CSC258: Computer Organization

Fall 2016

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*Based on slides originally created by Prof. Steve Engels

Let me introduce myself

- Frank (Franjo) Plavec
- **Education**
  - B.Sc. (with thesis) – University of Zagreb (Croatia), 2002
  - M.A.Sc., Ph.D. – University of Toronto, 2004, 2010
- **Research**
  - Soft Processors on programmable logic devices (FPGAs), Synthesis of software programs into FPGA hardware
- **Work**
  - Currently working full time at Intel
    - Programmable Solutions Group (formerly Altera)
    - Anything I say during lectures, office hours, etc. are my own opinions and have nothing to do with my work at Intel
- **Teaching** Experience
    - Electrical Measurements; Automata Theory, Formal Languages and Compiler Design, Digital & Computer Systems; Computer Hardware; Microprocessor Software; Computer Organization, Embedded Systems

CSC258 Course Details

- Understand the underlying architecture of digital and computer systems.
- Learn how to build systems for computation and data storage.
- Use the principles of hardware design to create digital logic solutions to given problems.

CSC258 Course Details

- Lectures
- Labs (28%):
  - 7 total (4% each)
  - Must complete pre-lab exercises ahead of time.
- Project (14%):
  - Large, cool digital creation.
  - Proposal and 3 demos.
- Exams:
  - Midterm (18%) - Week of Oct 17th, time TBD.
  - Final exam (40%).
    - You must get 40% on the final to pass the course!

Why take CSC258?

- To understand computers better!
  1. How does a computer store "`false`" or "`true`" in memory?
  2. Why is there a maximum value for an `int`?
  3. Where do the operators "`and`", "`or`" and "`not`" come from?
  4. What actually happens when you press `Ctrl-Alt-Delete` on your keyboard?
  5. What happens when a Java or C program is compiled?

CSC258 has the answers!

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

- The way computers are today has a lot to do with 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 integers stored?
  - As ones and zeroes.

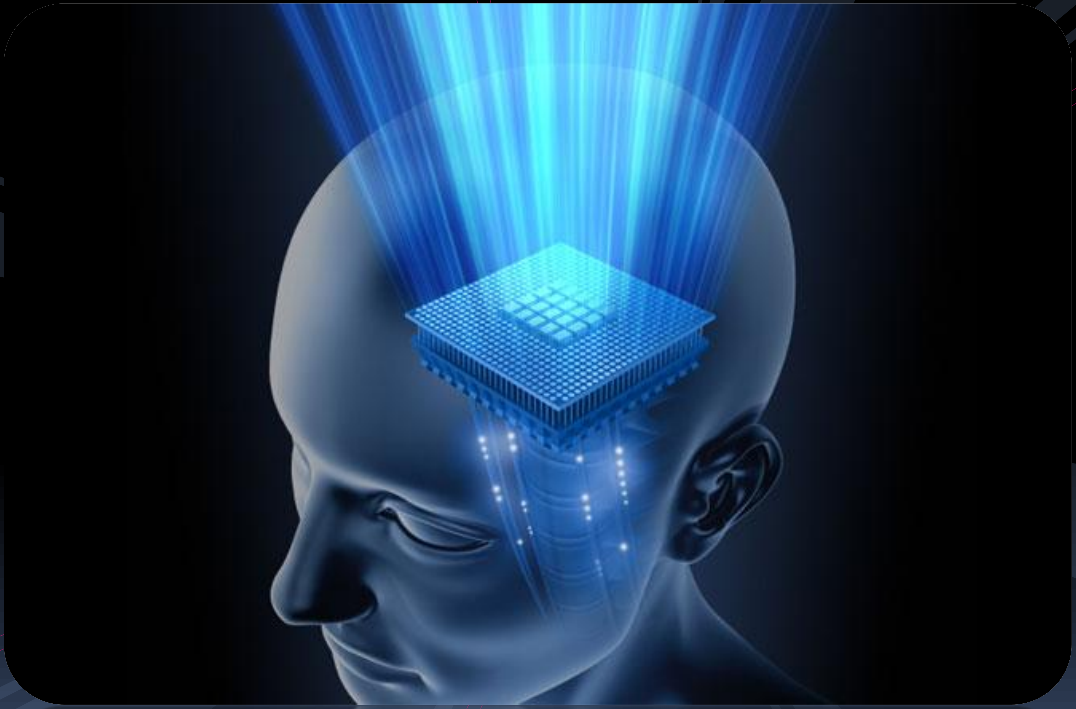
Binary

Decimal

1234 → 10011010010

- How many values can integers have?
  - This can vary based on language and architecture, but commonly integers have 2^{32} different values.

