - generally one line/command at a time
  - limited processing
  - easy to debug, make changes, view intermediate results
  - languages: BASIC, LISP, Perl, Java, Matlab, Python
Compilation vs. Interpretation

**Compilation**
- translates statements into machine language
- does not execute, but creates executable program
- performs optimization over multiple statements
- change requires recompilation
- can be harder to debug, since executed code may be different
- languages: C, C++, Fortran, Pascal, Ada
Compilation vs. Interpretation

• Consider the following algorithm:
  
  Get W from the keyboard.
  
  \[
  X = W + W \quad \checkmark \\
  Y = X + X \quad \checkmark \\
  Z = Y + Y \quad \checkmark \\
  \]

  Print Z to screen.

• If interpreting, how many arithmetic operations occur?

• If compiling, we can analyze the entire program and possibly reduce the number of operations. Can we simplify the above algorithm to use a single arithmetic operation?

\[
8w \\
w < c \ 3
\]
Compilation

- **Source Code Analysis**
  - “front end”
  - parses programs to identify its pieces
  - variables, expressions, statements, functions, etc.
  - depends on language (not on target machine)

- **Code Generation**
  - “back end”
  - generates machine code from analyzed source
  - may optimize machine code to make it run more efficiently
  - very dependent on target machine

- **Symbol Table**
  - map between symbolic names and items
  - like assembler, but more kinds of information
“Hello World”

- The only way to learn a new programming language is by writing programs in it. The first program to write is the same for all languages:
  
  \[
  \text{Print the words}
  \]
  \[
  \text{``hello, world``}
  \]

- This is a big hurdle; to leap over it you have to be able to create the program text somewhere, compile it successfully, load it, run it, and find out where your output went.

- With these mechanical details mastered, everything else is comparatively easy.

6 does
#include <stdio.h>

int main(void)
{
    printf("Hello, world!\n"); // Uses the I/O library to print
    return 0;
}
Embedded C Code

```c
#include <stdio.h>

int main(void)
{
    printf("Hello, world!\n");

    while (1); // Loop forever and never return
}
```

reset
```c
int main(void)
{
    while (1) {
        // Read inputs
        // Perform calculations
        // Update outputs
    }
}
```
Setting up the IDE
Configuring the Simulator

Set the Debug simulator to wait at the beginning of the main() function.
Reseting MPLAB®X windows

As you will see MPLABX has numerous adjustable windows. New MPLABX users can get a little confused about where and how the set the windows.

If you get confused

**Windows -> Reset Window**

Restores MPLABX Windows back to their original locations
Opening a Project

Select the Open Project button
Opening a Project

1) Navigate to the Project Directory

2) Select the Project

3) Select Open Project
Opening a Project

Project will Open in MPLAB X
Building a Project

To build the project and send it to the Debugger select the **Debug Project Button**
Building a Project

- Simulation ready to start
- Successful Build
- Control Buttons Appear
Running the Simulation

To run the project push the **Continue** button.
Pausing the Simulation

To pause execution of the simulation hit the Pause button.
Windows used in Examples

Variables Window

**Variable Window** displays a particular set of program variables.

To Open the Variables window:

Select:
Windows->Debugging->Variables
Windows used in Examples

Variables Window

**Variable Window** displays several columns of data

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Address</th>
<th>Value</th>
<th>Decimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>localVar1</td>
<td>int</td>
<td>0x88A</td>
<td>0x0003</td>
<td>3</td>
</tr>
<tr>
<td>localVar2</td>
<td>int</td>
<td>0x888</td>
<td>0x0004</td>
<td>4</td>
</tr>
</tbody>
</table>

You may find it convenient to alter the columns displayed.

“right click” on the column heading
Windows used in Examples

UART1 Output

UART1 Output Window prints out text from C programs

To clear this window:

Right click inside of the window then select Clear
**Windows used in Examples**

**Watches Window** is similar to the Variables window but displays a different set of data.

To Open the Watches Window:

Select:
- Windows -> Debugging -> Watches
**Windows used in Examples**

**Watches Window** needs to be ‘told’ what data to watch.

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Address</th>
<th>Decimal</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>globalVar1</td>
<td>int</td>
<td>0x850</td>
<td>1</td>
<td>0x0001</td>
</tr>
<tr>
<td>globalVar2</td>
<td>int</td>
<td>0x852</td>
<td>2</td>
<td>0x0002</td>
</tr>
</tbody>
</table>

“Right click” while in the Watches Window to add or delete watches.

