SIGPwny
Reverse Engineering Part 2

Announcements

- Manticore Focus Group
- UIUCTF Challenge Feedback -
  - https://goo.gl/forms/ggq7F4RFd05o2fFF3

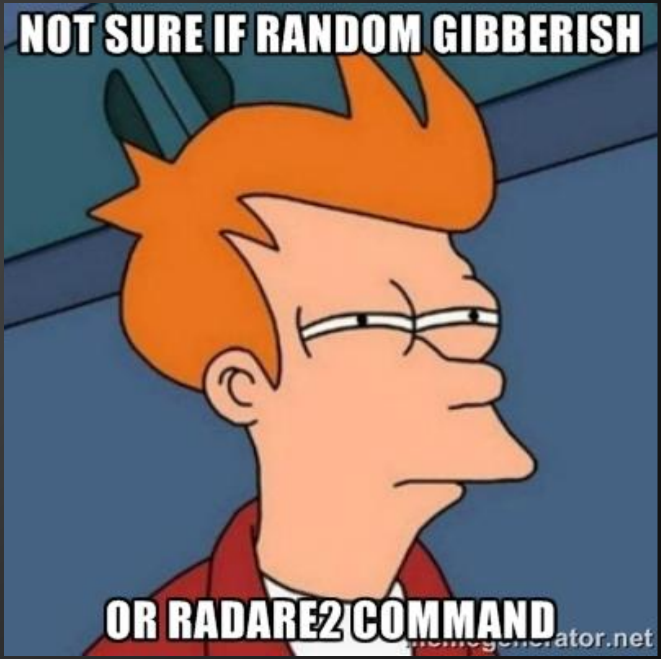
News of the Week

- SHAttered Binary PoC
- US Incapable of Responding to CyberAttacks
- FBI Drops Child Porn Case to Preserve TOR Vuln
- Backdoor in DblTek IoT Devices
- Vault7

Reverse Engineering

Tools used in RE

- Disassemblers/Decompilers
  - IDA Pro/Hex Rays
  - Hopper
  - Radare2
  - Binary Ninja
- Debuggers
  - OllyDbg
  - GDB
  - WinDBG

