ECE 471 – Embedded Systems
Lecture 4

Vince Weaver

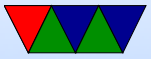
http://www.eece.maine.edu/~vweaver

vincent.weaver@maine.edu

11 September 2014

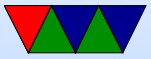
Announcements

- Any questions on HW#1?
- HW#2 will be posted Friday
- If you wanted to borrow a Pi for the semester, stop by my office to pick it up.



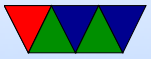
Assembly Language: What's it good for?

- Understanding your computer at a low-level
- Shown when using a debugger
- It's the eventual target of compilers
- Operating system writers (some things not expressible in C)
- Embedded systems (code density)
- Research. Computer Architecture. Emulators/Simulators.
- Video games (or other perf critical routines, glibc, kernel, etc.)



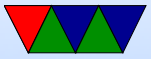
How Code Works

- Compiler generates ASM (Cross-compiler)
- Assembler generates machine language objects
- Linker creates Executable (out of objects)



Tools

- compiler: takes code, usually (but not always) generates assembly
- assembler: GNU Assembler as (others: tasm, nasm, masm, etc.)
  creates object files
- linker: ld
  creates executable files. resolves addresses of symbols. shared libraries.

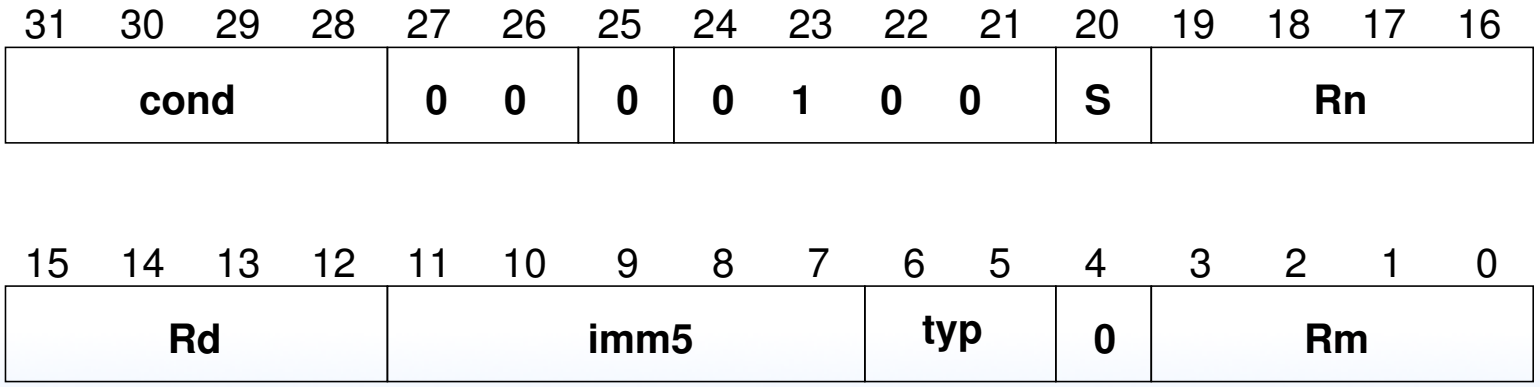


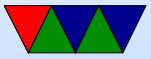
Converting Assembly to Machine Language

Thankfully the assembler does this for you.

