Administrivia

- Labs and lecture schedule changed - check updated EECS 40 syllabus online.
- This lecture is self-contained
- Homework (and solutions) from Spring 2003 is up
- Midterm stuff

Last Time...

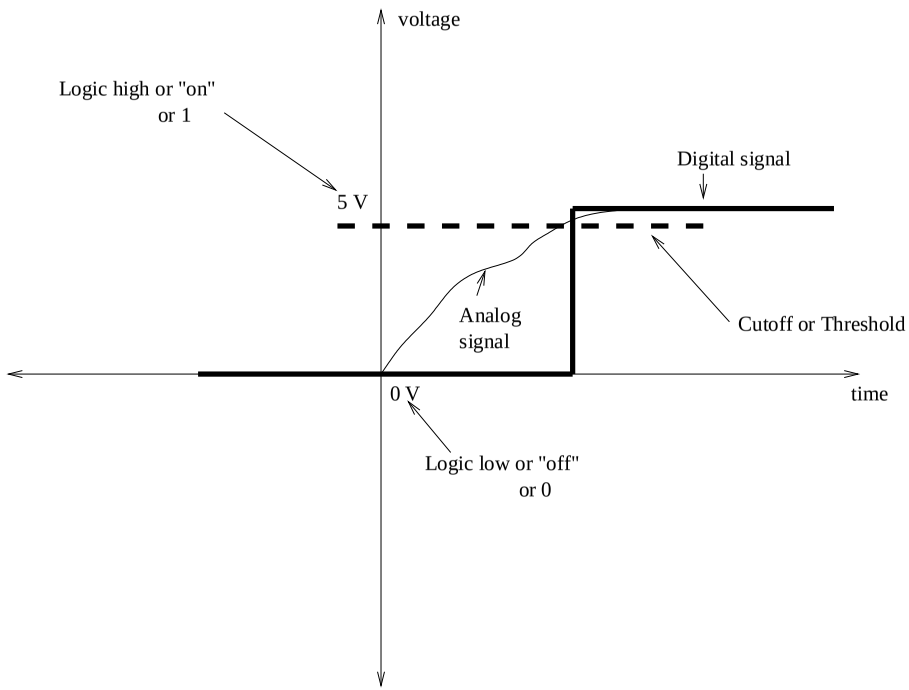
- Umm...just the midterm!

This Time...

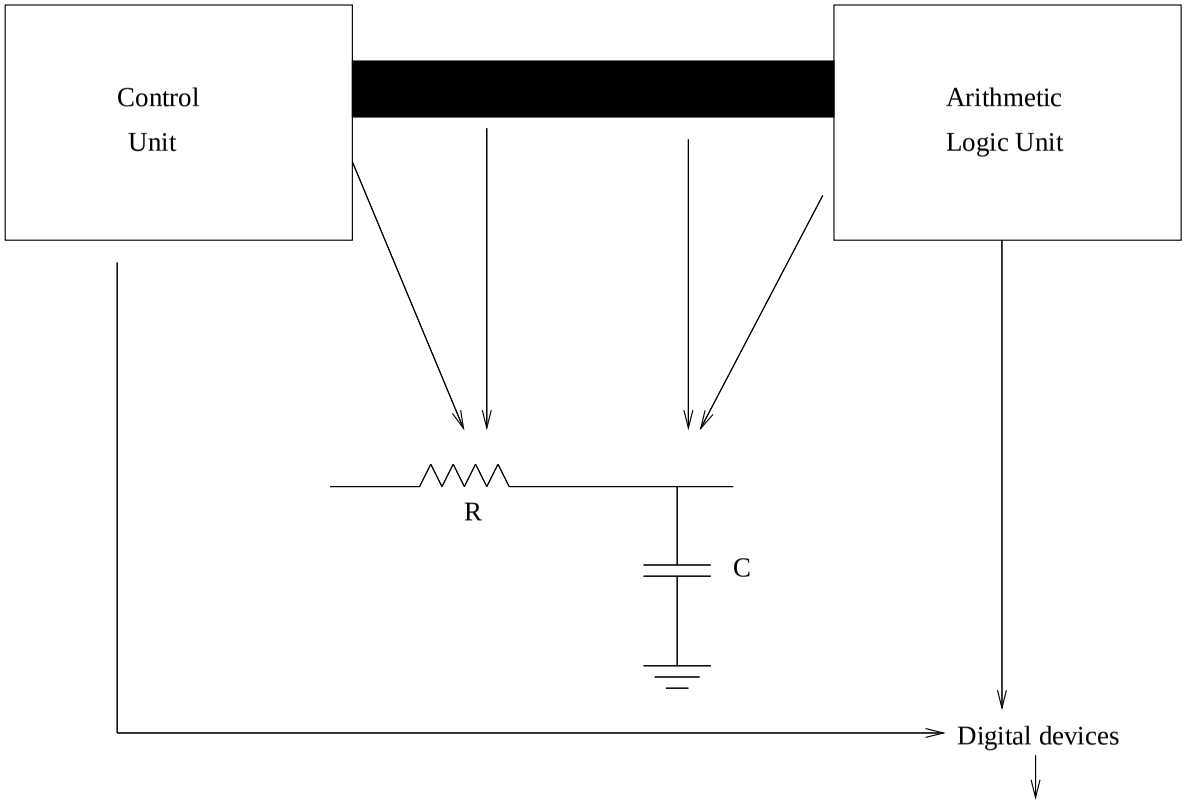
- Digital logic!
  - What is digital logic?
  - Why study digital logic?
  - Counting
  - Boolean algebra and truth tables
  - Logic gates
- Propogation Delay
  - Definition
  - An example
  - Timing Diagrams
  - Logic gates + RC circuits