What you already know

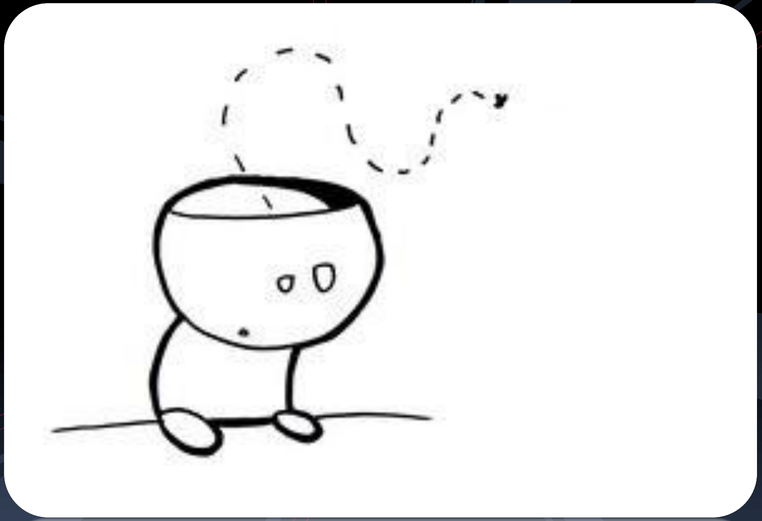


Logic from CSC165/CSC240

- What you may not realize, is that you already know how some of the basics of logic gates.
- <u>Example:</u> Create an expression that is true if the variables `A` and `B` are true, or `C` and `D` are true.

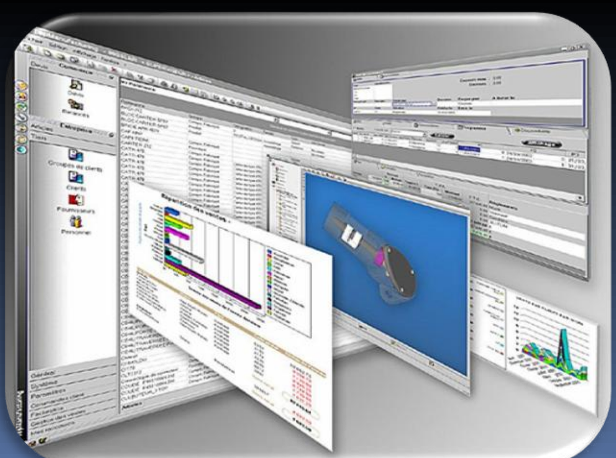
```
G = (A & B) | (C & D)
```

What you might not know yet



Programming hardware

- In CSC258, we will design
  - Custom circuits that can do same things a software program written in Python or Java.
    - But faster and more efficient
  - General purpose processor that can execute any operations that software specified.



Programming parallels

Python/Java

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

Computer hardware

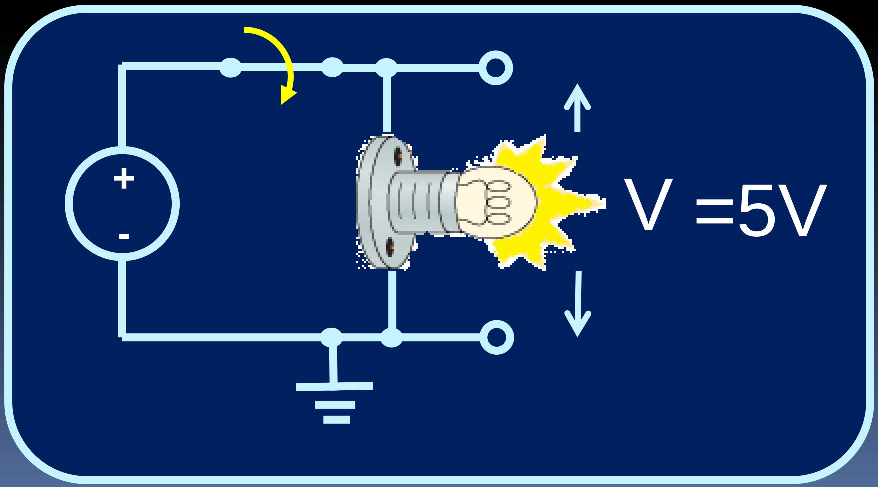
- High and low voltages
- Logic gates (AND, OR, NOT,…)
- Registers, memory
- Adder/subtractor circuits, multiplier circuits
- Processors

