Function Pointers, Vulnerabilities

CS 2130: Computer Systems and Organization 1

Xinyao Yi Ph.D.
Assistant Professor

UNIVERSITY of VIRGINIA | ENGINEERING

Announcements

- Homework 10 due tonight on Gradescope
- Final exam: 7-9 pm Dec 12, Physics 338 (different room!)
  - Cumulative, see practice tests
- Remember to fill out course evaluations
  - 5 pts extra credit on final exam if completed by

    Wednesday, Dec 10 at 5pm!

Example Code

Consider the following code:

```
void apply(double (*f)(double), double *l, unsigned n) {
  for(int i=0; i<n; i+=1)
    l[i] = f(l[i]);
}
```

What are its parameters? How do we call it?

Example Code

```
int main() {
  double vals[5] = { M_PI, M_E, 2130, 1, 0 };
  for(int i=0; i<5; i+=1) printf("%f\t", vals[i]);
  puts("");
  apply(sqrt, vals, 5);
  for(int i=0; i<5; i+=1) printf("%f\t", vals[i]);
  puts("");
  apply(sin, vals, 5);
  for(int i=0; i<5; i+=1) printf("%f\t", vals[i]);
  puts("");
  apply(cos, vals, 5);
  for(int i=0; i<5; i+=1) printf("%f\t", vals[i]);
  puts("");
}
```

Function Pointers

```
void apply(double (*f)(double), double *l, unsigned n) {
  for(int i=0; i<n; i+=1)
    l[i] = f(l[i]);
}
```

`double (*f)(double)` means:

- `*f` – `f` is a pointer
- `(double)` – with a single `double` argument
- `double` – that returns a `double`
- `( )` – to make it parse as `*f` instead of `double *`

Function Pointers

```
const char *(*fv)(const char *) = findVowel;
```

A **function pointer** is a pointer that references code

- In assembly, the address of the function is just a label
  - Follow calling conventions
  - Push return address
  - Jump to that label
- C tries to hide that with this function pointer syntax
- Be aware of operator precedence!

Vulnerabilities...
...and when to report them

Memory

Common Memory Problems (from reading)

- Memory leak
- Uninitialized memory
- Accidental cast-to-pointer
- Wrong use of ‘sizeof‘
- Unary operator precedence mistakes
- Use after free
- Stack buffer overflow
- Heap buffer overflow
- Global buffer overflow
- Use after return
- Uninitialized pointer
- Use after scope

Vulnerabilities

Vulnerabilities

Vulnerability: a program for which something like this could happen (security holes)

- Ex: stack buffer overflow possibility
- Not necessarily malicious (like when we talked about backdoors)

Exploit: a way to use a vulnerability or backdoor that has been created

- Ex: the magic long word to type into our program

Vulnerabilities

Warning

Anytime you can modify memory the programmer did not expect you to be able to modify, there's something you can do to give yourself power or rights the programmer didn't mean to give you

Memory

Common Memory Problems (from reading)

- Memory leak
- Uninitialized memory
- Accidental cast-to-pointer
- Wrong use of ‘sizeof‘
- Unary operator precedence mistakes
- Use after free
- Stack buffer overflow
- Heap buffer overflow
- Global buffer overflow
- Use after return
- Uninitialized pointer
- Use after scope

Vulnerabilities

What should you do when you find a vulnerability?