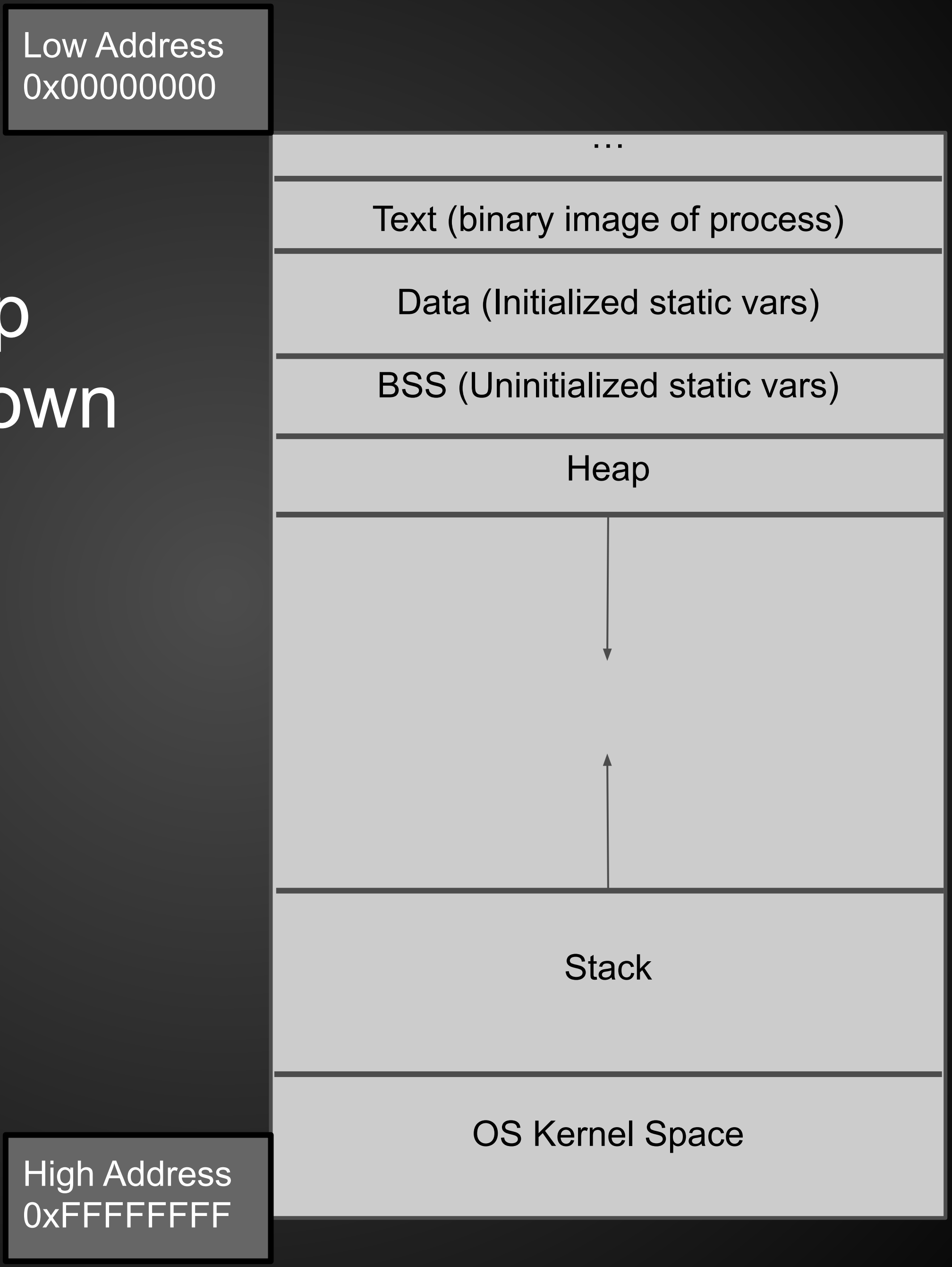


Tools used in RE

- https://ctf.oddcoder.com/toolset

Memory

- Stack grows up
- Heap grows down


Low Address
0x00000000
…
Text (binary image of process)
Data (Initialized static vars)
BSS (Uninitialized static vars)
Heap
Stack
OS Kernel Space
High Address
0xFFFFFFFF

Introduction to IA-32 (x86)

x86 Architectural Features

- “Intel Architecture, 32-bit”
- Sometimes called i386, x86
- 32 bit version of the x86 architecture

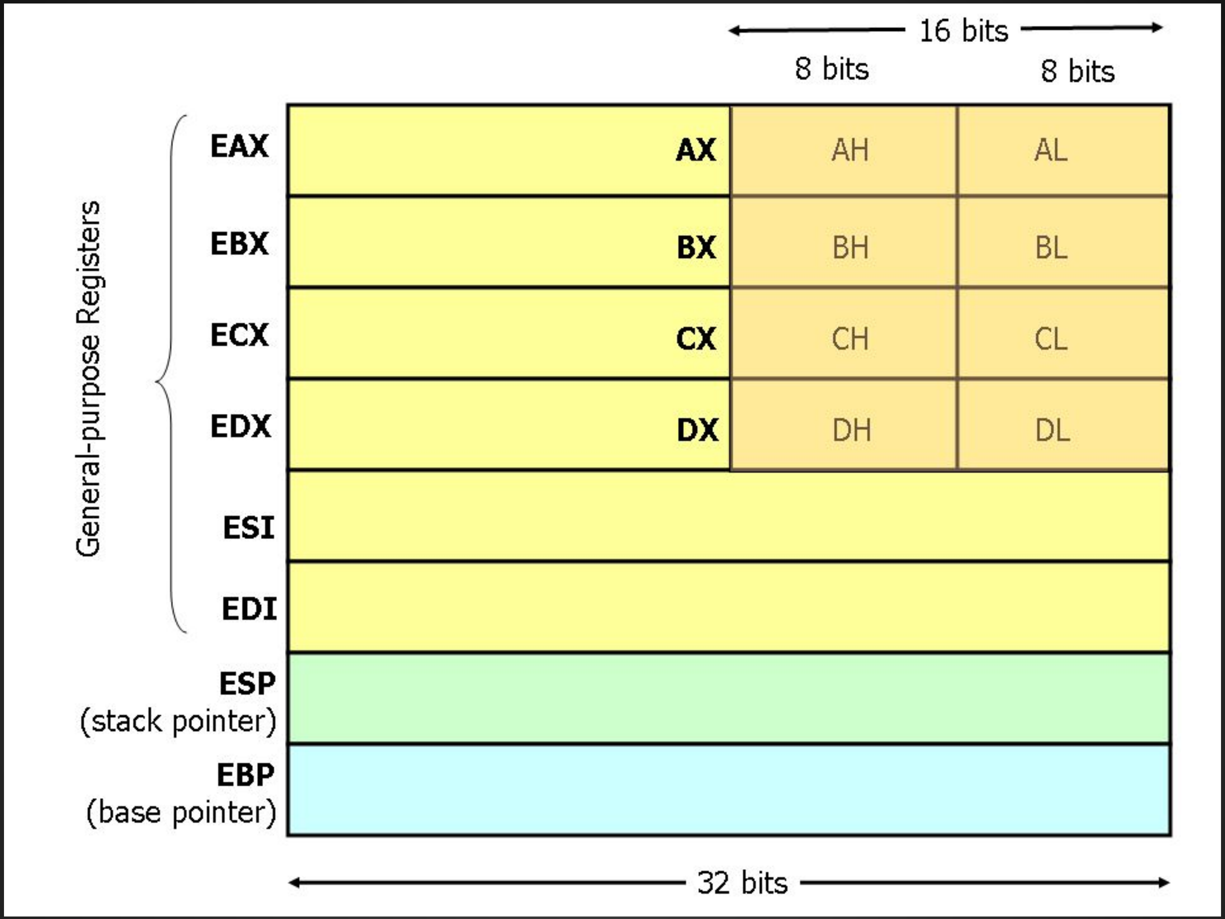
x86 Outline

- Registers
- Syntax
- Common Instructions

Registers

Registers

- Memory that the processor can access much faster than RAM
- There are a lot of them, but we'll focus on a few of the more important ones
- EAX, EBX, ECX, EDX, ESI, EDI can be used as general storage registers
- "E" stands for extended (32 bits vs 16 bits)
- RAX, RBX, etc. for 64-bit registers


16 bits
8 bits
8 bits
General-purpose Registers
EAX
AX
AH
AL
EBX
BX
BH
BL
ECX
CX
CH
CL
EDX
DX
DH
DL
ESI
EDI
ESP
(stack pointer)
EBP
(base pointer)
32 bits

