Introduction to “C” Programming

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\[ \frac{1r}{n} \cdot \frac{\text{cool term}}{31r} = \frac{n}{\text{paranoid}} \]

Saturday Consistency

3.0 \times 2.0 = 6.00000
Unit testing
Unit testing

• Testing portions of code in isolation

• Normally testing is per function

• Requires input and expected output to be known a priori

Your code
Unit testing

Rationale

- Find problems early
  - Before integration
- Simplify testing by only testing small, segmented portions of code
- Test functionality that may not be exposed otherwise
- Find documentation errors
Unit testing
Preparation

- The most important question:

  "How am I going to test this?"

- Break code into clean functions with:
  - Clear input
  - Clear output
  - No/minimal side effects
Unit testing
Testing architecture

Expected output

Output matches

Print failure

Known input

f()

Actual output

Print success
// Declare test constants
testInput ← some input
testExpOutput ← precalculated output

// Calculate result
testActOutput ← function result

// Output test results
if testActOutput equals testExpOutput
   output "Test passed"
else
   output "Test failed!"
Unit testing
Trivial example

ExampleLib.c

```c
int AddFive(int x)
{
    return x + 5;
}
```

main.c

```c
#include "ExampleLib.h"

int main(void)
{
    // Declare test constants
    int test1Input = 0;
    int test1ExpOutput = 5;

    // Calculate result
    int test1ActOutput;
    test1ActOutput = AddFive(test1Input);

    // Output test results
    if (test1ActOutput == test1ExpOutput) {
        printf("Test1 passed.\n");
    } else {
        printf("Test1 failed!\n");
    }
}
```
Unit testing
Writing tests

- Write multiple tests
  - At least 1 for every group of inputs
  - Each edge case should have their own test

- Each test should check **one** part of the total functionality
  - One function or logical block of code at a time

Try to break the code you're testing!
Unit testing
Testing framework

- Track how many tests passed/failed
  - Per function

- Track how many functions passed/failed
  - With all tests must pass for the function to pass

- Each test cleanly separated from other tests
  - Both in code and in logic

- Output results
  - Per function/per test results
Unit testing example
\( \Sigma = 0.0001 \)

\[ \text{if } ((a-b) <= 5 \Sigma) \]
Parameter passing

Pass by value
Pass by reference
Parameter Passing
By Value

• Parameters passed to a function are generally passed by value
• Values passed to a function are copied into the local parameter variables
• The original variable that is passed to a function cannot be modified by the function since the function has a duplicate of the variable, not the original
Parameter Passing
By Value

Example

```c
int a, b, c;

int Foo(int x, int y)
{
    x = x + (y++);  // The value of a is copied into x.
    return x;
}

int main(void)
{
    a = 5;          // The value of b is copied into y.
    b = 10;
    c = Foo(a, b);  // The function does not change the value of a or b.
}
```
Parameter Passing

By Value

Example function

```c
int Foo(int x, int y)
{
    int z = x + (y++);
    return z;
}
```

Example main

```c
int main(void)
{
    int a = 6, b = 19;
    Foo(a, b);
    while (1);
}
```
Parameter Passing

By Reference

- Parameters can be passed to a function by reference
- Entails passing around memory address
- The original variable that is passed to a function can be modified by the function since the function knows where the data "lives" in memory
Parameter Passing

By Reference

Example function

```c
int Foo(int x[3])
{
    int z = x[2];
    x[1] = 0;
    return z;
}
```

Example main

```c
int main(void)
{
    int a[3] = {6, 19, -1};
    Foo(a);
    while (1);
}
```
Scope
Scope

Variables Declared Within a Function

• Variables declared within a code block are local to that block.

Example

```c
int x, y, z;

int Foo(int n)
{
    int a;
    ...
    a += n;
}
```

The `n` refers to the function parameter `n`.

The `a` refers to the `a` declared locally within the function body.
Scope

Variables Declared Within a Function

- Variables declared within a block are not accessible outside that block

Example

```c
int x;
int Foo(int n)
{
    int a;
    return (a += n);
}
int main(void)
{
    x = Foo(5);  // This will generate an error. a may not be accessed outside of the scope where it was declared.
    x = a;
}
```
Scope
Variables Declared Within a Function

- Variables declared within a block are not accessible outside that block.

Example

```c
int x;
int main(void)
{
    {
        int a = 6;
    }
    x = Foo(5);  // This will generate an error. 'a' may not be accessed outside of the scope where it was declared.
    x = a;
}
```
Scope

And the stack

Stack (top)

<table>
<thead>
<tr>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>z</td>
</tr>
<tr>
<td>Return address</td>
</tr>
<tr>
<td>x</td>
</tr>
<tr>
<td>y</td>
</tr>
<tr>
<td>b</td>
</tr>
<tr>
<td>a</td>
</tr>
<tr>
<td>Return address</td>
</tr>
</tbody>
</table>

Example function

```c
int Foo(int x, int y)
{
    int z = x + (y++);
    return z;
}
```

Example main

```c
int main(void)
{
    int a = 6, b = 19;
    Foo(a, b);
    while (1);
}
```
Scope
And the stack

Example function

```c
int Foo(int x, int y)
{
    int z = x + (y++);
    return z;
}
```

Example main

```c
int main(void)
{
    int a = 6, b = 19;
    Foo(a, b);
    while (1);
}
```
Scope