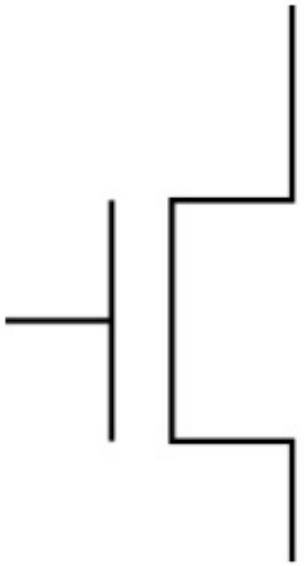
Good Practices

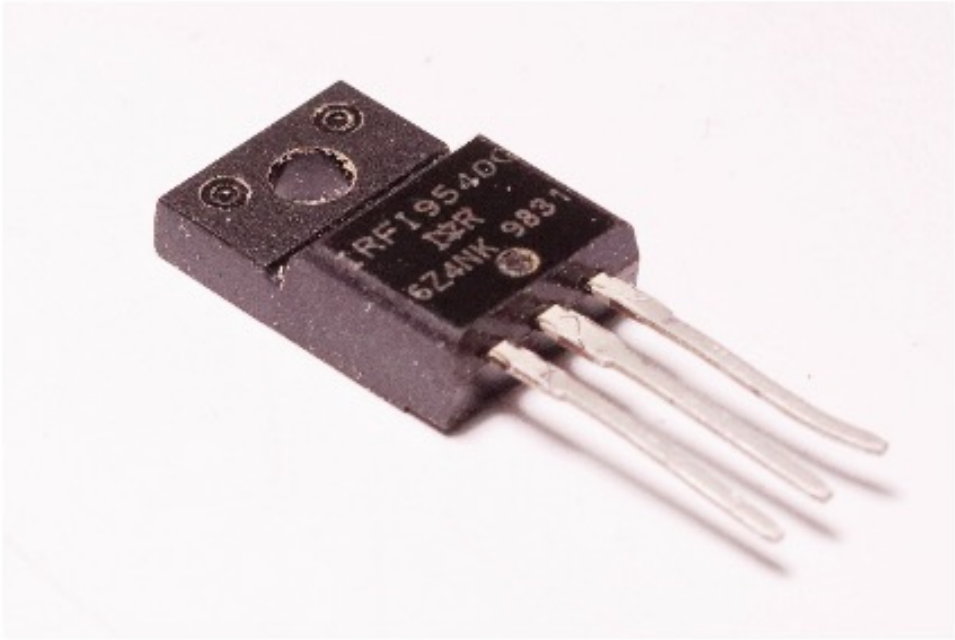
Good practices when finding a vulnerability:

1. Tell the owner
2. Wait (a reasonable amount of time for a fix)
3. Publish

Where have we been?

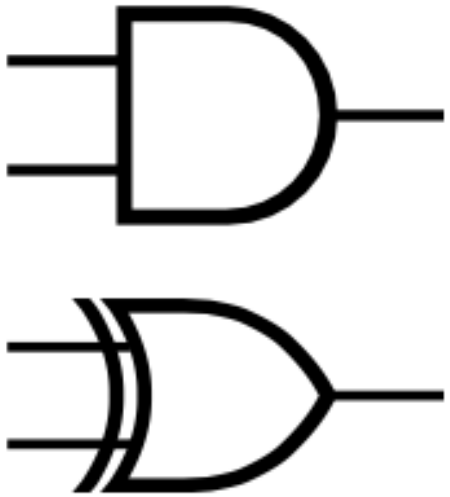
Where are we going?