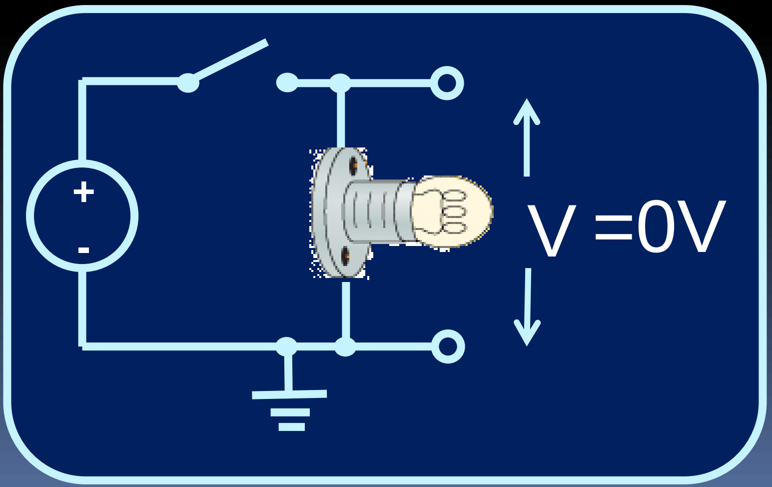
Thinking in hardware

- CSC258 is very, very different than software courses!
- Not about creating programs and algorithms, but building circuits.
  - Very important concept to grasp early in this course!
  - Need to understand what certain terms mean in the context of hardware.

What is “true” and “false”?

- Once you know the logical operation a circuit performs, all that’s left is supplying the input values.
  - How do we represent Boolean values like “true” and “false”?
- In hardware, “true” and “false” refers to the electrical voltage values on the wires.
  - True, or One: a predefined voltage difference relative to the ground.
    - In labs, we will use chips that use 5 Volts
  - False, or Zero: little to no voltage at that point: 0 Volts