Registers

- Conventional use - not so much in practice
- EAX
    - Accumulator
    - **Return value**
- EBX
    - Base index (arrays)
- ECX
    - Counter (loops)
- EDX
    - Data

Registers

- ESI
  - Source index (memory copying operations)
- EDI
  - Destination index (memory copying operations)
- EBP
  - Base pointer (base of the current stack frame)
- ESP
  - Stack pointer (address of highest element on stack)

Registers

- EIP
  - Instruction Pointer (pointer to next instruction)
- EFLAGS
  - Relevant flags are carry flag (CF), zero flag (ZF), Sign flag (SF), and overflow flag (OF)
  - Used for conditional statements
- You can’t directly move values into these registers

Registers

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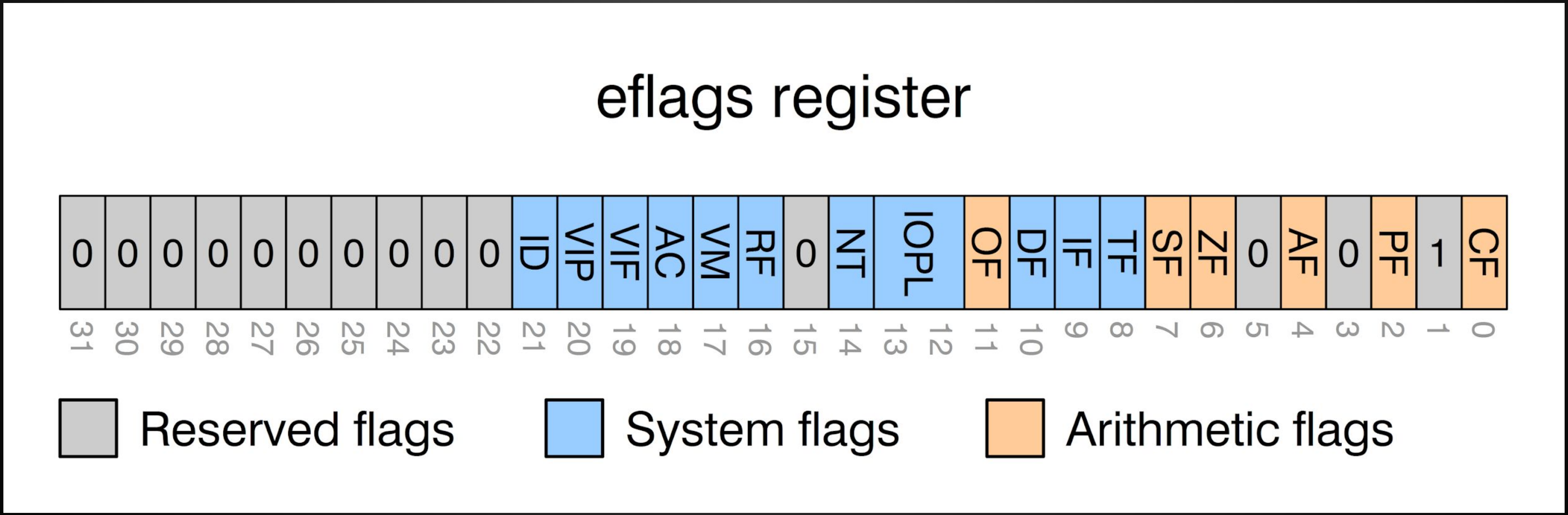

Instruction Syntax

Intel Syntax

- Intel
  - Operation Destination, Source
  - Parameter size derived from name of register (rax, eax, ax, al/ah)
  - No prefixes on immediates or registers
  - mov eax, 0x05

AT&T Syntax

- AT&T (GAS)
  - Operation Source, Destination
  - Suffix for size of operands: q,l,w,b
  - Immediates prefixed with $ and registers prefixed with %
  - movl $0x05, %eax

Common Instructions

Instructions

- We will be using Intel Syntax
    - destination, source
- Like registers, there are a lot of x86 instructions.
    - We will focus on some of the more common ones
- When starting RE, don’t focus on memorizing instructions.
    - Look them up as needed

Instructions

- MOV
  - mov eax, 1   // eax = 1

Instructions

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  - ADD eax, 4 // eax += 4
  - SUB eax, 8 // eax -= 8

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  - xor eax, ebx // eax = eax ^ ebx

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- AND, OR, NOT, XOR
  - xor eax, ebx // eax = eax ^ ebx
- SAL, SAR, SHL, SHR
  - shl edx, 4 // edx = edx * 16

Instructions

- LEA
  - “Load Effective Address”
  - Often used to load an absolute address from a relative offset in a general purpose register
  - Good Stackoverflow descriptions of LEA
- PUSH, POP
  - Stack Manipulation
- CALL, RET
- Stack set up and teardown per C calling convention

