



Assembly

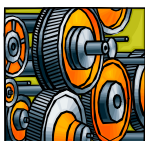
Part 3



Assembly Basics

The beautiful language of the computer

Assembly Language



- *Assembly* allows you to write machine language programs using easy-to-read text
- Assembly programs is based on a specific processor architecture
- So, it won't "port"

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Assembly Benefits

1. Consistent way of writing instructions
2. Automatically counts bytes and allocates buffers
3. *Labels* are used to keep track of addresses which prevents a common machine-language mistake

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1. Consistent Instructions

- Assembly combines related machine instructions into a single notation (*and name*)
- For example, the following machine-language actions are different, but related:
 - register → memory
 - register → register
 - constant → register

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2. Count and Allocate Buffers

- Assembly automatically counts bytes and allocates buffers
- Miscounts (when done by hand) can be very problematic – and can lead to hard to find errors

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3. Labels & Addresses

- Assembly uses *labels* are used to store addresses
- These can be memory locations or parts of your running program
- They are automatically calculated when the assembler is creating machine code

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Battle of the Syntax

- The basic concept of assembly's notation and syntax hasn't changed
- However, there are two major competing notations
- They are *just* different enough to make it confusing for students and programmers (*who are use to the other notation*)

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Battle of the Syntax

- AT&T / GNU Syntax
 - dominate on UNIX / Linux systems
 - registers prefixed by %, values prefixed with \$
 - receiving register is last
- Intel Syntax
 - dominate on DOS / Windows systems
 - neither registers or values have a prefix
 - receiving register is first

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AT&T / GNU Example (not x86)

```
# Just a simple add

mov $42, %b      #b = 42
mov value, %a     #a = value
add %b, %a       #a += b
```

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Intel Example (not x86)

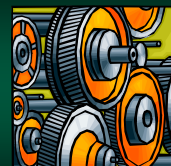
```
; Just a simple add

mov b, 42        ;b = 42
mov a, value     ;a = value
add a, b         ;a += b
```

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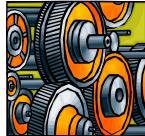


Assembly Program Structure

How these little beasts are organized

Assembly Programs

- Assembly programs are divided into two sections
- data section* allocate the bytes to store your constants, variables, etc...
- text/code section* contains the processor instructions that will make up your program



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Labels

- As the machine code is created, the assembler keeps track of the current address
- You can define *labels*
 - will be assigned an *address*
 - ... of the program created up to that point
- Notation: end in a colon



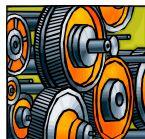
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Literals – the dollar sign

- Literals are denoted using a dollar sign \$ prefix
- This is commonly used for constants and to get the actual value of a label (an address)
- A common mistake is to forget it



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Registers – the percent sign

- Registers are using a percent sign % prefix
- If a percent sign is left off, the assembler will think you typed a label
- The explicit notation is actually useful – albeit odd looking



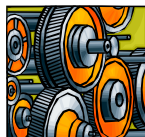
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Directives

- A *directive* is a special command for the assembler
- Notation: starts with a period
- What they do:
 - allocate space
 - define constants
 - start the text or data section
 - define the "start" address



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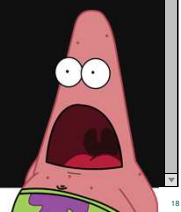
Hello World – Using csc35.o

```
.data
message:
.ascii "Hello World!\n\0"

.text
.global _start

_start:
mov $message, %rcx
call PrintCString

call EndProgram
```



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Hello World – Using csc35.o

```
.data
message:
    .ascii "Hello World!\n\0"
```

Data Section

```
.text
.global _start

_start:
    mov $message, %rcx
    call PrintCString

    call EndProgram
```

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Data Section

Start data section

Create a label called 'message'. It is an address.

```
.data
message:
    .ascii "Hello World!\n\0"
```

Allocate the bytes required to store text

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Hello World – x86, Linux

```
.data
message:
    .ascii "Hello World!\n\0"
```

```
.text
.global _start

_start:
    mov $message, %rcx
    call PrintCString

    call EndProgram
```

Text / Code Section

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Text / Code Section

Start text section

```
.text
.global _start
```

Make visible to the linker. Header will call _start

```
_start:
    mov $message, %rcx
    call PrintCString

    call EndProgram
```

Move the address of message into rcx

Call the library subroutine

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Compilers, Assemblers & Linkers

Programs, Coding, and Nerds... oh my!