**Column configuration is identical to Variables Window**
Closing a Project

1. Stop the simulation by pushing the Finish Debugger Session button.
Closing a Project

2) "Right Click" on the project name then select Close
Fundamentals of C

A Simple C Program

Example

Preprocessor Directives

#include <stdio.h>

#define PI 3.14159

Header File

Constant Declaration (Text Substitution Macro)

int main(void)
{
  float radius, area;
  //Calculate area of circle
  radius = 12.0;
  area = PI * radius * radius;
  printf("Area = %f", area);
}

Variable Declarations

Function

Comment
Comments

Definition

Comments are used to document a program's functionality and to explain what a particular block or line of code does. Comments are ignored by the compiler, so you can type anything you want into them.

- Two kinds of comments may be used:
  - Block Comment
    ```
    /* This is a comment */
    ```
  - Single Line Comment
    ```
    // This is also a comment
    ```
Comments
Using Block Comments

- Block comments:
  - Begin with `/**<` and end with `*/`
  - May span `multiple lines`

```c
/* ******************************************************/
* Program: hello.c
* Author: R. Ostapiuk
/* ******************************************************/
#include <stdio.h>

/* Function: main() */
int main(void)
{
    printf("Hello, world!\n"); /* Display "Hello, world!" */
}
```
• Single line comments:
  – Begin with `//` and run to the end of the line
  – May *not* span multiple lines

```c
// Program: hello.c
// Author: R. Ostapiuk
#include <stdio.h>

// Function: main()
int main(void)
{
    printf("Hello, world!\n"); // Display "Hello, world!"
}
```
Comments

Nesting Comments

- Block comments may not be nested within other delimited comments
- Single line comments may be nested

Example: Single line comment within a delimited comment.

```c
/*
   code here    // Comment within a comment
*/
```

Example: Delimited comment within a delimited comment.

```c
/**
   code here    /* Comment within a comment */
   code here    /* Comment within a... oops! */
*/
```

Delimiters don’t match up as intended!

Dangling delimiter causes compile error
```c
/**
 * @file
 * @author R. Ostapiuk
 * @section DESCRIPTION
 * This is an example Hello World program
 */
#include <stdio.h>

/**
 * Main, the entrypoint for this C program.
 * @return A success code, where non-zero values indicate failure
 */
int main(void)
{
    int i;     // Loop counter variable
    char *p;   // Pointer to text string

    // Display greeting
    printf("Hello, world!\n");
}
```
Variables and Data Types

A Simple C Program

Example

```
#include <stdio.h>

#define PI 3.14159

int main(void)
{
    float radius, area;

    // Calculate area of circle
    radius = 12.0;
    area = PI * radius * radius;
    printf("Area = \%f", area);
}
```
Variables

Definition

A **variable** is a name that represents one or more memory locations used to hold program data.

- A variable may be thought of as a container that can hold data used in a program

```c
int myVariable;
myVariable = 5;
```
Variables

- Variables are names for storage locations in memory

```c
int warp_factor;
char first_letter;
float length;
```

Diagram:
- `41_{16}`
- ‘A’
- `5.74532370373175 \times 10^{-44}`
Variables

- Variable declarations consist of a unique identifier (name)...

```c
int warp_factor;
char first_letter;
float length;
```
Variables

- ...and a **data type**
  - Determines **size**
  - Determines how **values** are **interpreted**

```c
int warp_factor;
char first_letter;
float length;
```
Identifiers

• Names given to program elements:
  – Variables, Functions, Arrays, Other elements

Example of Identifiers in a Program

```c
#include <stdio.h>

#define PI 3.14159

int main(void)
{
    float radius, area;

    // Calculate area of circle
    radius = 12.0;
    area = PI * radius * radius;
    printf("Area = \%f", area);
}
```
Identifiers

- Valid characters in identifiers:
  - First Character: ‘_’ (underscore) ‘A’ to ‘Z’ ‘a’ to ‘z’
  - Remaining Characters: ‘_’ (underscore) ‘A’ to ‘Z’ ‘a’ to ‘z’ ‘0’ to ‘9’

- Case sensitive!
- Only first 31 characters significant*

*Maxwell James Dunne – Summer 2016
long foo name
long foo rename

x < 32

4.3 GB
ANSI C Keywords

- auto
- break
- case
- char
- const
- continue
- default
- do
- double
- else
- enum
- extern
- float
- for
- goto
- if

Some compiler implementations may define additional keywords.
Data Types

Fundamental Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>char</td>
<td>single character</td>
<td>8</td>
</tr>
<tr>
<td>int</td>
<td>integer</td>
<td>16</td>
</tr>
<tr>
<td>float</td>
<td>single precision floating point number</td>
<td>32</td>
</tr>
<tr>
<td>double</td>
<td>double precision floating point number</td>
<td>64</td>
</tr>
</tbody>
</table>

The size of an `int` varies from compiler to compiler.