Instructions

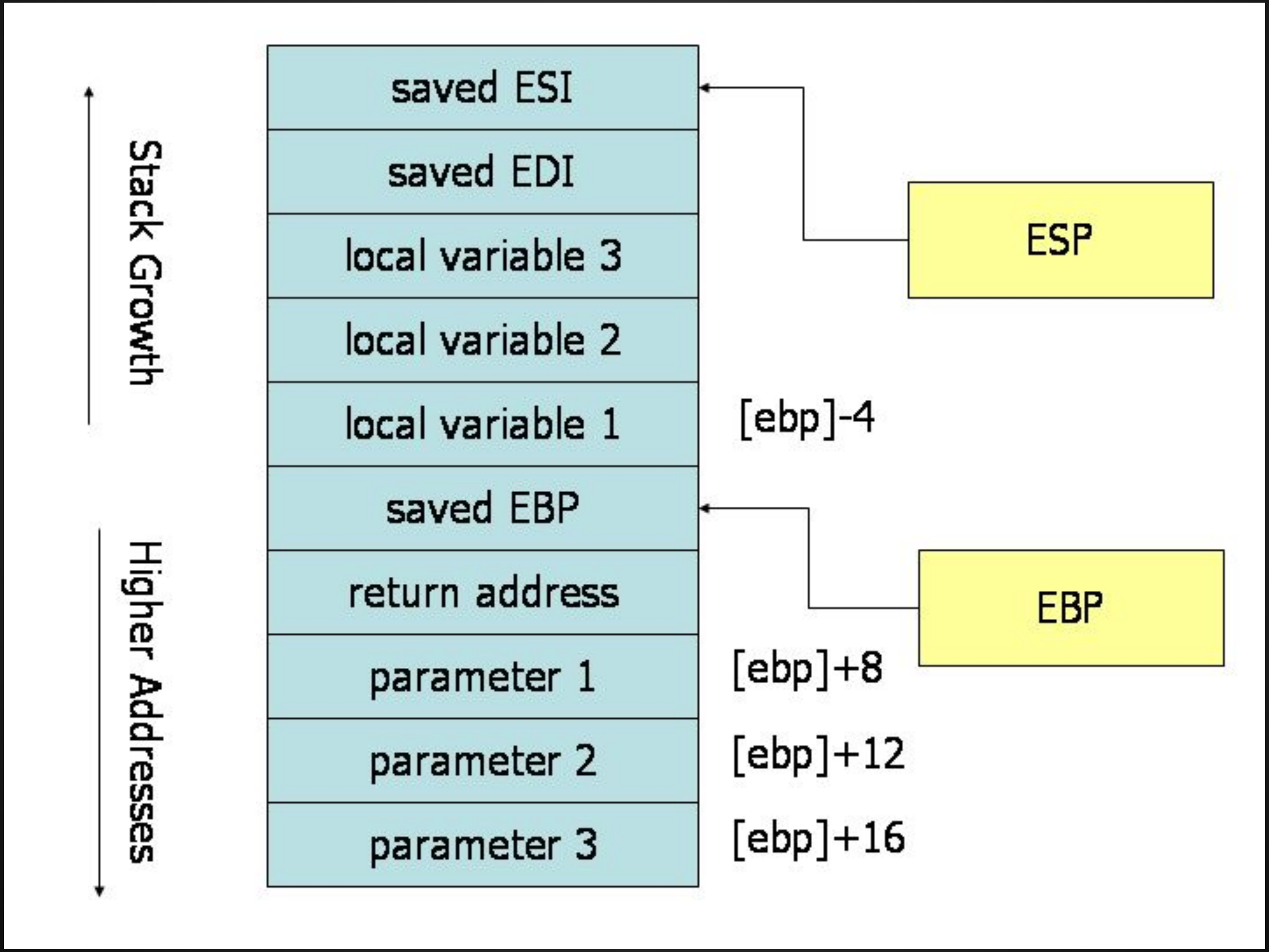
- CMP
  - Subtracts operands but discards result
  - Sets flags
- TEST
  - ANDs operands but discards result
  - Sets flags
- JMP/Jxx
  - JNE, JAE, etc

Memory addressing

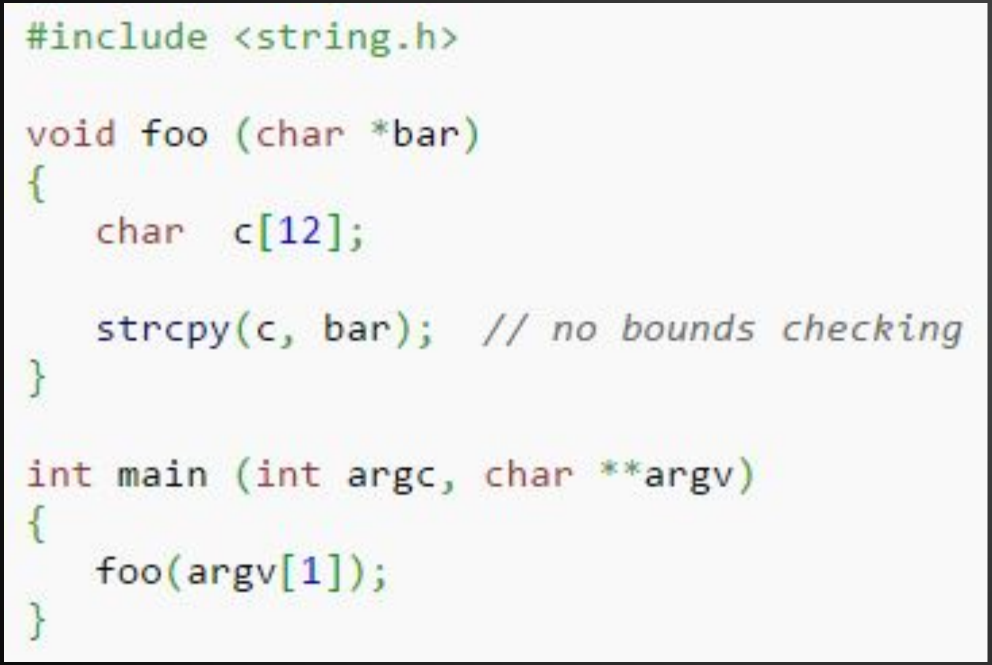
- mov eax, [ebx+4*ecx]
  - eax = *(ebx + 4*ecx)
  - [ ] dereferences an address

