# Introduction to C

# C: A High-Level 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 LC-3 doesn’t have a multiply instruction
- 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, C-shell
- *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

# Compilation vs. Interpretation

- Consider the following algorithm:

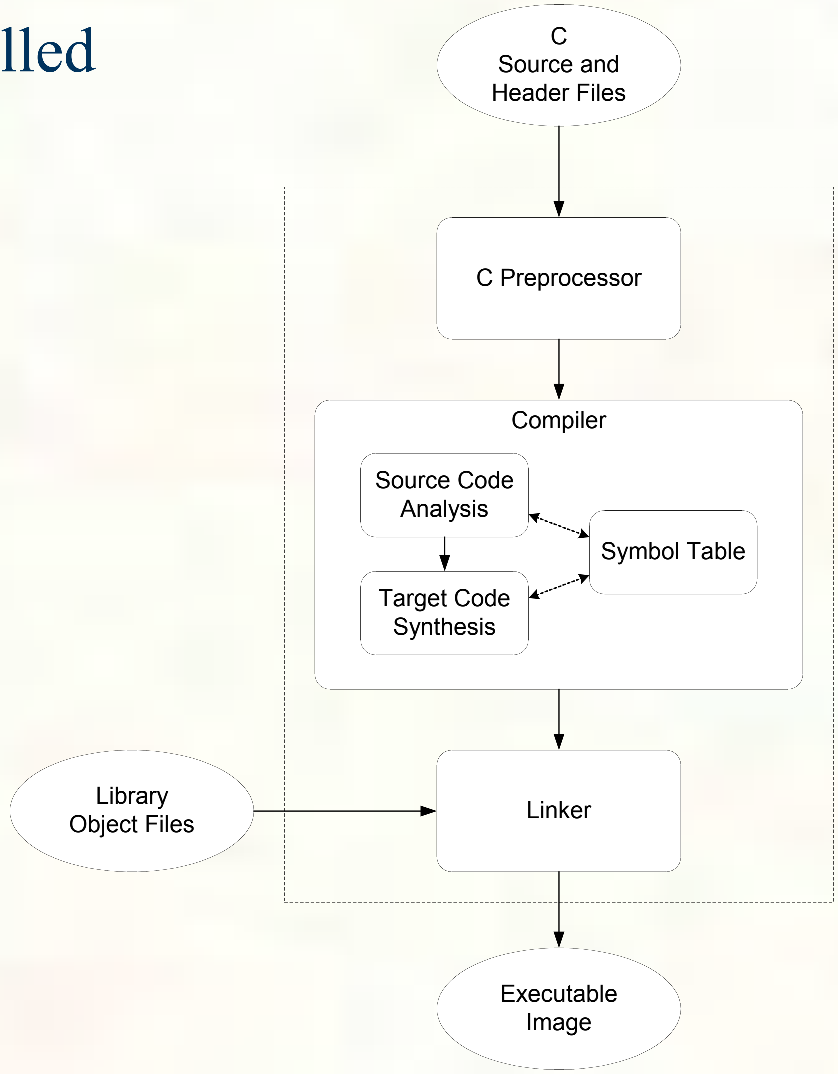
  ```
  Get W from the keyboard.
  X = W + W
  Y = X + X
  Z = Y + Y
  Print Z to screen.
  ```

- 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?

# Compiling a C Program

- Entire mechanism is usually called the “compiler”
- Preprocessor
  - macro substitution
  - conditional compilation
  - “source-level” transformations
    - output is still C
- Compiler
  - generates object file
    - machine instructions
- Linker
  - combine object files (including libraries) into executable image



# Compiler

- 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

# A Simple C Program

```c
#include <stdio.h>
#define STOP 0

/* Function: main                                   */
/* Description: counts down from user input to STOP */
main()
{
  /* variable declarations */
  int counter;  /* an integer to hold count values */
  int startPoint; /* starting point for countdown */
  /* prompt user for input */
  printf("Enter a positive number: ");
  scanf("%d", &startPoint);  /* read into startPoint */
  /* count down and print count */
  for (counter=startPoint; counter >= STOP; counter--)
    printf("%d\n", counter);
}
```

# Preprocessor Directives

- `#include <stdio.h>`
  - Before compiling, copy contents of header file (stdio.h) into source code.
  - Header files typically contain descriptions of functions and variables needed by the program.
    - no restrictions -- could be any C source code

- `#define STOP 0`
  - Before compiling, replace all instances of the string "STOP" with the string "0"
  - Called a *macro*
  - Used for values that won't change during execution, but might change if the program is reused. (Must recompile.)

# Comments

- Begin with /* and end with */
- Can span multiple lines
- Cannot have a comment within a comment
- Comments are not recognized within a string
  - example: "my/*don't print this*/string"
    would be printed as: my/*don't print this*/string
- As before, use comments to help reader, not to confuse or to restate the obvious

# `main` Function

- Every C program must have a function called `main()`.

- This is the code that is executed
  when the program is run.

- The code for the function lives within brackets:

```
main()
{
   /* code goes here */
}
```

# Variable Declarations

- Variables are used as names for data items.
- Each variable has a *type*,
  which tells the compiler how the data is to be interpreted
  (and how much space it needs, etc.).

- `int counter;`
- `int startPoint;`

- `int` is a predefined integer type in C.

# Input and Output

- Variety of I/O functions in *C Standard Library*.
- Must include `<stdio.h>` to use them.

- `printf("%d\n", counter);`
  - String contains characters to print and formatting directions for variables.
  - This call says to print the variable `counter` as a decimal integer, followed by a linefeed (`\n`).

- `scanf("%d", &startPoint);`
  - String contains formatting directions for looking at input.
  - This call says to read a decimal integer and assign it to the variable `startPoint`. (Don't worry about the `&` yet.)

# More About Output

- Can print arbitrary expressions, not just variables
-
```
    printf("%d\n", startPoint -
counter);
```

- Print multiple expressions with a single statement
-
```
    printf("%d %d\n", counter,
                startPoint - counter);
```

- Different formatting options:
- `%d` decimal integer
- `%x` hexadecimal integer
- `%c` ASCII character
- `%f` floating-point number

# Examples

- This code:

```
printf("%d is a prime number.\n", 43);
printf("43 plus 59 in decimal is %d.\n", 43+59);
printf("43 plus 59 in hex is %x.\n", 43+59);
printf("43 plus 59 as a character is %c.\n",
43+59);
```

- produces this output:

```
43 is a prime number.
43 + 59 in decimal is 102.
43 + 59 in hex is 66.
43 + 59 as a character is f.
```

# Examples of Input

- Many of the same formatting characters are available for user input.

- `scanf("%c", &nextChar);`
  - reads a single character and stores it in nextChar
- `scanf("%f", &radius);`
  - reads a floating point number and stores it in radius
- `scanf("%d %d", &length, &width);`
  - reads two decimal integers (separated by whitespace), stores the first one in length and the second in width

- Must use ampersand (&) for variables being modified. **(Explained in Chapter 16.)**

# Compiling and Linking

- Various compilers available
  - cc, gcc
  - includes preprocessor, compiler, and linker
- Lots and lots of options!
  - level of optimization, debugging
  - preprocessor, linker options
  - intermediate files --
    object (.o), assembler (.s), preprocessor (.i), etc.

# Remaining Chapters

- A more detailed look at many C features.
  - Variables and declarations
  - Operators
  - Control Structures
  - Functions
  - Data Structures
  - I/O

- Emphasis on how C is converted to
- LC-3 assembly language.

- Also see C Reference in Appendix D.