- XC16 `int` as 16-bits
- XC32 defines `int` as 32-bits

If you need precise length variable types, use `stdint.h`

- `uint8_t` is unsigned 8 bits
- `int16_t` is signed 16 bits, etc.
## Data Type Qualifiers

**Modified Integer Types**

Qualifiers: *unsigned, signed, short and long*

<table>
<thead>
<tr>
<th>Qualified Type</th>
<th>Min</th>
<th>Max</th>
<th>Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>unsigned char</td>
<td>0</td>
<td>255</td>
<td>8</td>
</tr>
<tr>
<td>char, signed char</td>
<td>-128</td>
<td>127</td>
<td>8</td>
</tr>
<tr>
<td>unsigned short int</td>
<td>0</td>
<td>65535</td>
<td>16</td>
</tr>
<tr>
<td>short int, signed short int</td>
<td>-32768</td>
<td>32767</td>
<td>16</td>
</tr>
<tr>
<td>unsigned int</td>
<td>0</td>
<td>65535</td>
<td>16</td>
</tr>
<tr>
<td>int, signed int</td>
<td>-32768</td>
<td>32767</td>
<td>16</td>
</tr>
<tr>
<td>unsigned long int</td>
<td>0</td>
<td>$2^{32}$-1</td>
<td>32</td>
</tr>
<tr>
<td>long int, signed long int</td>
<td>-$2^{31}$</td>
<td>$2^{31}$-1</td>
<td>32</td>
</tr>
<tr>
<td>unsigned long long int</td>
<td>0</td>
<td>$2^{64}$-1</td>
<td>64</td>
</tr>
<tr>
<td>long long int, signed long long int</td>
<td>-$2^{63}$</td>
<td>$2^{63}$-1</td>
<td>64</td>
</tr>
</tbody>
</table>
# Data Type Qualifiers

## Modified Floating Point Types

<table>
<thead>
<tr>
<th>Qualified Type</th>
<th>Absolute Min</th>
<th>Absolute Max</th>
<th>Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>float</td>
<td>$\pm \sim 10^{-44.85}$</td>
<td>$\pm \sim 10^{38.53}$</td>
<td>32</td>
</tr>
<tr>
<td>double $^{(1)}$</td>
<td>$\pm \sim 10^{-44.85}$</td>
<td>$\pm \sim 10^{38.53}$</td>
<td>32</td>
</tr>
<tr>
<td>long double</td>
<td>$\pm \sim 10^{-323.3}$</td>
<td>$\pm \sim 10^{308.3}$</td>
<td>64</td>
</tr>
</tbody>
</table>

MPLAB-X XC32 Uses the IEEE-754 Floating Point Format
Variables
How to Declare a Variable

Syntax

```c
_type identifier_1, identifier_2,...,identifier_n;
```

- A variable must be declared before it can be used
- The compiler needs to know how much space to allocate and how the values should be handled

Example

```c
int x, y, z;
float warpFactor;
char text_buffer[10];
unsigned index;
```
Variables
How to Declare a Variable

Variables may be declared in a few ways:

Syntax

One declaration on a line

```c
type identifier;
```

One declaration on a line with an initial value

```c
type identifier = InitialValue;
```

Multiple declarations of the same type on a line

```c
type identifier_1, identifier_2, identifier_3;
```

Multiple declarations of the same type on a line with initial values

```c
type identifier_1 = Value_1, identifier_2 = Value_2;
```
Chor a:

Money or Speed

Delete a file 32 times
Variables
How to Declare a Variable

Examples

```c
unsigned int x;
unsigned y = 12;
int a, b, c;
long int myVar = 0x12345678;
long z;
char first = 'a', second, third = 'c';
float big_number = 6.02e+23;
```

It is customary for variable names to be spelled using "camel case", where the initial letter is lower case. If the name is made up of multiple words, all words after the first will start with an upper case letter (e.g. myLongVarName).
Variables
How to Declare a Variable

• Sometimes, variables (and other program elements) are declared in a separate file called a header file
• Header file names customarily end in `.h`