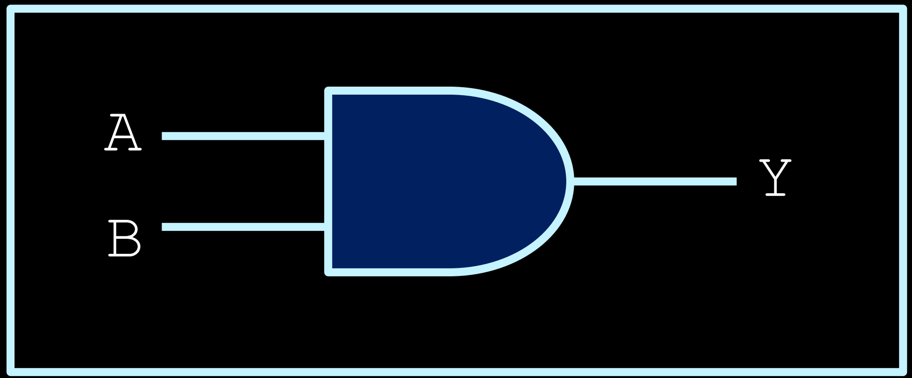


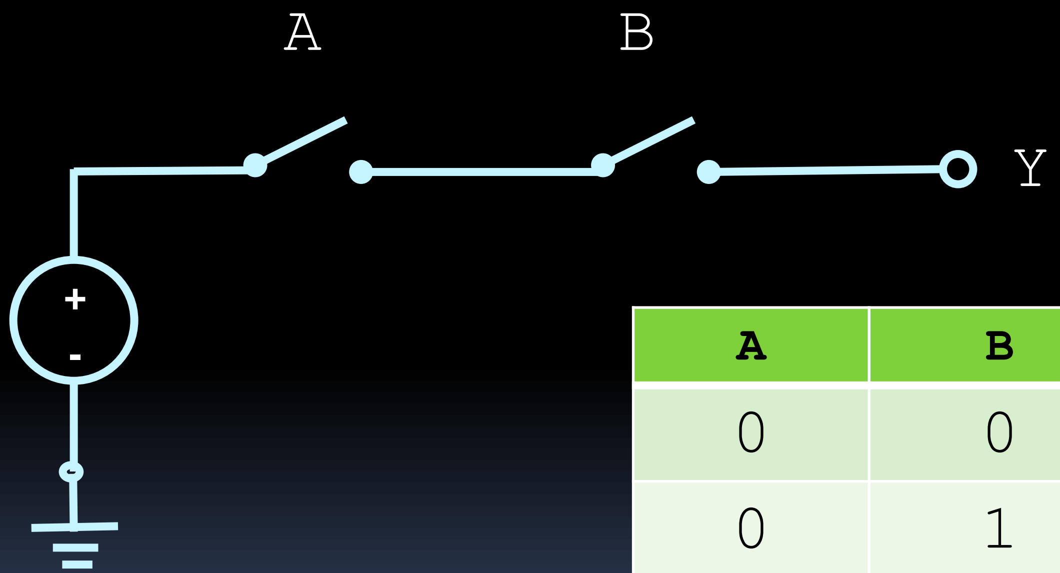


Gates and Boolean logic

- If you know how to create simple logical expressions, you already know the basics of putting logic gates together to form simple circuits.
- Just need to know which logic operations are represented by which gate!
  - AND gates, OR gates, etc.