Compilers & Assemblers



- When you hit "compile" or "run" (e.g. in your Java IDE), many actions take place *"behind the scenes"*
- You are usually only aware of the work that the parser does

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Development Process

1. Write program in high-level language
2. Compile program into assembly
3. Assemble program into objects
4. Link multiple objects programs into one executable
5. Load executable into memory
6. Execute it

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Compiler

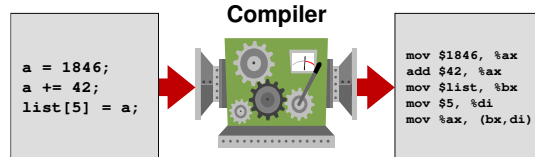
- Convert programs from high-level languages (such as C or C++) into assembly language
- Some create machine-code directly...
- *Interpreters*, however...
 - never compile code
 - Instead, they run parts of their own program

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Compilers



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Assembler

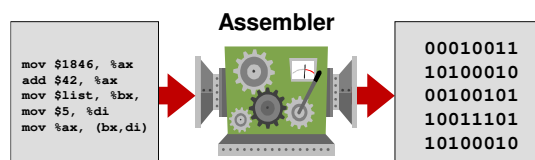
- Converts assembly into the binary representation used by the processor
- Often the result is an *object file*
 - usually not executable - yet
 - contains computer instructions and information on how to "link" into other executable units
 - file may include: relocation data, unresolved labels, debugging data

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Assembler



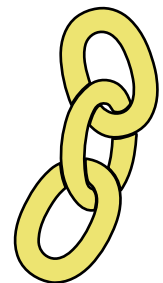
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Linkers

- Often, parts of a program are created *separately*
- Happens *more often than you think* – almost always
- A *linker* joins multiple parts (usually object files) into a single file



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What a Linker Does

- Connects labels (identifiers) - used in one object - to the object to that defines it
- So, one object can call another object
- What you will see: label conflicts and missing labels



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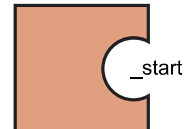
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Linking your program

- UNIX file header defined by [crt1.o](#) and [crti.o](#)
- They are supplied behind the scenes, so **you don't need to worry about them**

UNIX Header



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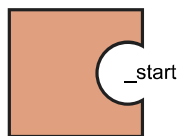
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Linking your program

- It references a subroutine called [_start](#)
- But... it is **not** defined in the header
- It is used to start your program (main in Java)

UNIX Header



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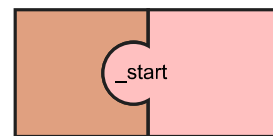
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Linking your program

- Your program supplies this subroutine
- The linker connects the two, so the header calls your subroutine

UNIX Header lab.o



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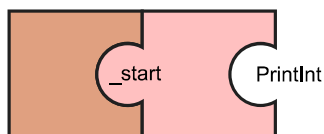
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You will use my library

- To make labs easier, you will use my library
- Your program will reference its subroutines

UNIX Header lab.o



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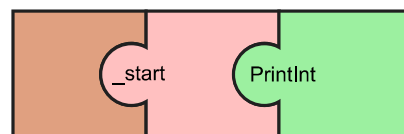
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You will use my library

- Once the object file "csc35.o" is linked, the program is complete


UNIX Header lab.o csc35.o



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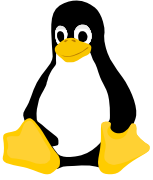


Basics of UNIX

Feel the pow-wah of the dark side

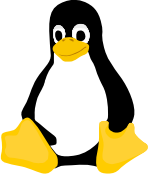
Basics UNIX

- UNIX was developed at AT&T's Bell Labs in 1969
- Design goals:
 - operating system for mainframes
 - stable and powerful
 - but not exactly easy to use – GUI hadn't been invented yet



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Basics UNIX




- There are versions of UNIX with a nice graphical user interface
- A good example is all the various versions of Linux
- However, all you need is a command line interface

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Command Line Interface

- Command line interface is text-only
- But, you can perform all the same functions you can with a graphical user interface
- This is how computer scientists have traditionally used computers



```
>gcc hello.c
>ls
a.out hello.c
>a.out
Hello world!
```

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Command Line Interface

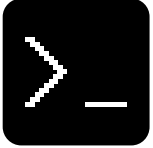
- Each command starts with a name followed by zero or more arguments
- Using these, you have the same abilities that you do in Windows/Mac

name «argument 1» «argument 2» ...