ARM32 ADD instruction – `0xe0803080` == `add r3, r0, r0, lsl #1`

`ADD{S}<c> <Rd>,<Rn>,<Rm>{,<shift>}`

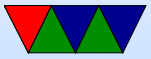




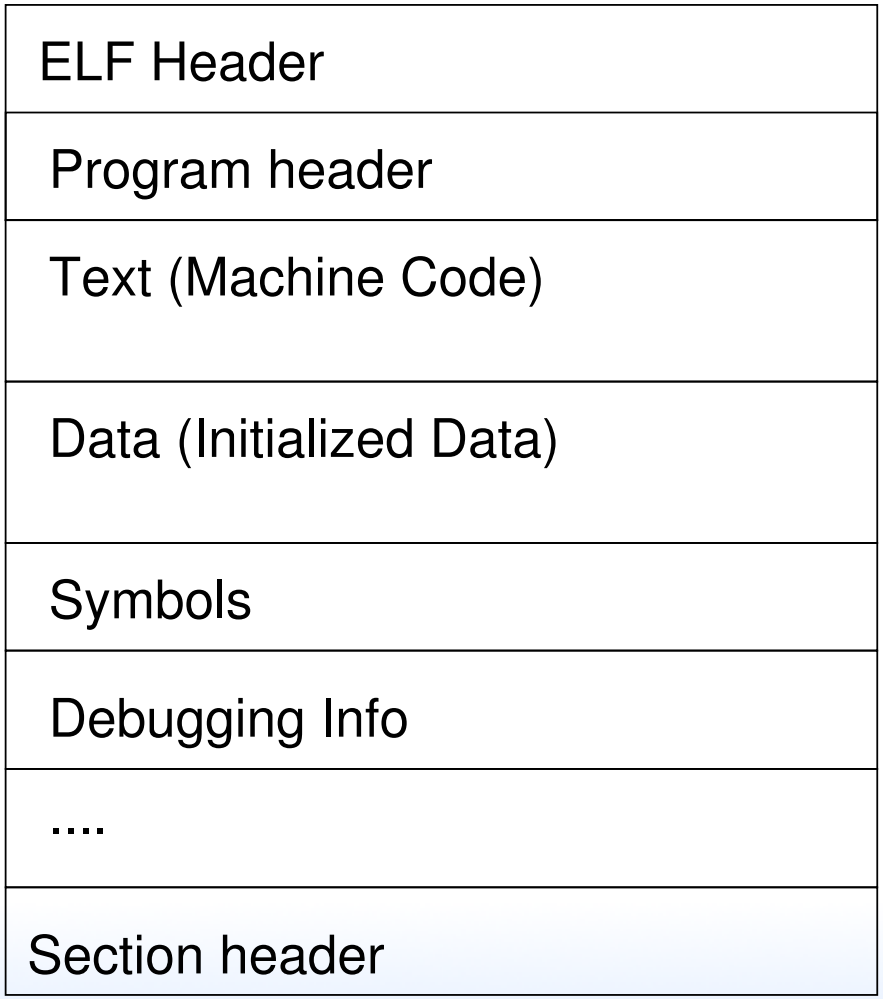
Executable Format

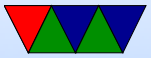
- ELF (Executable and Linkable Format, Extensible Linking Format)
  Default for Linux and some other similar OSes
  header, then header table describing chunks and where they go

- Other executable formats: a.out, COFF, binary blob



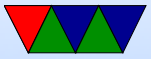
ELF Layout


ELF Header
Program header
Text (Machine Code)
Data (Initialized Data)
Symbols
Debugging Info
....
Section header



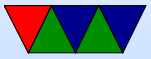
ELF Description

- ELF Header includes a "magic number" saying it's 0x7f,ELF, architecture type, OS type, etc. Also location of program header and section header and entry point.
- Program Header, used for execution:
  has info telling the OS what parts to load, how, and where (address, permission, size, alignment)
- Program Data follows, describes data actually loaded into memory: machine code, initialized data