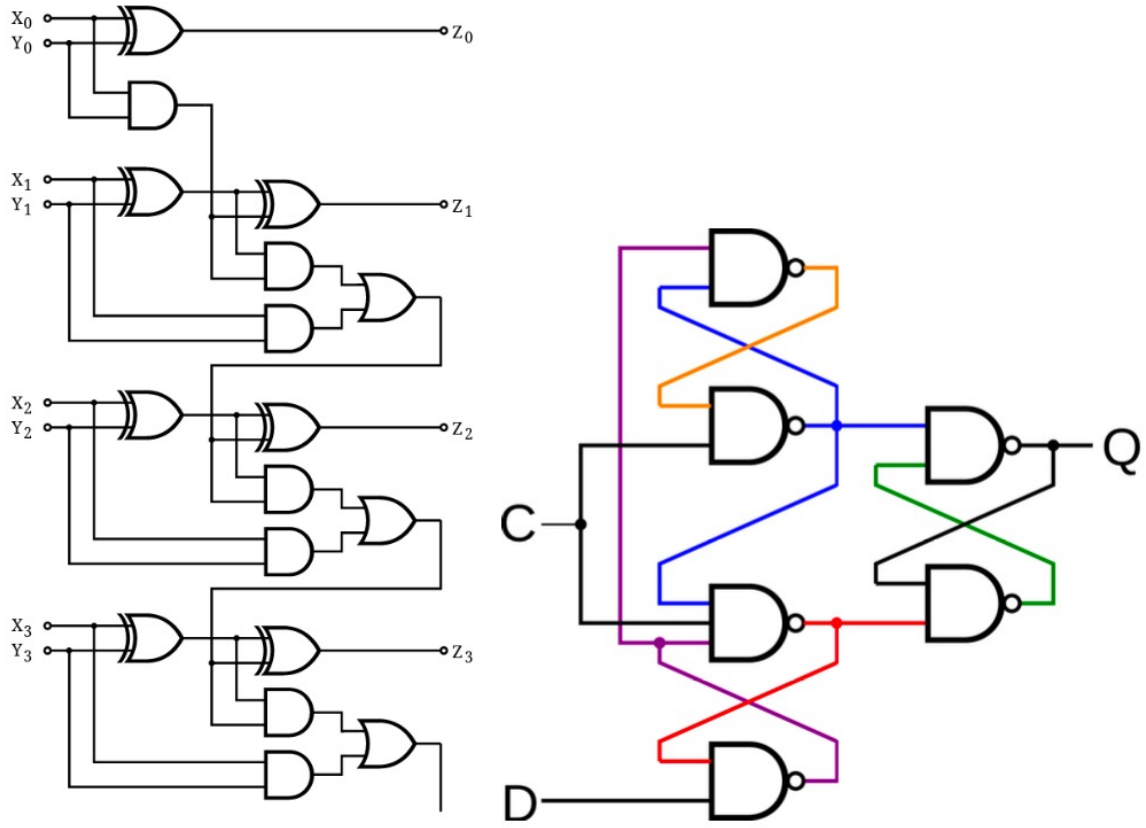


0 and 1

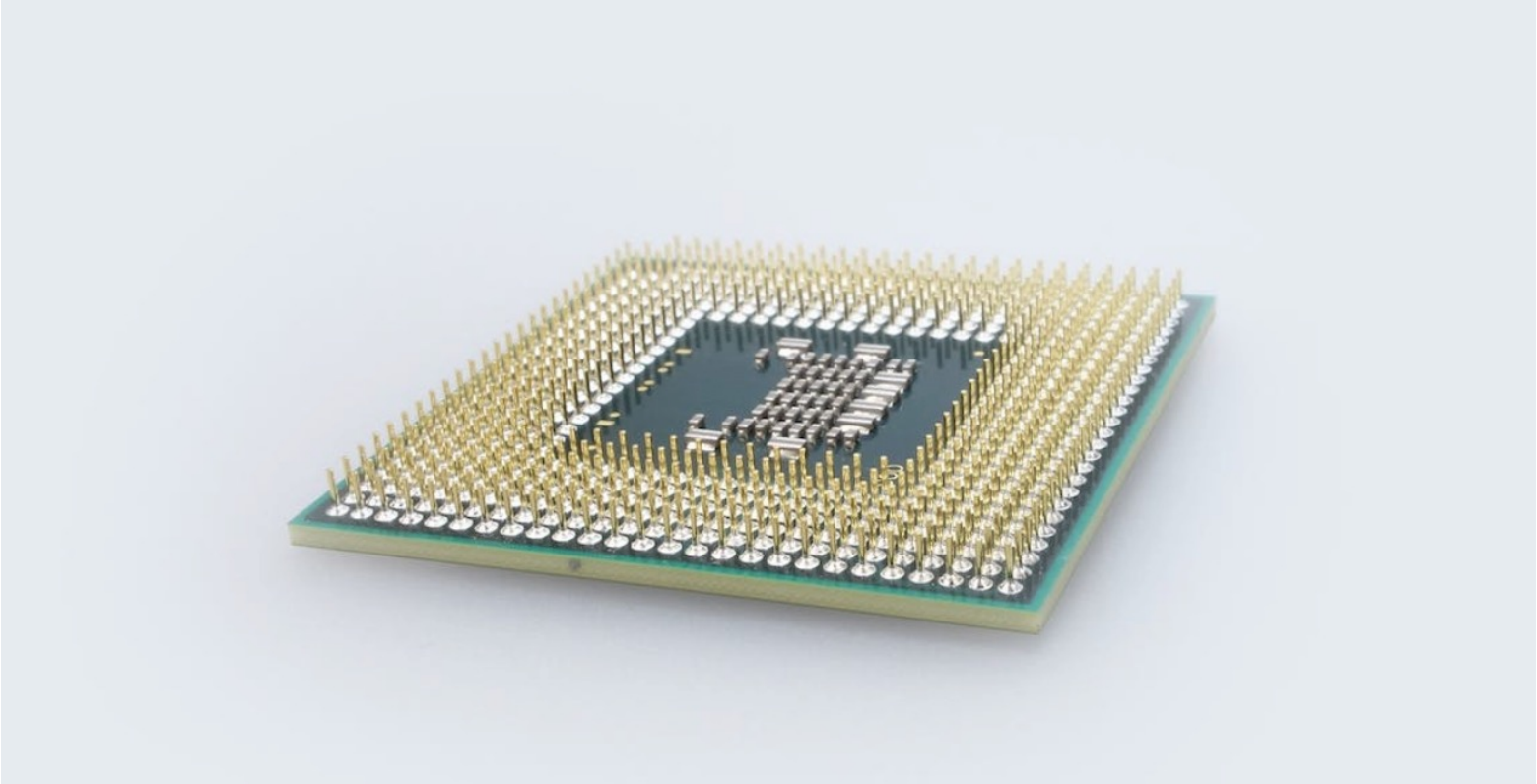
Where are we going?