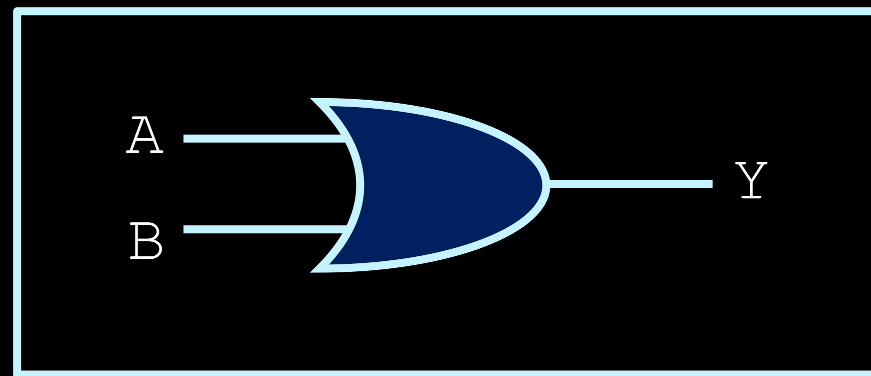
AND Gates

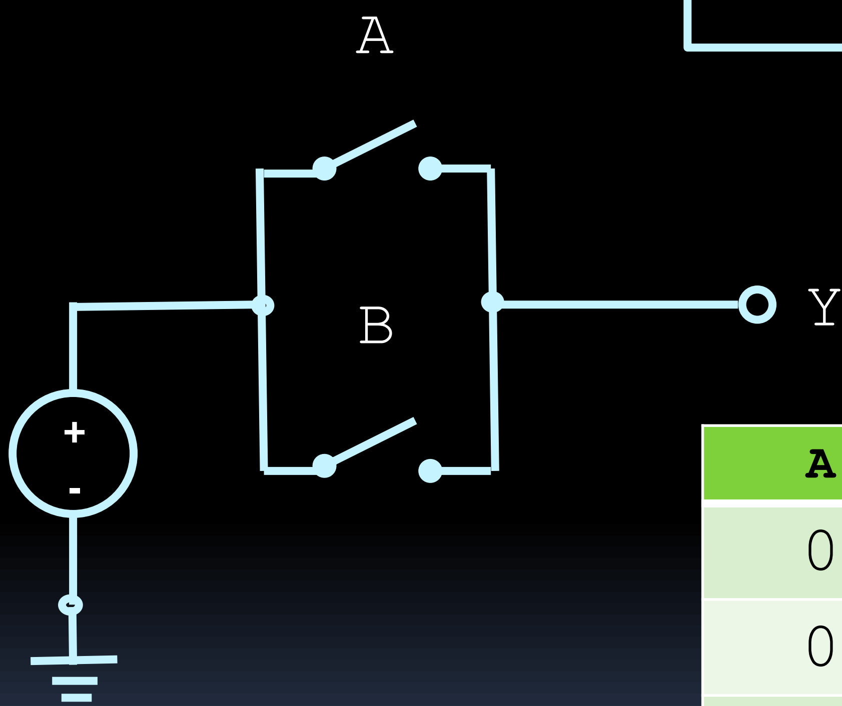




A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

OR Gates

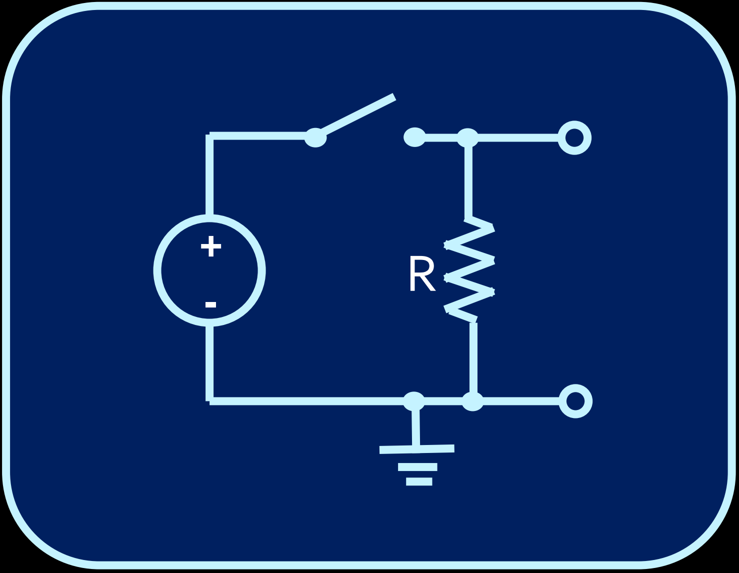


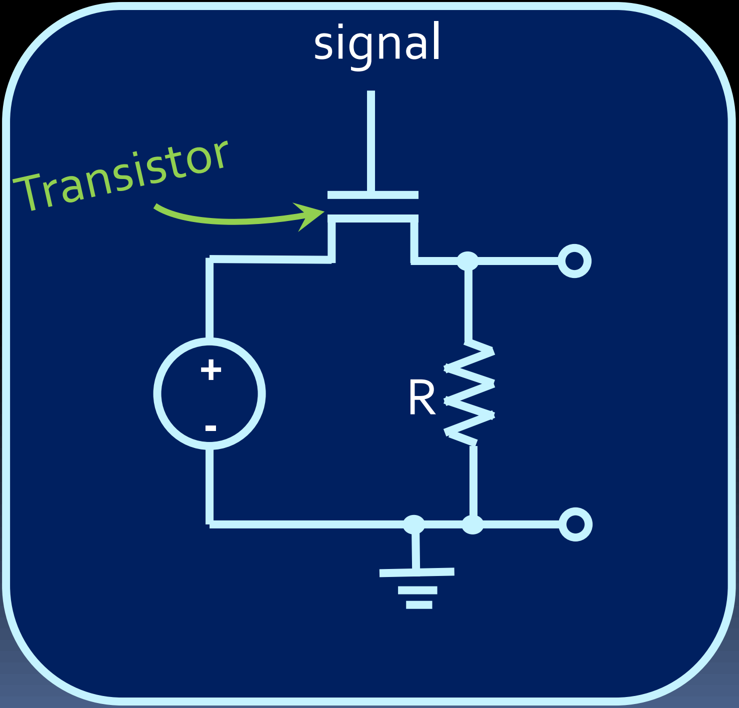


A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

What are gates?

- Gates are like switches, which control whether an output wire will have a high value (5V) or a low value (0V)
  - Switches are physical devices for manually closing a circuit.
  - Gates consist of transistors, which are semiconductor devices that close a circuit electrically.





What are circuits?

