CSC258: Computer Organization

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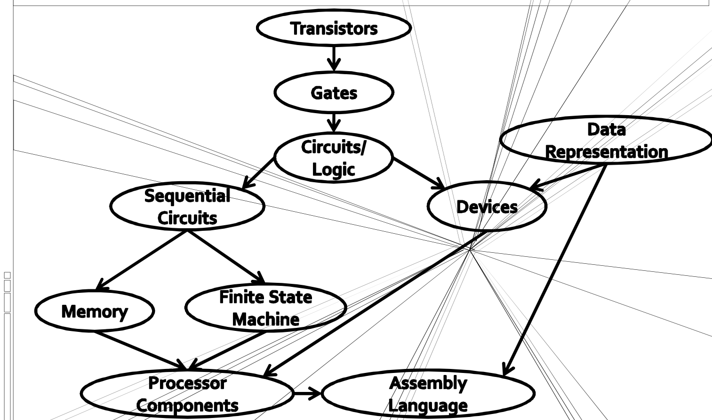
* Original slides by Steve Engels

Breaking down CSC258



CSC258 Course Details

- Lectures
  - Lectures cover topics (generally one per week)
  - Each week builds on the week before
- Tutorials
  - 30 minutes topic review (from previous week)
  - 30 mintues lab prep (for following week)
- In-class Quiz (4%)
  - 12 problem sets to be solved in pairs
  - To be handed in during class

CSC258 Course Details

- Labs (28%):
  - 7 total (4% each)
  - Must complete pre-lab exercises ahead of time (1%) and demonstrate completed lab tasks to TAs in the lab rooms (BA3145, BA3155, BA3165).
  - Must work in pairs, in your assigned room.
  - Your partner and your lab station are yours for the duration of all 7 labs.
  - No eating or drinking allowed in the lab rooms.

CSC258 Course Details

- Project (10%):
  - Project proposal (1%)
  - 3 milestone demos (3% each)
  - Goal: Large, cool digital creation.
- Exams:
  - Midterm (18%) – June 26th, 6pm-8pm
    - Email me ASAP if you have conflicts.
  - Final exam (40%)
    - Must get 40% to pass the course.

Finally, two common questions

What is the point of this course?

Why are you making me take this?

"Why are you making me take this?"

- CSC258 isn't needed if you're just a causal technology user.
  - You can still drive a car, even if you don't understand how the engine works.

"Why are you making me take this?"

- Computer science majors aren't casual technology users.
  - At the very least, you'll need to know how the programs you write are affected by hardware.
  - Processor knowledge is needed for OS courses.
  - Assembly language is needed for low-level tasks like compilers.

“What is the point of this course?”

- Course outcomes:
  - Understand the underlying architecture of computer systems.
  - Learn how to use this architecture to store data and create behaviour.
  - Use the principles of hardware design to create digital logic solutions to given problems.

“What is the point of this course?”

- Our course goals:
  - Make you a better computer scientist.
  - Expose you to new programming paradigms.
  - Give deeper insights into past/current courses.
  - Help prepare you for future courses.
- How we do this:
  - Show you how your computer works.
  - Start from electricity, end with assembly.

Let the learning begin

A few questions to start

- How much do you actually understand about your computer and the programs you run?
- For instance:
  1. When you set a variable to “`false`” or “`true`”, how are these boolean values stored?
  2. Why is there a maximum value for an `int`?
  3. Is it cheaper to do an addition operation or a multiplication?
  4. How do boolean operations like “`and`”, “`or`” and “`not`” work?
  5. What happens when you press `Ctrl-Alt-Delete`?
  6. What happens when you compile a Java or C program?
  7. What causes a blue screen error on your computer?

CSC258 has the answers

- Computers are physical things, therefore they have certain behaviours and limitations:
  - Data values are finite.
  - All data is stored as ones and zeroes at some level.
  - Many high-level operations depend on low-level ones.

- The way computers are today take their origins from how computers were created in the past.

Example #1: Booleans

- How are boolean values stored?
- <u>Example:</u> `if` statements:

```
if x:
   print 'Hello World'
   # what values can x have
   # that make this happen?
```

  - What if x is a boolean?
  - What if x is an int?
  - What if x is a string?