Where are we going?



Where are we going?



Where are we going?

```
0000000000000000 <main>:
   0:   55                      push   %rbp
   1:   48 89 e5                mov    %rsp,%rbp
   4:   31 c0                   xor    %eax,%eax
   6:   c7 45 fc 00 00 00 00    movl   $0x0,-0x4(%rbp)
   d:   c7 45 f8 03 00 00 00    movl   $0x3,-0x8(%rbp)
  14:   48 c7 45 f0 04 00 00    movq   $0x4,-0x10(%rbp)
  1b:   00
  1c:   48 8d 4d f8             lea    -0x8(%rbp),%rcx
  20:   48 89 4d e8             mov    %rcx,-0x18(%rbp)
  24:   48 8d 4d f0             lea    -0x10(%rbp),%rcx
  28:   48 89 4d e0             mov    %rcx,-0x20(%rbp)
  2c:   48 8b 4d e8             mov    -0x18(%rbp),%rcx
  30:   48 63 09                movslq (%rcx),%rcx
  33:   48 89 4d d8             mov    %rcx,-0x28(%rbp)
  37:   48 8b 4d e0             mov    -0x20(%rbp),%rcx
  3b:   48 8b 09                mov    (%rcx),%rcx
  3e:   89 4d d4                mov    %ecx,-0x2c(%rbp)
  41:   5d                      pop    %rbp
  42:   c3                      retq
```

Where are we going?

```
void swap(int *a, int *b) {
    int tmp = *a;
    *a = *b;
    *b = tmp;
}
```

Where are we going?

Along the way:

- Interact with the terminal and SSH
- Learn basic command-line tools and editors
- Access command-line documentation
- Practice C and using the C standard library
- Learn how to debug with lldb and the address sanitizer
- Discuss related security and social topics
- Think about the next steps of Generative AI

Finale

Along the way:

- Interact with the terminal and SSH
- We have covered a LOT
- Electricity on wires
- Transistors to gates (AND, OR, ...)
- Combined gates to make circuits
- Connected circuits and registers to build a 1-byte computer
- Wrote an ISA for that computer (1-byte instructions, Toy ISA)
- Expanded to x86-64 Assembly (saw the binary)
- Concluded with C (how it compiles and connects with Assembly)

Finale

Thanks for a great semester!