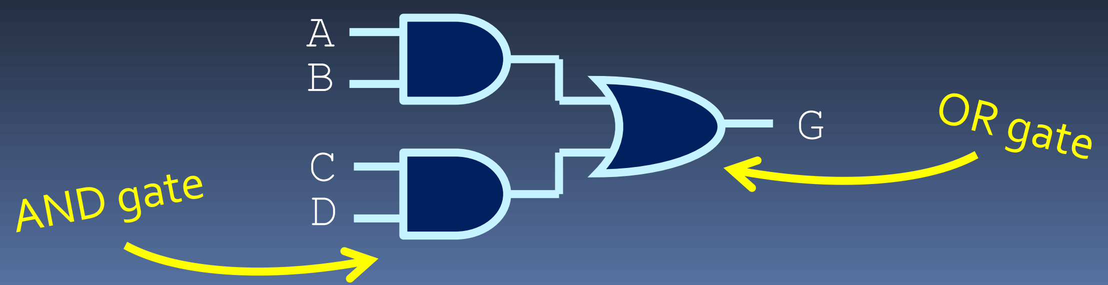
- Assuming that certain signals can be turned on (one) or off (zero), we need have ways to combine these signals together.
  - Example #1: If the Ctrl, Alt and Delete buttons are being pressed, restart the computer.
  - Example #2: If three train tracks converge onto a single track, only turn on the green light if a single track has a train waiting.
- Every digital electronic device uses gates to combine input signals to create output signals.
- Very similar to CSC165/CSC240 problems, but in hardware.

Back to CSC165/CSC240 example

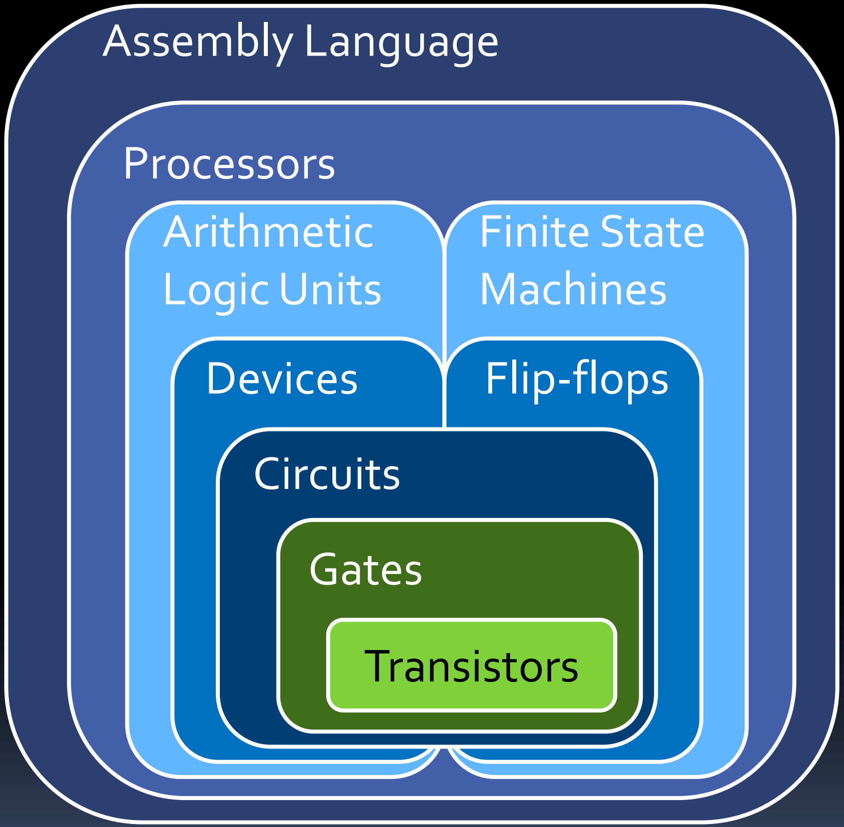
- Example: Create an expression that is true if the variables `A` and `B` are true, or `C` and `D` are true.

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

- Now create a circuit that does the same thing:



The course at a glance



How to Succeed In This Course

- Lectures
- Labs
- Final project
- Discussion board
- Office hours
- Study Groups

Lectures

- “*the lecture is a process whereby the notes of the lecturer are transmitted to the notes of the student, without passing through the minds of either.*” (Taylor, J.C. 1998)

- I don’t want it to be that way!

Questions!

- IMPORTANT:
  - Ask questions when you don't understand something
  - If you have no clue what I'm talking about, stop me immediately
    - I might have assumed you know something that you have no previous knowledge about!
  - I may not always have all the answers, but I'll do my best to find out or direct you to additional resources.