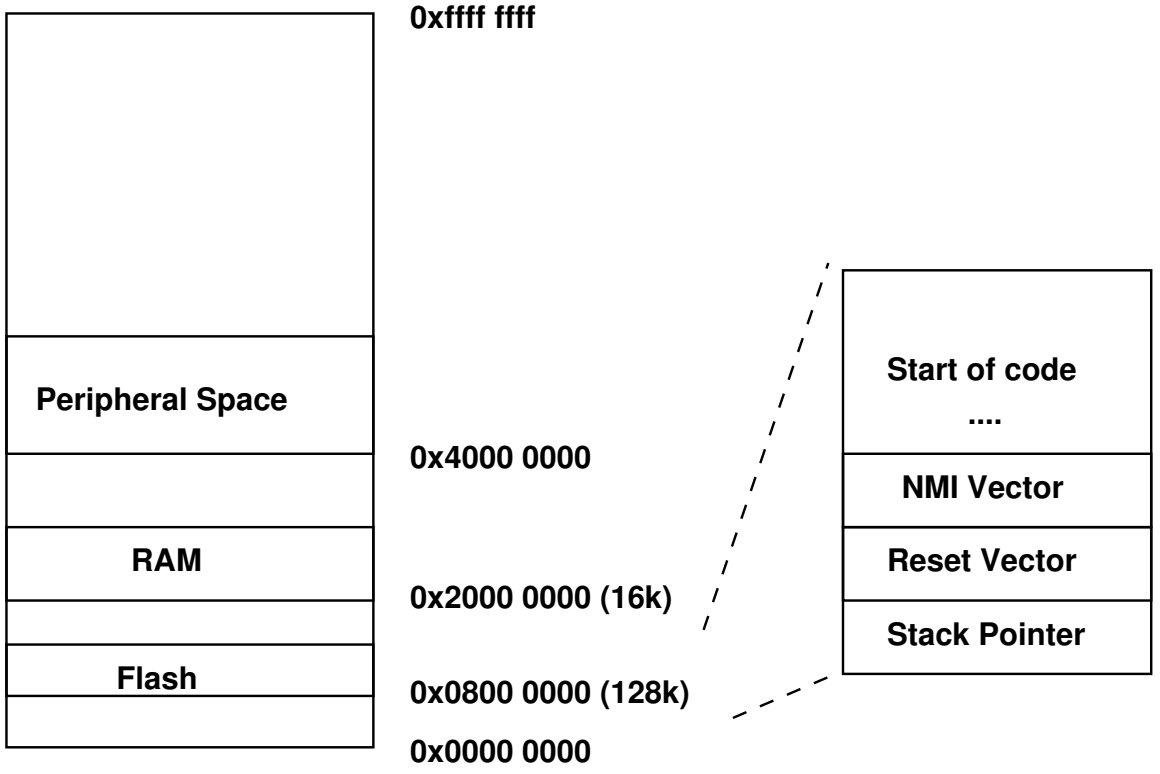


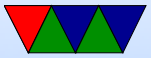
- Other data: things like symbol names, debugging info (DWARF), etc.
  DWARF backronym = "Debugging with Attributed Record Formats"

- Section Header, used when linking:
  has info on the additional segments in code that aren't loaded into memory, such as debugging, symbols, etc.