• Header files are associated with a program through the `#include` directive
#include Directive

- Three ways to use the #include directive:

**Syntax**

```c
#include <file.h>
Look for file in the compiler search path
The compiler search path usually includes the compiler's directory and all of
its subdirectories.
For example: C:\Program Files\Microchip\MPLABX\XC16\*.*

#include "file.h"
Look for file in project directory only

#include "c:\MyProject\file.h"
Use specific path to find include file
```
The contents of main.h are **effectively** pasted into main.c starting at the `#include` directive’s line.
#include Directive

Equivalent main.c File

- After the preprocessor runs, this is how the compiler sees the main.c file
- The contents of the header file aren’t actually copied to your main source file, but it will behave as if they were copied
Header Guards
Duplicate #includes

main.h

unsigned int a;
unsigned int b;
unsigned int c;

main.c

#include "main.h"
#include "main.h"

int main(void)
{
    a = 5;
    b = 2;
    c = a + b;
}
Header guards
Equivalent main.c File

- Duplicate declarations will occur.
- Which will give compilation errors as there cannot exist multiple declarations of the same variable in the same scope.

```c
unsigned int a;
unsigned int b;
unsigned int c;
unsigned int a;
unsigned int b;
unsigned int c;

int main(void)
{
    ...
}
Equivalent main.c file without #include
```
Header guards

Realistic example

```
#include "OledDriver.h"
#include "Oled.h"
#include "OledDriver.h"
#include "Oled.h"
```

Maxwell James Dunne – Summer 2016
Header guards
How do you write/use them

- Declare a macro when a header file is processed.
- Check for that macro before including the code.
Questions?
Expressions

- Represents a single data item (e.g. character, number, etc.)
- May consist of:
  - A single entity (a constant, variable, etc.)
  - A combination of entities connected by operators (+, -, *, / and so on)
Expressions

Examples

Example

\[ a + b \]
\[ x = y \]
\[ \text{speed} = \frac{\text{dist}}{\text{time}} \]
\[ z = \text{ReadInput}() \]
\[ c \leq 7 \]
\[ x \equiv 25 \]
\[ ++\text{count} \]
\[ d = a + 5 \]
Statements

• Cause an action to be carried out

• Three kinds of statements in C:
  – Expression Statements
  – Compound Statements
  – Control Statements
Expression Statements

- An expression followed by a semi-colon;
- Execution of the statement causes the expression to be evaluated

Examples

```c
i = 0;
i++;  
a = 5 + i;
y = (m * x) + b;
printf("Slope = %f", m);
;
```
Compound Statements

- A group of individual statements enclosed within a pair of curly braces { and }
- Individual statements within may be any statement type, including compound
- Allows statements to be embedded within other statements
- Does NOT end with a semicolon after }
- Also called Block Statements
```c
{
    float start, finish;
    start = 0.0;
    finish = 400.0;
    distance = finish - start;
    time = 55.2;
    speed = distance / time;
    printf("Speed = %f m/s", speed);
}
```
Control Statements

- Used for loops, branches and logical tests
- Often require other statements embedded within them

Example

```c
while (distance < 400.0) {
    printf("Keep running!");
    distance += 0.1;
}
```

(while syntax: `while expr statement`)
Boolean Expressions

- Boolean data type added in C99
- Boolean expressions return integers:
  - 0 expressions evaluate as false
  - non-zero expressions evaluate as true (generally 1)

```c
int x = 5;
bool y, z;

y = (x > 4);  // TRUE
z = (x > 6);  // FALSE
while (1);    // TRUE (1)
```
Boolean Expressions

Equivalent Expressions

• If a variable, constant, or function call is used alone as the conditional expression:
  \[(\text{myVar}) \text{ or } (\text{Foo}())\]
  \[
  \underline{\text{myVar}} \underline{\text{Foo}}
  \]

• This is the same as saying:
  \[(\text{myVar} \neq 0) \text{ or } (\text{Foo}() \neq 0)\]
  \[
  \underline{\text{myVar}} \underline{\text{Foo}}
  \]

• In either case, if \(\text{myVar} \neq 0\) or \(\text{Foo}() \neq 0\), then the expression evaluates as true (non-zero)
if Statement

Syntax

if (expression) statement

- expression is evaluated for boolean true(≠0) or false (=0)
- If true, then statement is executed

Note

Whenever you see statement in a syntax guide, it may be replaced by a compound (block) statement.