The Stack and C Calling Convention

int func(param1, param2, param3)
{ int var1, var2, var3; }



C Call Stack

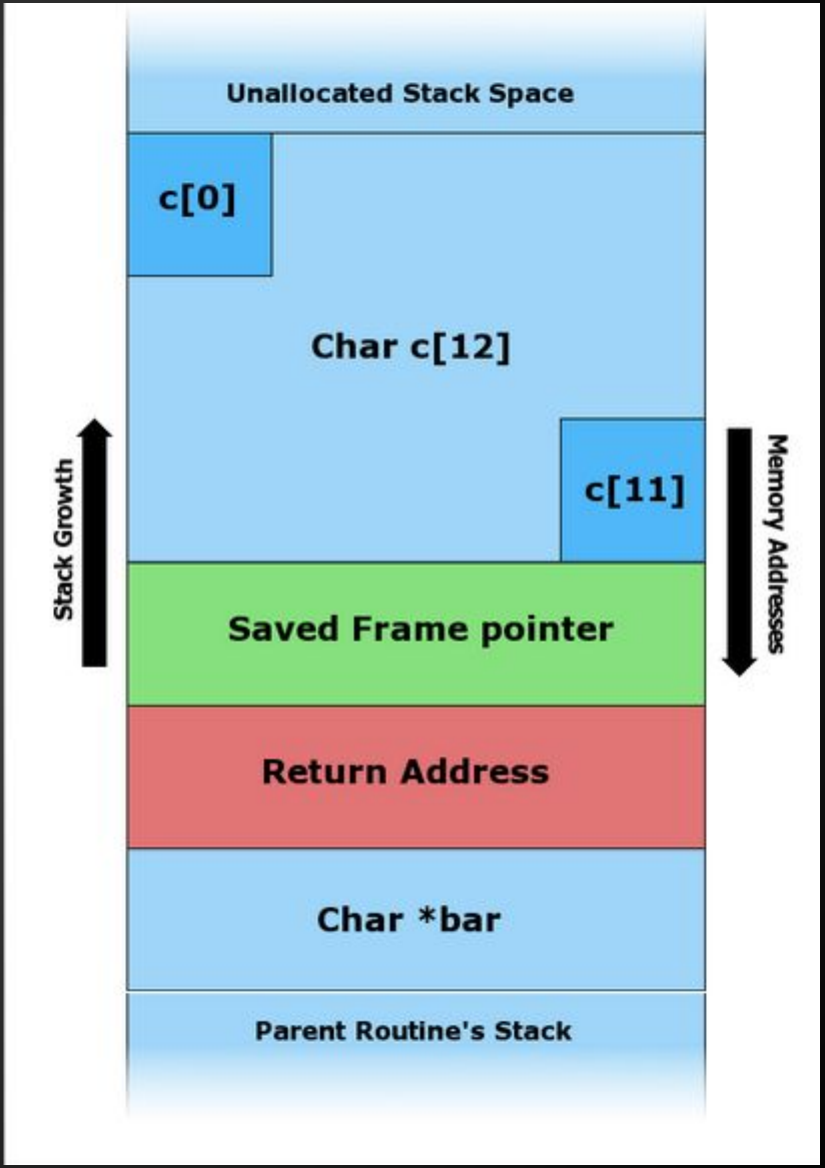


```
#include <string.h>

void foo (char *bar)
{
   char  c[12];

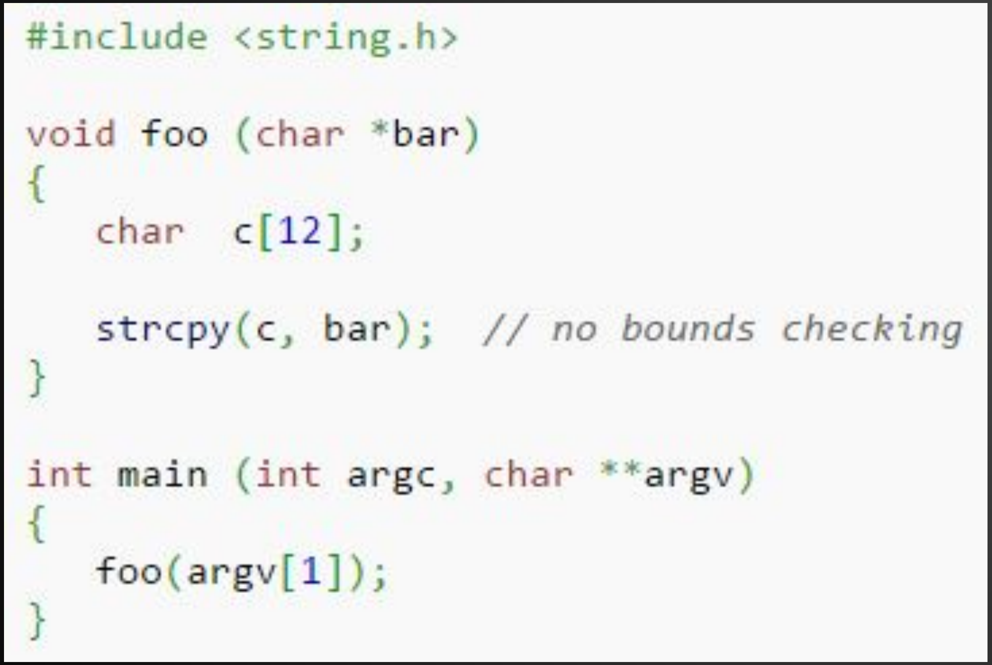
   strcpy(c, bar);  // no bounds checking
}

int main (int argc, char **argv)
{
   foo(argv[1]);
}
```



