University of Illinois at Urbana-Champaign
Dept. of Electrical and Computer Engineering

ECE 120: Introduction to Computing

Introduction to the
C Programming Language

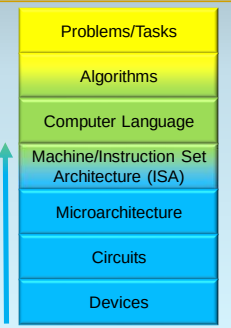
Few Programmers Write Instructions (Assembly Code)

So far, you learned to **use bits to represent information**.

Our class will teach you **how to design a computer**.

But computer **instructions are quite simple** (add two numbers, copy some bits).

Not many programmers use them directly.

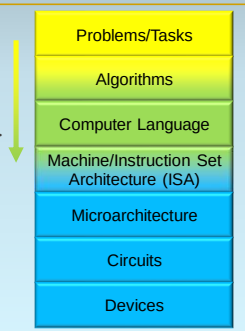


Most Programs Are Written in High-Level Languages

Since 1954 (FORTRAN), people have been trying to bridge the **semantic gap** between human problems/tasks and ISAs.

The result is 1000s of computer languages.

Most programs are written in these languages.



Spend a Week Learning the C Programming Language

Before we move upwards from bits into gates, we will spend a week on the language **C**.

Why?

- Allow more time to **become familiar with mechanical aspects** of computer languages (2 semesters instead of 2/3 of a semester in ECE classes a few years ago).
- **Start simple**: make small modifications.
- **Read examples** before writing your own.

We Will Not Teach You How to Program (Yet)

To be clear:

> Programming means translating a human task into an algorithm expressed in a computer language (or an ISA).

We are **NOT teaching you how to program** yet.

So What ARE We Teaching You Now?

Three skills:

- how to **express certain types of tasks formally** enough for a computer to understand them,
- how to **read and interpret (simple) formal expressions** of computation in **C**, and
- how to **use a compiler** to translate a **C** program into instructions.

Computers (Programs) Help with Digital Design

Remember: the world is digital.

So we will

- **connect these skills** (expressing tasks and reading **C** programs) **to the material** (how to build a computer)
- to **help you learn the skills**
- and to realize that **computers can help** with much of what you are learning.

What about Programming?

So far, **computers don't know how to program**.

In our class,

- you will start learning that skill (art)
- in part 4 of the class (week 12 / early April in Spring, or early November in Fall).

A Brief History of C

The **C programming language** was
- developed by Dennis Ritchie in 1972
- to simplify the task of writing Unix.

C has a transparent mapping to typical ISAs:
- easy to understand the mapping (ECE220)
- easy to teach a computer:
  C compiler (a program) converts a
  C program into instructions

C was first standardized in 1989 by ANSI.

Starting a Program Executes its `main` Function

Let's take a look at a **C** program…

```
int
main ()
{
    int answer = 42;  /* the Answer! */

    printf ("The answer is %d.\n", answer);

    /* Our work here is done.
       Let's get out of here! */
    return 0;
}
```

The function **`main`** executes when the program starts.

After **`main`** has finished, the program terminates.

The Function `main` Divides into Two Parts

`main` consists of two parts…

```
int
main ()
{
    int answer = 42;  /* the Answer! */

    printf ("The answer is %d.\n", answer);

    /* Our work here is done.
       Let's get out of here! */
    return 0;
}
```

Declarations for variables used by **`main`**.

A sequence of statements.

What Does the Program Do? Execute Statements in Order

```
int
main ()
{
    int answer = 42;  /* the Answer! */

    printf ("The answer is %d.\n", answer);

    /* Our work here is done.
       Let's get out of here! */
    return 0;
}
```

Prints "The answer is 42." followed by an ASCII newline character to the display.

Terminates the program; returns 0 (success, by convention) to the operating system.

Comments Help Human Readers (Including the Author!)

Good programs have many comments…

```
int
main ()
{
    int answer = 42;  /* the Answer! */

    printf ("The answer is %d.\n", answer);

    /* Our work here is done.
       Let's get out of here! */
    return 0;
}
```

Comments start with /* and end with */ .

Comments can span more than one line.

So Far, We Have Four Pieces of C Syntax

a few elements of **C syntax***:

- **`main`**: the function executed when a program starts
- **variable declarations** specify symbolic names and data types
- **statements** tell the computer what to do
- **comments** help humans to understand the program

* A computer language's **syntax** specifies the rules that one must follow to write a valid program in that language.