All comes down to hardware in the end!

Example #2: Integers

- How are `int` values stored?
  - Again, as ones and zeroes.

Binary

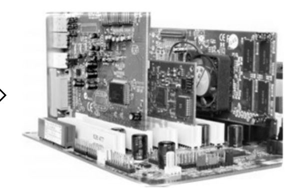
Decimal

```
1234 → 0011000000111001
```

- How many values can integers have?
  - This can vary based on language and architecture, but generally integers have 2^{32} different values.
  - <u>Signed integers</u>: range from -2^{31} to $2^{31}-1$
  - <u>Unsigned integers</u>: range from 0 to $2^{32}-1$
  - Different ranges for `long`, `short` and `byte`.

What does all this involve?

- Computers do on the hardware level what programs do on the software level.



- In CSC258, designing circuits follows many of the same ideas behind creating boolean logic in Python or Java.

Programming parallels

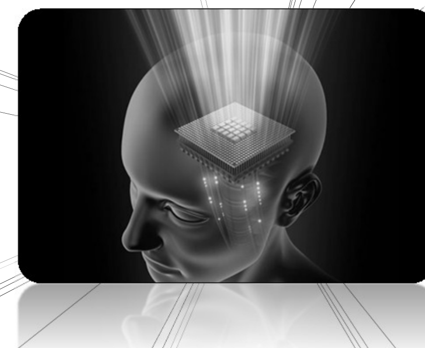
Python/Java

- Boolean variables
- Boolean operations (and, or, not, etc)
- Integers, doubles, chars
- Addition, subtraction, multiplication
- Storing values
- Executing instructions

Computer hardware

- High and low wire values
- Logic gates (AND, OR, NOT, etc)
- Registers
- Adder circuits, multiplier circuits
- Memory
- Processors

Things you already know



Programming from CSC148

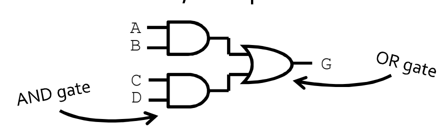
- You need to have basic coding literacy.
- *However…*
  - For CSC258, be prepared to let that all go.
    - Verilog → specification language
    - Assembly → low-level programming
  - Trying to connect these languages to CSC148 will only hold you back.
    - Embrace new ways of thinking.

Logic from CSC165

- Thanks to CSC165, you're already familiar with the first piece of CSC258: basics of logic gates.
- CSC165 example: Create an expression that is true if the variables `A` and `B` are true, or `C` and `D` are true.

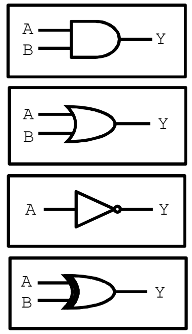
```
G = A & B | C & D
```

- CSC258 example: Create a circuit that turns on if inputs `A` and `B` are on, or inputs `C` and `D` are on:

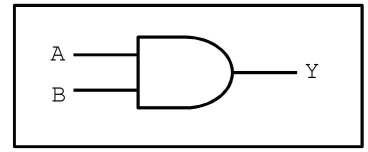


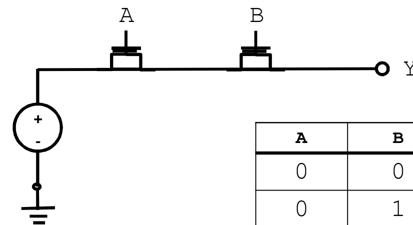
From CSC165 to logic gates

- We start with CSC165 basics to create simple circuits based on logical expressions, and expand from there to create bigger and more complicated systems.
- Each of these fundamental logical expressions is represented by a piece of hardware called a gate, that turns an output signal on based on which input signals are on.