Global versus Local Variables

Example

```c
int x = 5;

int Foo(int y)
{
    int z = 1;
    return (x + y + z);
}

int main(void)
{
    int a = 2;
    x = foo(a);
    a = foo(x);
}
```

- `x` can be seen by everybody
- `foo`'s local parameter is `y`
- `foo`'s local variable is `z`
- `foo` cannot see `main`'s `a`
- `foo` can see `x`
- `main`'s local variable is `a`
- `main` cannot see `foo`'s `y` or `z`
- `main` can see `x`
Scope
Parameters

"Overloading" variable names:

- Declared Locally and Globally:
  ```c
  int n;
  ...
  int Foo(int n)
  {
    ...
    y += n;  // local n hides global n
    ...
  }
  ```

- Declared Globally Only:
  ```c
  int n;
  int Foo(int x)
  {
    ...
    y += n;  // local n hides global n
    ...
  }
  ```

A locally defined identifier takes precedence.
Scope

Parameters

Example

```c
int n;

int Foo(int n)
{
    y += n;
}

int Bar(int n)
{
    z *= n;
}
```

- Different functions may use the same parameter names
- The function will only use its own parameter by that name
Scope
Preprocessor and scoping

Example

```c
#define x 2

void Test(void)
{
    #define x 5
    printf("%d\n", x);
}

void main(void)
{
    printf("%d\n", x);
    Test();
}
```

Result:
5
5
Storage Class Specifiers

Scope and Lifetime of Variables

- Scope and lifetime of a variable depends on its storage class:
  - Automatic Variables
  - Static Variables
  - External Variables
  - Register Variables

- Scope refers to where in a program a variable may be accessed.

- Lifetime refers to how long a variable will exist or retain its value.

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Storage Class Specifiers

Automatic Variables

- Local variables declared inside a function
  - Created when function called
  - Destroyed when exiting from function
- `auto` keyword *usually* not required – local variables are automatically `auto`
- Typically created on the stack

```c
int Foo(int x, int y)
{
    int a, b;
    ...
}
```

*Except when the compiler provides an option to make parameters and locals static by default.*
Storage Class Specifiers

**auto** Keyword with Variables

```c
int Foo(auto int x, auto int y)
{
    ...
}
```

- **auto** is almost never used
- Many books claim it has no use at all
- Some compilers still use **auto** to explicitly specify that a variable should be allocated on the stack when a different method of parameter passing is used by default
Storage Class Specifiers

Static Variables

- Given a permanent address in memory
- Exist for the entire life of the program
  - Created when program starts
  - Destroyed when program ends
- Global variables are always static (cannot be made automatic using auto)

```c
int x; // Global variable is always static

int main(void)
{
    ...
```
Storage Class Specifiers

**static** Keyword with Variables

- A variable declared as **static** inside a function retains its value between function calls (not destroyed when exiting function)
- Function parameters cannot be **static** with some compilers (XC32)

```c
int Foo(int x)
{
    static int a = 0;
    ...
    a += x;
    return a;
}
```

- `a` will remember its value from the last time the function was called.
- If given an initial value, it is only initialized when first created – not during each function call.
Storage Class Specifiers

External Variables

• Variables that are **defined** outside the scope where they are used
• Still need to be **declared** within the scope where they are used
• **extern** keyword used to tell compiler that a variable defined elsewhere will be used within the current scope

External Variable Declaration Syntax:

```
extern type identifier;
```

External Variable Declaration Example:

```
extern int x;
```
Storage Class Specifiers

External Variables

- A variable declared as `extern` within a function is analogous to a function prototype – the variable may be defined outside the function after it is used.

Example

```c
int Foo(int x)
{
    extern int a;
    ...
    return a;
}
```

```
int a;
```
Storage Class Specifiers

External Variables

- A variable declared as `extern` outside of any function is used to indicate that the variable is defined in another source file – memory only allocated when it's defined.

```c
// Main.c
extern int x;

int main(void)
{
    x = 5;
    ...
}

// SomeFileInProject.c
int x;

int Foo(void)
{
    ...
}
```
Storage Class Specifiers

Register Variables

- register variables are placed in a processor's "hardware registers" for higher speed access than with external RAM
  - Common with loop counters
- Not as important when RAM is integrated into processor package (microcontrollers, ...)
- May be done with PIC®/dsPIC®, but it is architecture/compiler specific...
Storage Class Specifiers

Scope of Functions

- Scope of a function depends on its storage class:
  - Static Functions
  - External Functions
- Scope of a function is either local to the file where it is defined (static) or globally available to any file in a project (external)
Storage Class Specifiers

External Functions

- Functions by default have global scope within a project
- `extern` keyword not required, but function prototype is required in calling file

```c
Main.c

int foo(void);

int main(void)
{
    ...
    x = foo();
}

SomeFileInProject.c

int foo(void)
{
    ...
}
```
Storage Class Specifiers

Static Functions

- If a function is declared as `static`, it will only be available within the file where it was declared (makes it a local function)
**Storage Class Specifiers**

**Define**

- If a variable is declared as `static`, it will only be available within the file where it was declared.

```c
Main.c
extern int myVar;

int main(void)
{
    ...
    myVar = 6;
}

SomeFileInProject.c
static int myVar = 0;
```
#define PI 3.1415