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ls Command

- Lists all the files in the current directory (folder)
- It has arguments that control how the list will look
- Folder names will have a slash suffix
- Programs have an asterisk suffix



```
>
```

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ls Command

```
> ls
a.out*  csc35/  html/  mail/
test.s
```

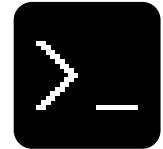
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ll Command

- This command is a shortcut notation for ls -l
- It displays all the files in "long" format
- Besides the filename, its size, access rights, etc... are displayed



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ll Command

```
> ll
-rwx----- 1 cookd othesc 4650 Sep 10 17:44 a.out*
drwx----- 2 cookd othesc 4096 Sep  5 17:49 csc35/
drwxrwxrwx 10 cookd othesc 4096 Sep  6 11:04 html/
drwxrwxrwx  2 cookd othesc 4096 Jun 20 17:58 mail/
-rw----- 1 cookd othesc   74 Sep 10 17:44 test.s
```

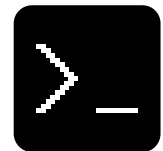
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mkdir Command

- This command will "make a directory"
- You will want to create one to store your CSc 35 work



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mkdir Command

```
> ls
a.out*  html/  mail/  test.s

> mkdir csc35

> ls
a.out*  csc35/  html/  mail/  test.s
```

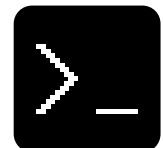
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cd Command

- To change your current folder, you will use the "change directory" command
- If you specify a folder name, you will move into it
- If you use .. (two dots), you will go to the parent folder



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cd Command

```
> cd csc35
> cd ..
```

Move into csc35 folder

Return to parent folder

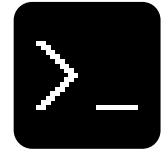
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rm Command

- If you want to delete a file, you can use the "remove" command
- It's good to cleanup your folders from time to time
- It can also delete multiple files using patterns



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rm Command

```
> ls
a.out*  html/  mail/  test.s

> rm a.out

> ls
html/  mail/  test.s
```

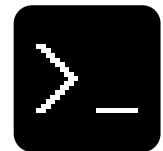
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nano

- Nano is the UNIX text editor (well, the best one – that is)
- It is very similar to Windows Notepad – but can be used on a terminal
- You will use this to write your programs



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nano

- Nano can create new file (use a new name)
- It can also open an existing file to edit

```
nano filename
```

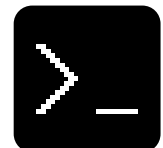
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as Command

- This is the GNU assembler
- It will take an assembly program and convert it into an object
- You will be alerted of any syntax errors or unrecognized mnemonics (typos)



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as Command

- **Be very careful** – if you list your input file first, it will be destroyed
- There is no "undo" in UNIX!
- Check if the two extensions are "o" then "s"

```
as -o lab.o lab.s
```

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as Command

```
> ls
lab.s

> as -o lab.o lab.s

> ls
lab.s  lab.o
```

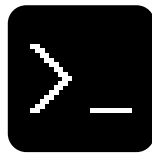
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ld Command

- This is the GNU linker
- It will take one (or more) objects and link them into an executable
- You will be alerted of any unresolved labels



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ld Command

- The "-o" specifies the next name is the output
- The second is the output file (executable)
- The third is your input objects (1 or more)

```
ld -o a.out csc35.o lab.o
```

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ld Command

- **Be very careful** – if you list your input file first, it will be destroyed
- I will provide the "csc35.o" file

```
ld -o a.out csc35.o lab.o
```

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ld Command

```
> ls
lab.o  csc35.o

> ld -o a.out lab.o csc35.o

> ls
lab.o  csc35.o  a.out*
```

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