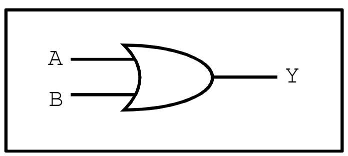
AND Gates

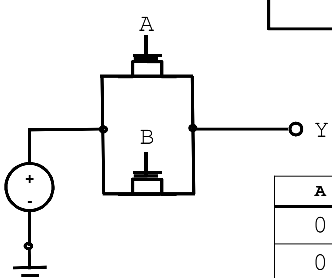




A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

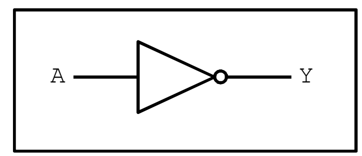
OR Gates

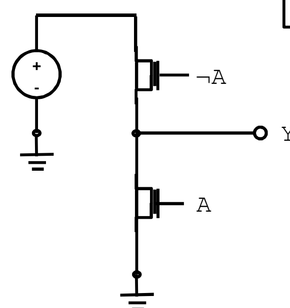




A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

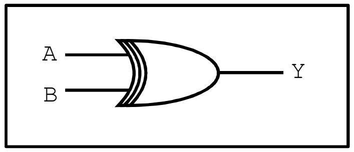
NOT Gates

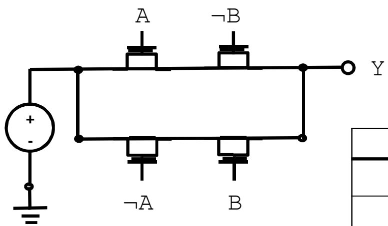




A	Y
0	1
1	0

XOR Gates



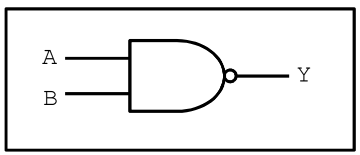


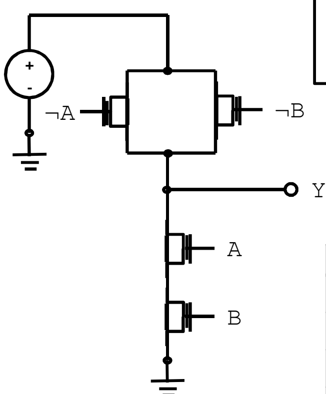
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Bill Gates

- ...ha ha...moving on....

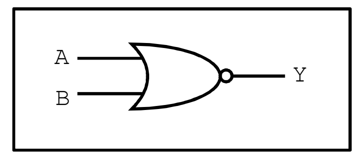
NAND Gates

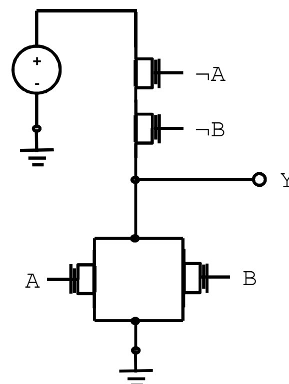




A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

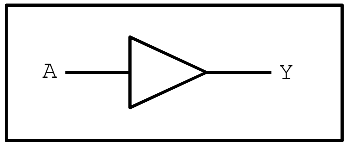
NOR Gates

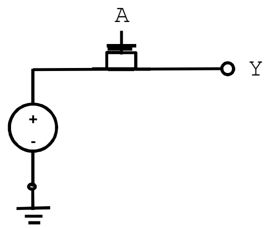




A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Buffer

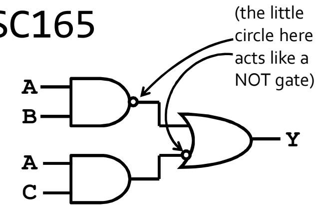


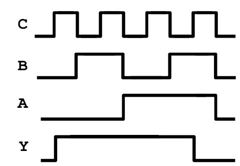


A	Y
0	0
1	1

From gates to CSC165

- Given a logic problem or circuit, can you make a truth table to describe its behavior (as in CSC165)?
  - Sometimes illustrated using a waveform.