C Call Stack

Input: “Hello”



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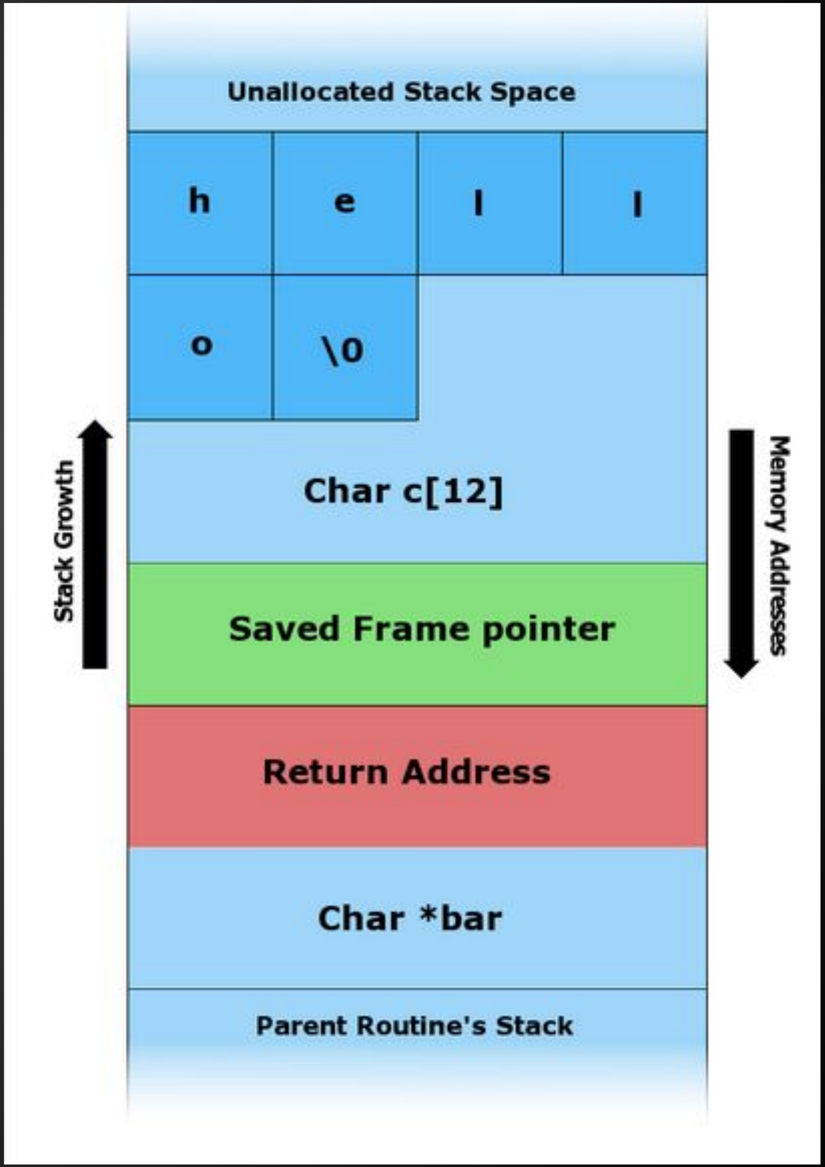
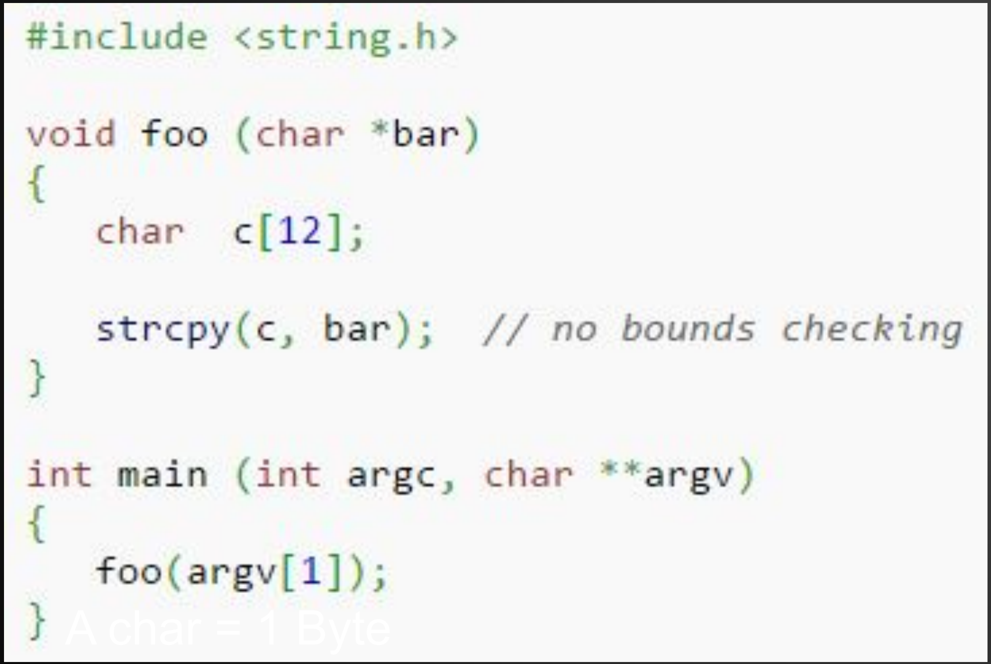