Remember: spaces and new lines are not significant.
**if Statement**

Flow Diagram

**Syntax**

\[ \texttt{if (expression) statement} \]
if Statement

Example

```c
int x = 5;

if (x) {
    printf("x = %d\n", x);  // If x is TRUE (non-zero)...
    ...then print the value of x.
}
while (1);
```

- What will print if \( x = 5 \)? ... if \( x = 0 \)?
- ...if \( x = -82 \)?
- ...if \( x = 65536 \)?
if Statement

Testing for TRUE

- if (x) vs. if (x == 1)
  - if (x) only needs to test for not equal to 0
  - if (x == 1) needs to test for equality with 1
  - Remember: true is defined as non-zero, false is defined as zero

Example: if (x)

```assembly
if (x)
  bnez 0x0011c0
```

Example: if (x == 1)

```assembly
if (x == 1)
  bnez 0x0011ce
```
Nested `if` Statements

```c
int power = 10;
float band = 2.0;
float frequency = 146.52;

if (power > 5) {
    if (band == 2.0) {
        if ((frequency > 144) && (frequency < 148)) {
            printf("Yes, it's all true!\n");
        }
    }
}
```
**if-else Statement**

**Syntax**

```
if (expression) statement_1 
else statement_2
```

- `expression` is evaluated for boolean true (\(\neq 0\)) or false (\(= 0\))
- If true, then `statement_1` is executed
- If false, then `statement_2` is executed
**if-else** Statement

*Flow Diagram*

**Syntax**

\[
\begin{align*}
\textbf{if} \ (\text{expression}) \ &\ 	extbf{statement}_1 \\
\textbf{else} \ &\ 	extbf{statement}_2
\end{align*}
\]

- **START**
- **expression ≠ 0**
  - **true**
    - **statement}_1
  - **false**
    - **expression = 0**
      - **statement}_2
- **END**
float frequency = 146.52; // Frequency in MHz

if ((frequency > 144.0) && (frequency < 148.0)) {
    printf("You're on the 2 meter band\n");
} else {
    printf("You're not on the 2 meter band\n");
}
if-else if Statement

Syntax

```plaintext
if (expression₁) statement₁
else if (expression₂) statement₂
else statement₃
```

- `expression₁` is evaluated for boolean true (≠0) or false (=0)
- If true, then `statement₁` is executed
- If false, then `expression₂` is evaluated
- If true, then `statement₂` is executed
- If false, then `statement₃` is executed
if-else if Statement

Flow Diagram

Syntax

if (expression₁) statement₁
else if (expression₂) statement₂
else statement₃
if-else if Statement

Example

```c
if ((freq > 144) && (freq < 148)) {
    printf("You're on the 2 meter band\n");
} else if ((freq > 222) && (freq < 225)) {
    printf("You're on the 1.25 meter band\n");
} else if ((freq > 420) && (freq < 450)) {
    printf("You're on the 70 centimeter band\n");
} else {
    printf("You're somewhere else\n");
}
```
while Loop

Syntax

```plaintext
while (expression) statement
```

- If `expression` is true, `statement` will be executed and then `expression` will be re-evaluated to determine whether or not to execute `statement` again.

- It is possible that `statement` will never execute if `expression` is false when it is first evaluated.
**while Loop**

Flow Diagram

**Syntax**

```plaintext
while (expression) statement
```

Start

- **expression?**
  - `true` goes to **statement**
  - `false` goes to **END**

END
**while Loop**

Example

```
int i = 0;  // Loop counter initialized outside of loop

while (i < 5) {  // Condition checked at start of loop iterations
    printf("Loop iteration %d\n", i++);
}
```

Expected Output:

```
Loop iteration 0
Loop iteration 1
Loop iteration 2
Loop iteration 3
Loop iteration 4
```
**while Loop**

- Primary looping mechanism
- Completely generic
- Frequently used for main loop of program

**Generic loop:**

```c
while (HaveData()) {
    PrintData();
}
```

**Main loop:**

```c
while (1) {
    ...
}
```
Functions
Program Structure

main()
{
    ... 
    eat();
    ... 
    drink();
    ... 
}

eat()
{
    ... 
    return;
}

be_merry()
{
    ... 
    return;
}

drink()
{
    ... 
    be_merry();
    return;
}
Functions

What is a function?

**Definition**

Functions are self contained program segments designed to perform a specific, well defined task.