Improving Lectures

- Lecture slides will be uploaded to the web-site before the lectures
  - However, they will be incomplete
  - E.g.: Your favourite course this semester will be:

    ____

- Taking notes is important for learning
- Hand-written notes are better than notes on your laptop/tablet(*)
  - If you prefer to use laptop, turn WiFi off to minimize distractions

(*)Muller, P. A., and Oppenheimer, D. M., (2014). The pen is mightier than the keyboard: Advantages of longhand over laptop note taking. *Psychological Science, 25* (6), 1159-1168.

Course Evaluation

- Formal: at the end of the semester
- Informal: October 3, at the end of the class
  - Gives you a chance to influence the way the course is taught and the labs are conducted
  - Benefits YOU!

Labs

- A picture is worth a thousand words
- A lab is worth a thousand pictures
- Labs done in pairs
  - Find a lab partner from the same room
  - If you want to partner with somebody from a different room, it is your responsibility to find someone to swap with
- Prelab work is important
  - If you do not prepare you will not have enough time in the lab to finish work and learn
  - One prelab per group, but each person graded separately
    - TAs will ask questions to verify your understanding!

Labs

- Labs constitute significant portion of your marks
- There will be questions on the midterm/final covering what you learn in the lab!
- Time Management is Important
  - Read the lab beforehand (part of prelab)
  - Estimate the time each part will take you
  - If you find yourself spending too much time on one part, you may be doing something wrong
    - Use TAs help
    - TAs are there to help you solve the problems, NOT to solve them for you or debug your code

Final project

- Opportunity to show your creativity
- Must have significant component related to the material covered in this course
- Equivalent to 3 weeks worth of labs
- Labs done in groups, but graded separately

Discussion board

- Use the Discussion Board (Piazza)
  - More students might benefit from the answer.
  - Please DO NOT post solutions to labs.
  - Watch for pinned posts.
- Pay attention to Piazzas privacy policy
  - You may want to use anonymous email address to register with Piazza

Office Hours

- Tentatively scheduled for Mondays, 9-11am in BA3219
  - Does this time work for most students?

Midterm

- Week of October 17
- Midterm: 2 hours
- No lab during midterm week
- Ideally, midterm would be held in one of the lab slots
  - Wednesday, October 19
    - 6PM – 8PM, or 7PM – 9PM
  - Thursday, October 20
    - 6PM – 8PM, or 7PM – 9PM

#cometogether … and study

Recognized Study Groups

- Guarantee regular study time
- Gain motivation and understanding
- Meet your peers
- Get quick access resources and supports
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Learning

- Different people learn differently
  - Through experimentation
  - Through introspection
  - Through discussion
  - Big picture first, then details, or vice versa
- There is actually a body of research on how people learn
- This will NOT be on the test. ☺

Learning Styles

- Sequential and Global Learners
  - Sequential: Gain understanding step-by-step
  - Global: Learn in jumps; don't get much at first, then "get it"
- Active and Reflective Learners
  - Active: prefer to do something active (e.g. discuss)
  - Reflective: prefer to think about it quietly first
- Sensing and Intuitive Learners
  - Sensors like routine and practical things
  - Intuitors like insights and possibilities
- Visual and Verbal Learners
  - Visual: picture is worth a thousand words
  - Verbal: prefer written and spoken explanations

Improve Your Learning

- Most people are not 100% one or the other, but many have a preferred way of learning
- Recommended to fill the questionnaire at http://www.engr.ncsu.edu/learningstyles/ilsweb.html
- Then check how you can improve your learning: http://www4.ncsu.edu/unity/lockers/users/f/felder/public/ILSdir/styles.htm
- More information can be found at http://www4.ncsu.edu/unity/lockers/users/f/felder/public/ILSpage.html

Academic Integrity

- Using someone else's ideas without credit, pretending someone else's work is your own, or copying without citing are all examples of plagiarism
- When working in pairs in the lab, both students required to understand and contribute equally
  - Particularly important for the final project!
- Maintaining integrity makes things easier for everyone.
  - Hard work is rewarded, and the value of your university degree is protected.
- When in doubt, ask, or consult http://www.artsci.utoronto.ca/osai/students/students

Accessibility

- The University of Toronto is committed to accessibility. If you require accommodations or have any accessibility concerns, please visit http://www.accessibility.utoronto.ca as soon as possible.

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