C Call Stack

Input: “AAAAAAAAAAAAAAAA\x08\x35\xC0\x80”



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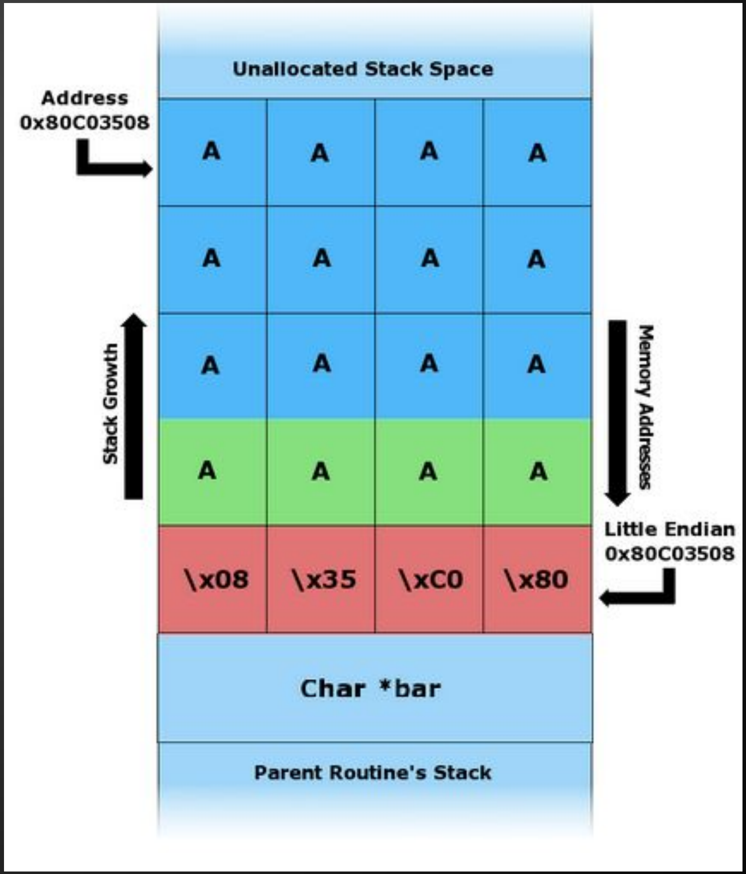
```

A char = 1 Byte

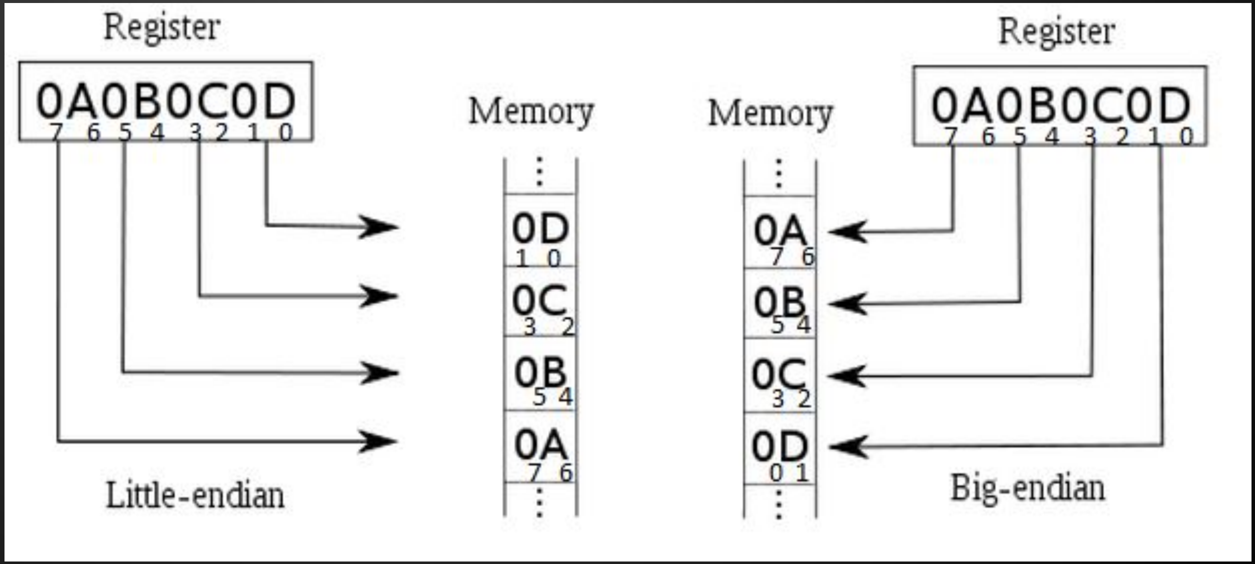
Hex (“\x0”) = 4 Bits = ½ Byte

2 Hex (“\x00”) = 1 Byte



Endianness

- Intel x86 uses little endian
  - “Little end” (least significant byte) goes into lower memory address
- Bytes are in reverse order in little endian
  - Address 0x0A0B0C0D looks like 0x0D0C0B0A in memory.



Some IDA Commands

- n // rename function, variable, register
- h // toggle between hex and decimal
- alt + t // search for text
- spacebar // toggle between views
- x // cross references to function, variable
- ctrl - left click // highlight multiple nodes
- right click -> group nodes // groups nodes
- y // change type (int, char) of variable
- alt-Q // list of structures

GDB commands

- gdb <program>   // runs program in gdb
- set disassembly-flavor intel
- b <address/function> // sets breakpoint
- r   // run (restart) program
- p $<register>   // prints register value
- n   // next instruction
- s   // step into function
- si   // step 1 assembly instruction
- c   // continue executing
- x <address>   // examine memory

GDB stuff

- "set follow-fork-mode child"
- gdb <program>   // opens and loads program into gdb
  - file <program>   // loads program into gdb
  - r <params>   // runs the loaded program with params as argument
  - r < <file.txt>   // runs the program with contents of file.txt as parameter
  - \xCC   // Debugger trap, when executed in gdb, program should exit with SIGTRAP. Use to test if you get code execution.
  - b <function name or line number>   // set breakpoint

Some radare2 commands

- r2 <program>   // runs in read mode
- r2 -A <program> // run and analyze funcs
- r2 -Aw <program> // analyze and write-mode

- s <address> // set selector to address
- pd <size> // print disassembly at selector
- pdr // print disassembled function (if -A)
- aa   // analyze functions and bbs
- ag $$ > a.dot   // creates basic block graph
- agc $$ > a.dot   // creates call graph
- $$ = at this location

Some radare2 debugger commands

- r2 -d <program> // run program in debugger
- db @ <address/function> // sets breakpoint