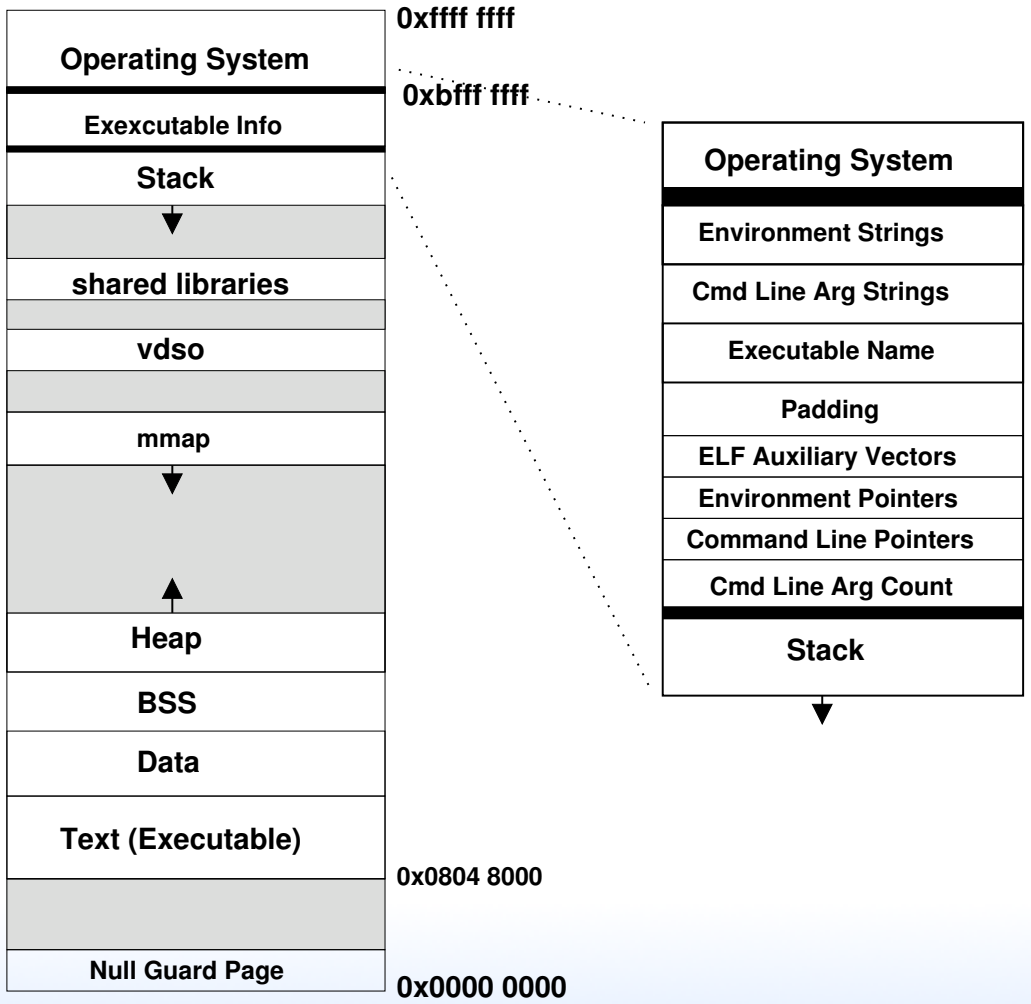


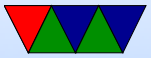
STM32L-Discovery Physical Memory Layout





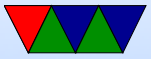
Linux Virtual Memory Map





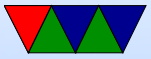
Program Memory Layout on Linux

- Text: the program's raw machine code
- Data: Initialized data
- BSS: uninitialized data; on Linux this is all set to 0.
- Heap: dynamic memory. `malloc()` and `brk()`. Grows up
- Stack: LIFO memory structure. Grows down.



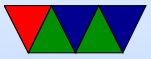
Program Layout

- Kernel: is mapped into top of address space, for performance reasons
- Command Line arguments, Environment, AUX vectors, etc., available above stack
- For security reasons "ASLR" (Address Space Layout Randomization) is often enabled. From run to run the exact addresses of all the sections is randomized, to make it harder for hackers to compromise your system.



Loader

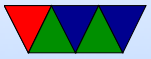
- /lib/ld-linux.so.2
- loads the executable



Static vs Dynamic Libraries

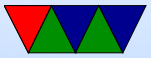
- Static: includes all code in one binary.
  Large binaries, need to recompile to update library code, self-contained

- Dynamic: library routines linked at load time.
  Smaller binaries, share code across system, automatically links against newer/bugfixes



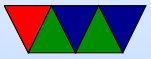
How a Program is Loaded

- Kernel Boots
- `init` started
- `init` calls `fork()`
- child calls `exec()`
- Kernel checks if valid ELF. Passes to loader
- Loader loads it. Clears out BSS. Sets up stack. Jumps



to entry address (specified by executable)

- Program runs until complete.
- Parent process returned to if waiting. Otherwise, init.



What you have at entry

- Registers
- Instruction pointer at beginning
- Stack
- command line arguments, aux, environment variables
- Large contiguous VM space