What is digital logic?

- It is an abstraction - a model that considers only the most important values in an electric circuit:



Wy bother with digital logic?



Need to understand them from an EE point of view so we can connect these devices to RC circuits

Counting in binary

- Another way to understand binary numbers (and hence digital logic): try to relate binary numbers to base 10:

Base 10	Base - 2	Base - 5
0	0	0
1	1	1
2	10	2
3	11	3
4	100	4
5	101	10
6	110	11
...	...	...

Boolean algebra

- An algebra on the base - 2 number system in the table above.
- In other words:
  - “On” or +5 V is a 1
  - “Off” or 0 V is a 0
- Named after George Boole
- Boolean algebra is just like ordinary algebra - except works on a number system that has only two digits - 0 and 1!

Boolean algebra

- Define the following operations on any two binary numbers A & B: ',+,.,$\oplus$:

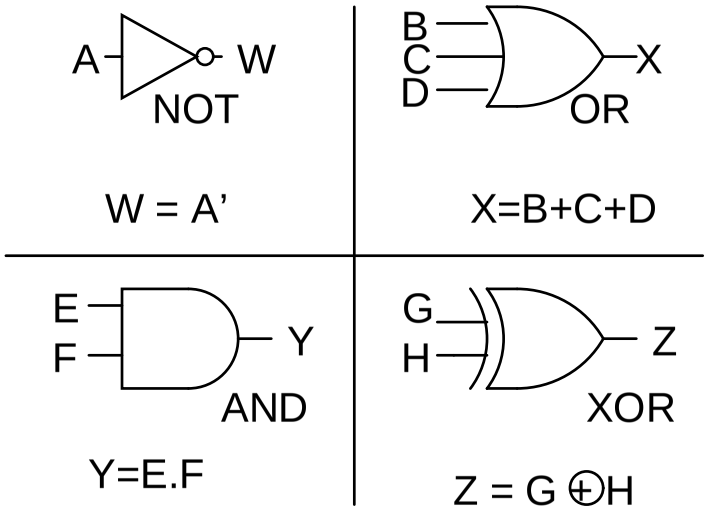
Laws of Boolean algebra

- Assuming A and B are binary numbers:

1	Common sense	A.0 = 0; A+1 = 1; 0’ = 1;1’ = 0
2	Commutativity	A+B = B+A; A.B = B.A
3	Associativity	A+(B+C) = (A+B)+C; A.(B.C) = (A.B).C
4	Distributivity	A.(B+C) = (A.B)+(A.C); A+(B.C) = (A+B).(A+C)
5	Tautology	A+A = A; A+A’=1; A.A’ = 0
6	Absorption	A+(A.B) = A; A.(A+B) = A
7	Double complement	(A’)’ = A
8	DeMorgan’s law	(A’+B’) = (A.B)’; (A’.B’) = (A+B)’

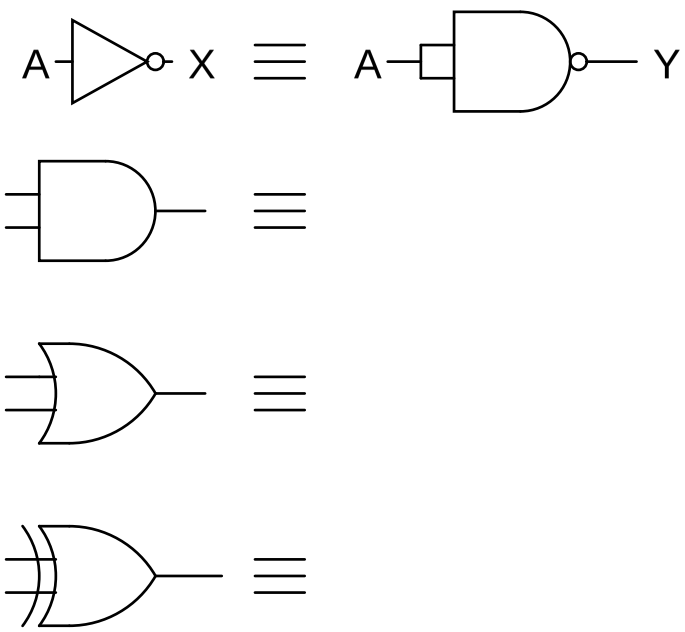
Logic gates

- Graphical representation of boolean operators - we can use this method to relate boolean algebra to EE circuits!
- Symbols:



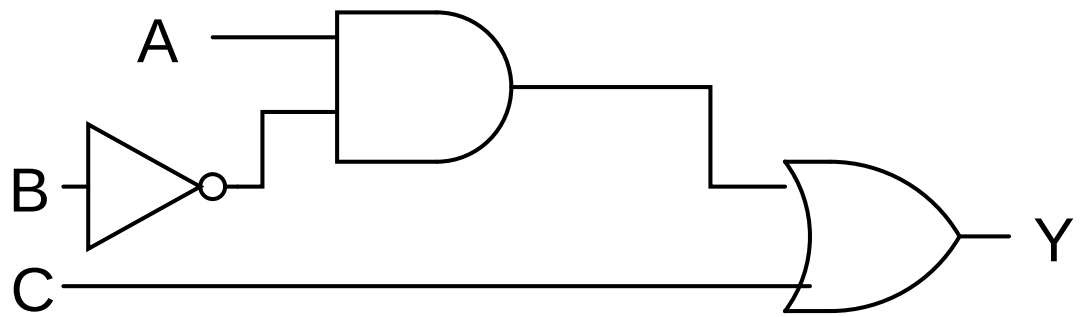
The universal NAND gate

- ANY of the four boolean operators (',+,.,$\oplus$) can be expressed using NAND gates alone:



Logic gates

- Example: In the digital circuit below,
  - Find the boolean expression at the output of the digital circuit
  - Write a boolean expression using NAND gates only.
  - Write a truth table for the output of the digital circuit

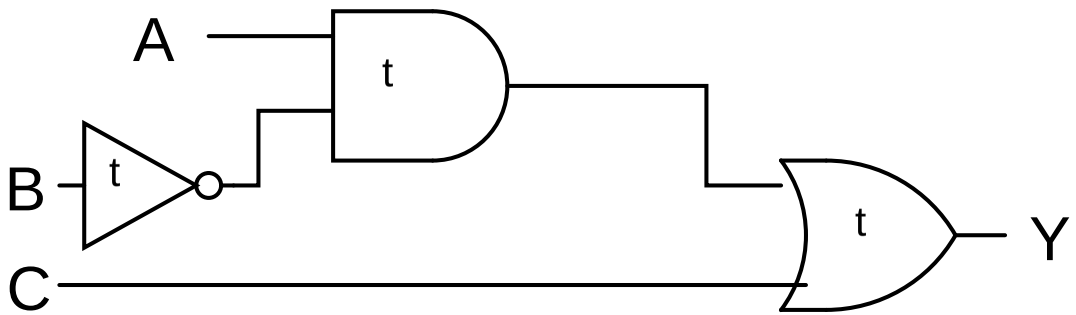


Propogation Delay

- Some definitions:
  - Unit gate delay
  - Critical Path
  - Fanout of a logic gate

Propogation Delay

- Example: What is the propogation delay in the circuit below?

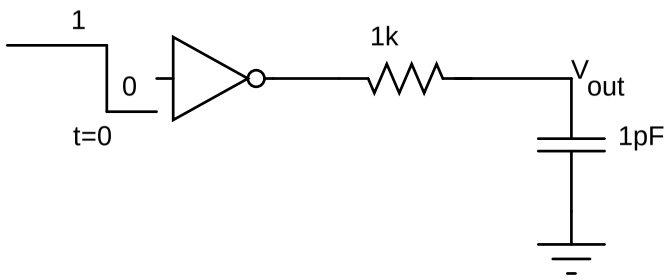


Propogation Delay

- We can also look at a **timing diagram** for the above circuit.

Logic gates + RC circuits

- In the circuit below, assuming the threshold voltage is 2.5 V, find the time it takes for V_{out} to reach the threshold voltage



In conclusion...

- Looked at digital logic concepts
- Remember the following concepts:
  - Counting in a non-decimal number system
  - Logic gates
  - Propogation delay:
    - What is it?
    - Critical path
    - Fanout
    - Timing diagrams
    - Threshold voltages
    - τ_{LH} and τ_{HL}

Next time

- Our first nonlinear element: diode!
- We will be talking about:
  - Diode terminology
  - Diode models: first approximation and second approximation
  - Load line method of solving circuits
  - Diode circuits
- Reading: Chapter 6 of your reader!
- Questions?