- do // reopen program in debugger
- dr // prints all register values
- dr?<register> // prints register value
- dr eax=0 // set register eax=0
- ds // step 1 assembly instruction
- dc // continue executing

radare2 commands

- Cheatsheet:

https://github.com/pwntester/cheatsheets/blob/master/radare2.md

Challenges

- RE50
- RE70
- RE150
-

Exercises

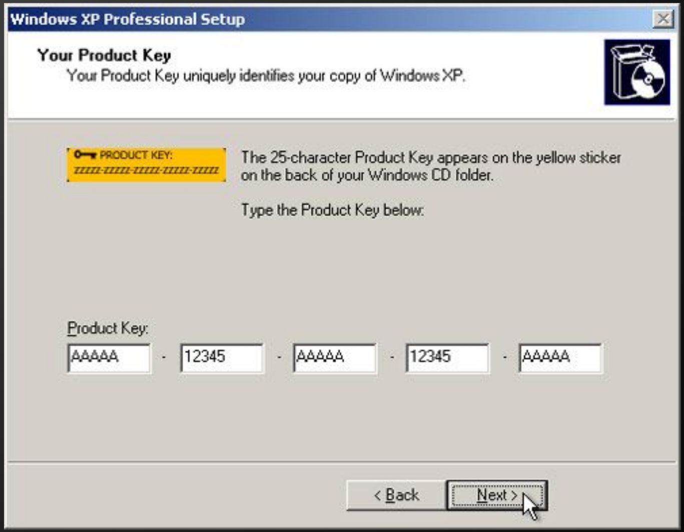
- https://github.com/sigpwny/RE_Labs
- Combination
- CD_Key
- Mr.E

Combination

This executable is like a lock. There are multiple stages that need to be unlocked one at a time. Dynamic analysis is a must!

CD_key

You downloaded Winrar, but it asks for a CD key before it will install. Ha. It should be fairly easy to crack the CD key validator on this. You might even go so far as to create a keygen...



Your Product Key
Your Product Key uniquely identifies your copy of Windows XP.

PRODUCT KEY:
XXXXX-XXXXX-XXXXX-XXXXX-XXXXX

The 25-character Product Key appears on the yellow sticker on the back of your Windows CD folder.

Type the Product Key below:

Product Key: AAAAA - 12345 - AAAAA - 12345 - AAAAA

Mr.E

Your name is Ben Bitdiddle. You are an ECE student at UIUC. Your GPA is 1.5 due to constantly ing your group projects with your horrible suggestions. You need to raise your GPA to at least a 2.0 by the end of the semester to graduate, but you don't know how. Your classmate Alyssa P. Hacker feels bad for you. She hacks the school network and brings you a flash drive containing a single file, "Mr.E", telling you that it is your ticket to graduation. What does this file do? How can this help you? Do you really trust her? Only one way to find out…

So you want to learn more..

- Books
  - Reversing: Secrets of Reverse Engineering
  - The IDA Pro Book
  - Practical Reverse Engineering
  - Practical Malware Analysis
- OpenSecurityTraining
  - Intro classes on x86, ARM, Reverse Engineering and more!
- CTF challenges

Troubleshooting the Challenges

- Turn off ASLR:

  as root: echo 0 > /proc/sys/kernel/randomize_va_space

  This only persists until next reboot

- If you get a Makefile compile error about missing libraries (probably if you are using a 64-bit machine) install g++-multilib

  sudo apt-get install g++-multilib