Pitfall: "Functions" in Programs are not Functions in Math

Be careful about terminology:

- **`main` is a "function"**
- **in the syntactic sense of the C language** (a set of variable declarations and a sequence of statements ending with a **`return`** statement)
- **but not necessarily in the mathematical sense**.

A "Function" is a Block of Code that Returns a Value

For example,

- although **`main`** does return an integer,
- we can **write a program that returns a random integer from 0 to 255**.

Given the same inputs,

- the value returned is **not unique**, and
- the value returned is **not reproducible** (running the program two times can give different answers).
- **Both properties are required for a mathematical function**.

Pitfall #2: "Functions" are Not Algorithms

The **`main`** function is **not necessarily an algorithm**.

For example, we can **write a program that runs forever** (never terminates, and never returns a value).

Algorithms must be finite
(see Patt & Patel).

Variable Declarations Allocate and Name Sets of Bits

Variable declarations
- allow the programmer to **name sets of bits**
- and to **associate a data type**

The declaration `int answer = 42;`

tells the compiler…
- to make space for a **32-bit 2's complement** number (an **`int`**),
- to initialize the bits to the bit pattern for 42,
- and to make use of those bits whenever a statement uses the **symbolic name answer**.

Pitfall #3: Variables in C are Not Variables in Algebra

In algebra, a variable is a name for a value.

A variable's value does not change.

For example:
- If we write **A=42** in algebra,
- the variable **A** continues to be equal to **42**
- for the duration of that problem or calculation.

In C, any statement can change the value of a variable.

Variables in C are Sets of Bits (0s and 1s)

In C, a variable is a name for a set of bits.

The bits will (of course!) **always be 0s and 1s**.

But **variables in C can change value as the program executes**.

Other properties of a variable must be inferred from the program (in the example program, **answer** is always 42, because no statement changes **answer**).

Each Variable Has a Specific Data Type

Many languages (such as **C**) require that the programmer **specify a data type for each variable**.

A **C** compiler uses a variable's data type to interpret statements using that variable.

For example, a "+" operation in **C** might mean to add two sets of bits
- as **unsigned** bit patterns,
- as **2's complement** bit patterns, or
- as **IEEE single-precision floating-point** bit patterns.

The compiler generates the appropriate instructions.

Primitive Data Types are Always Available

Primitive data types
- part of the **C** language
- include **unsigned**, **2's complement**, and **IEEE floating-point**
- 8-bit primitive data types can also be used to store **ASCII** characters

Pitfall #4: Primitive Data Types Depend on the System

Since the **C** language was designed to be efficient, **primitive data types are tuned to the system**.

Unfortunately, that means the actual data type can vary from one compiler to another.

For example, **`long int`** may be a **32-bit 2's complement** value, or it may be a **64-bit 2's complement** value.

Use `int32_t` or `int64_t` to be specific.

Code Examples in Slides Use Only a Few Types

We use these data types in examples.

name	meaning on lab machines
`char`	8-bit 2's complement / ASCII
`int`	32-bit 2's complement
	(Add `"unsigned"` before types above for unsigned.)
`float`	IEEE 754 single-precision floating-point (32 bits)
`double`	IEEE 754 double-precision floating-point (64 bits)

See the notes for a more complete listing.

Each Variable Also Has a Name (an Identifier)

Rules for **identifiers** in **C**
- composed of **letters and digits** (start with a letter)
- any length
  - **use words** to make the meaning clear
  - avoid using single letters in most cases
- **case-sensitive**
  - The following are distinct identifiers: variable, Variable, VARIABLE, VaRiAbLe.
  - **Do NOT use more than one**!

Examples of Variable Declarations

Putting the pieces together, a variable declaration is

```
<data type> <identifier> = <value>;
```

Here are a few examples:

```
int anIntegerIn2sComplement = 42;
unsigned int andOneUnsigned = 100;
float IEEE_754_is_Cool = 6.023E23;
```


Variables Always Contain Bits

The initialization for a variable is optional.

So the following is acceptable:

```
<data type> <identifier>;
```

For example,

```
int i;
```

What is the initial value of `i`?

You guessed it! **BITS**!
(They may be 0 bits, but they may not be.)

Statements Tell the Computer What to Do

In **C**, a statement specifies a complete operation.

In other words, **a statement tells the computer to do something**.

The function **`main`** includes a sequence of statements.

When program is **started** (or **runs**, or **executes**),
- **the computer executes the statements in `main`**
- in the order that they appear in the program.