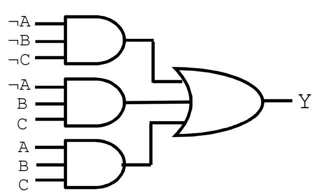


A	B	C	Y
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

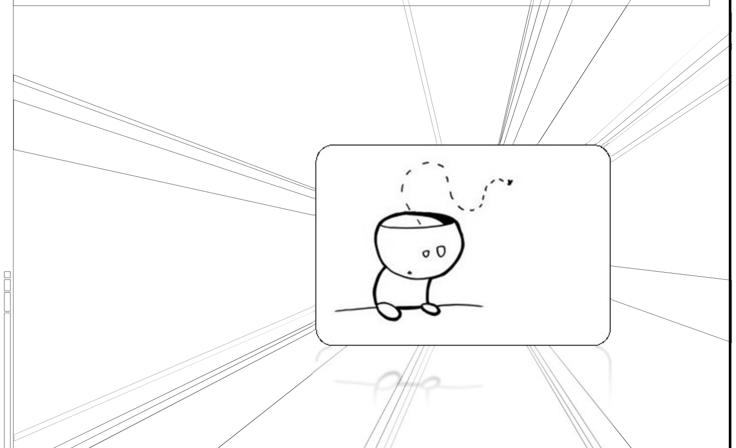
From expressions to circuits

- Creating and expressing circuit logic is similar to working with boolean logic in Python, C or Java:

```
Y = (!A and !B and !C) or (!A and
    B and C) or (A and B and C)
```



Things you might not know yet

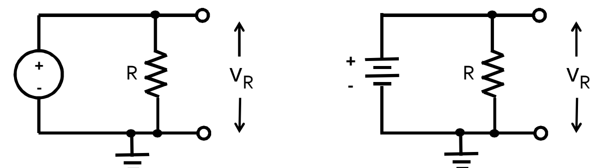


Thinking in hardware

- Although CSC258 has elements that are similar to other courses, it is very different in significant ways.
  - Unlike other software courses, CSC258 is not about creating programs and algorithms, but rather devices and machines.
    - Very important concept to grasp early in this course!
    - For instance: We need to understand what certain terms mean in the context of hardware.

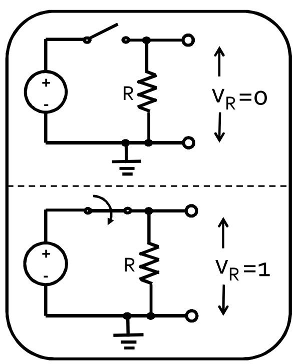
"True" and "False" in CSC258

- If a circuit performs a logical operation, how does it represent "`true`" and "`false`"?
  - In hardware, these boolean values are represented as electrical voltage values on a wire:
    - "`False`" (aka zero): little to no voltage at that point.
    - "`True`" (aka one): typically a voltage difference of 5 volts, relative to the ground.



Behind gates

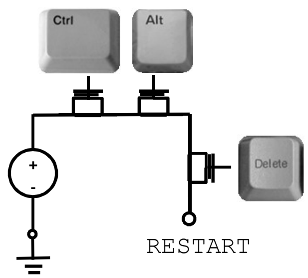
- For electricians, switches are physical devices for manually closing a circuit.
- Gates are like switches, which control whether an output wire will have a high value (`5V`) or a low value (`0V`)
  - Unlike physical switches, gates are semi-conductor devices that take electrical inputs to close the circuit.



Expressions = circuits

- CSC258 tasks assume that we have input signals can be turned on (one) or off (zero), and we need outputs that combine these signals together.
  - <u>Example #1:</u> If the Ctrl, Alt and Delete buttons are being pressed, restart the computer.
  - <u>Example #2:</u> If a train is approaching the platform, only turn on the green signal light if the track is clear and the previous train is a certain distance away.
- Every electronic device uses gates to combine input signals to create these output signals.
  - Very similar to CSC165 problems, but in hardware.

Example: Ctrl-Alt-Delete



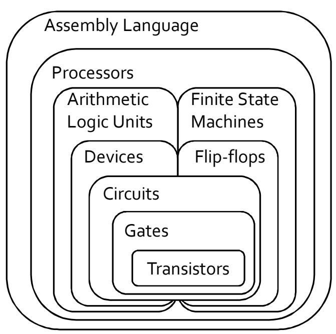
Ctrl	Alt	Del	RESTART
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

What we ask you to do (e.g. labs)

- Given a truth table or circuit description, determine the circuit that creates it.
- Look at the conditions that cause high output signals.
- Express the high conditions as a boolean statement, then convert this to gates.

A	B	C	MOVE
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

The course at a glance



Starting from the bottom

- Gates can combine values together like logical operators in C or Java.
- But how do gates work?
  - First, we need to understand electricity.
  - Then, we need to understand transistors.