- All C programs have one or more functions
- The `main()` function is required
- Functions can accept parameters from the code that calls them
- Functions return a single value (but can export more data)
- Functions help to organize a program into logical, manageable segments
Functions

Remember Algebra Class?

- Functions in C are conceptually like an algebraic function from math class...

- If you pass a value of 7 to the function: \( f(7) \), the value 7 gets "copied" into \( x \) and used everywhere that \( x \) exists within the function definition: \( f(7) = 7^2 + 4*7 + 3 = 80 \)
Functions

Definitions

Syntax

Data type of return **expression**

Name

Parameter List (optional)

```c
type identifier(type_1 arg_1, ..., type_n arg_n)
{
    declarations
    statements
    return expression;
}
```

Body

Header

Return Value (optional)
Functions

Function Definitions: Syntax Examples

Example

```c
int Maximum(int x, int y)
{
    int z;

    z = (x >= y) ? x : y;
    return z;
}
```

Example – A more efficient version

```c
int Maximum(int x, int y)
{
    return ((x >= y) ? x : y);
}
```
**Functions**

Function Definitions: Return Data Type

```c
typedef identifier(type1 arg1, ..., type_n arg_n)
{
    declarations
    statements
    return expression;
}
```

- A function's **`type`** must match the type of data in the return **`expression`**.
Functions

Function Definitions: Return Data Type

- A function may have multiple return statements, but only one will be executed and they must all be of the same type

Example

```c
int bigger(int a, int b)
{
    if (a > b) {
        return 1;
    } else {
        return 0;
    }
}
```
Functions

Function Definitions: Return Data Type

- The function type is **void** if:
  - The `return` statement has no `expression`
  - The `return` statement is not present at all
- This is sometimes called a `procedure function` since nothing is returned

Example

```c
void identifier(type_1 arg_1, ..., type_n arg_n)
{
    declarations
    statements
    return;  \textcolor{red}{\textit{return; may be omitted if nothing is being returned}}
}
```
Functions

Function Definitions: Parameters

• A function's parameters are declared just like ordinary variables, but in a comma delimited list inside the parentheses

• The parameter names are only valid inside the function (local to the function)

Syntax

```c
type identifier(type₁ arg₁,...,typeₙ argₙ)
{
  declarations
  statements
  return expression;
}
```
Functions

Function Definitions: Parameters

- Parameter list may mix data types
  
  ```
  int Foo(int x, float y, char z)
  ```

- Parameters of the same type must be declared separately – in other words:
  
  ```
  int Maximum(int x, y) will not work
  int Maximum(int x, int y) is correct
  ```

**Example**

```c
int Maximum(int x, int y)
{
    return ((x >= y) ? x : y);
}
```
Functions

Function Definitions: Parameters

• If no parameters are required, use the keyword void in place of the parameter list when defining the function

Example

```c
type identifier(void)
{
    declarations
    statements
    return expression;
}
```
Functions
How to Call / Invoke a Function

Function Call Syntax

- No parameters and no return value
  \[ \text{Foo}() ; \]
- No parameters, but with a return value
  \[ x = \text{Foo}() ; \]
- With parameters, but no return value
  \[ \text{Foo}(a, b) ; \]
- With parameters and a return value
  \[ x = \text{Foo}(a, b) ; \]
Functions

Function Prototypes

- Just like variables, a function must be declared before it may be used.
- Declaration must occur before main() or other functions that use it.
- Declaration may take two forms:
  - The entire function definition.
  - Just a function prototype – the function definition itself may then be placed anywhere in the program.
Functions

Function Prototypes

- Function prototypes may be take on two different formats:
  - An exact copy of the function header:

```
Example – Function Prototype 1

int Maximum(int x, int y);
```

- Like the function header, but without the parameter names – only the types need be present for each parameter (bad form!):

```
Example – Function Prototype 2

int Maximum(int, int);
```
Functions
Declaration and Use: Example 1

Example 1

```c
int a = 5, b = 10, c;

int Maximum(int x, int y)
{
    return ((x >= y) ? x : y);
}

int main(void)
{
    c = Maximum(a, b);
    printf("The max is %d\n", c)
}
```

Function is declared and defined before it is used in main()
Functions

Declaration and Use: Example 2

Example 2

```c
int a = 5, b = 10, c;

int Maximum(int x, int y);

int main(void)
{
    c = Maximum(a, b);
    printf("The max is %d\n", c);
}

int Maximum(int x, int y)
{
    return ((x >= y) ? x : y);
}
```

Function is declared with prototype before use in main()

Function is defined after it is used in main()