Max, Min, Average Circuits

ECE 320 Electronics I

Jake Glower - Lecture #9

Fuzzy Logic:

Fuzzy Logic is a branch of mathematics which deals with implementing rules for statements which are only partially true.

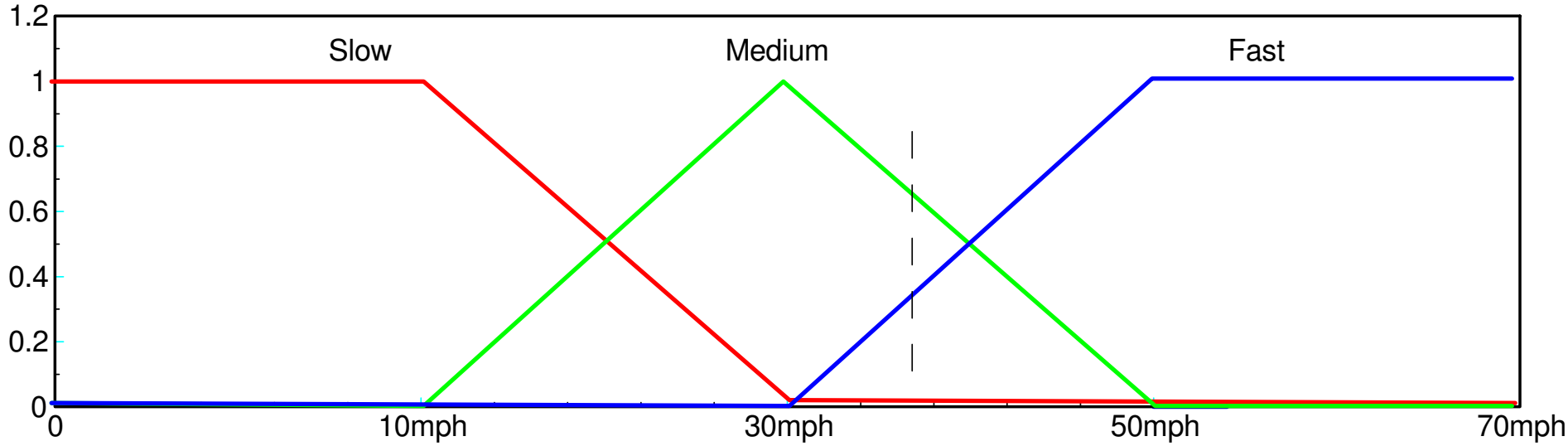
Example: The speed of a car could be defined as

- Fast if you're going 50mph
- Medium if you're going 30mph, and
- Slow if you're going 10mph.

What is 35mph?

With fuzzy logic, you can have degrees of truth. For example, with *fast, medium, slow* could be defined below, a 35mph would be

- Slow with a degree of truth being 0.00
- Medium with a degree of truth being 0.70, and
- Fast with a degree of truth being 0.30



Fuzzy Logic: Statements can be partially true

Useful when describing behavior

- If you are traveling during the day, and the roads are in good condition, and you are far from the next turn, and you are far from a city, drive fast.
- If you are approaching a turn or approaching a town, go medium.
- If you are turning or are driving by a school, drive slow
- etc.

If you could

- Come up with a rule base for an expert driver, and
- Implement this rule base

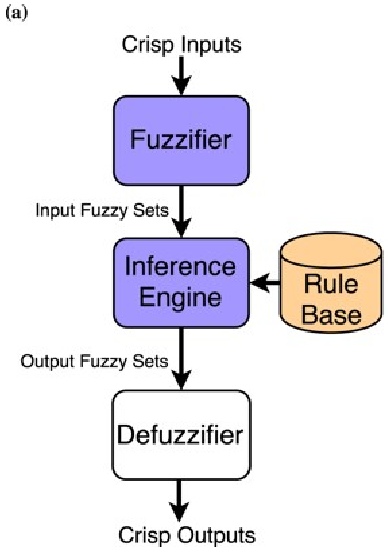
you could have every car (or subway car) driven by that expert

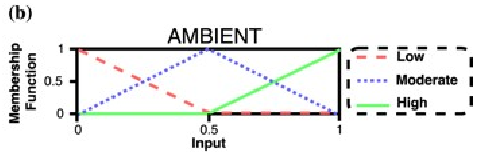
- or mathematical equivalent

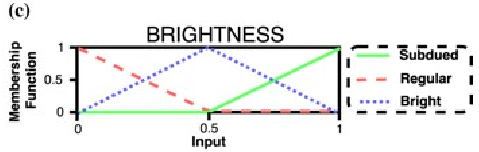
Applications of Fuzzy Logic

https://www.tutorialspoint.com/fuzzy_logic/fuzzy_logic_applications.htm

- Altitude Control of Spacecraft
- Appliances: Vacuum Cleaners, Washing Machines
- Automotive: Idle Speed Control
- Business: Personnel Evaluation
- Defense: Underwater Target Recognition
- Electronics: Exposure in Cameras, A/C, Microwave Ovens
- Optimizing Milk Production
- Securities Trading
- Ship Autopilots
- Speech and Handwriting Recognition
- Train Operation
- Water Purification Plants







(d)

BRIGHTNESS

AMBIENT	Subdued	Regular	Bright
Low	↔	↓	↓
Moderate	↑	↔	↓
High	↑	↑	↔

AND, OR, NOT

Logical AND: Logical AND has the following truth table:

A	B	A and B
0	0	0
0	1	0
1	0	0
1	1	1

A consistent definition of *and* is *min*

$$A \cdot B = \min(A, B)$$

(70% true) and (30% true) = min(70%, 30%) = 30%

Logical OR: Logical OR has the following truth table

A	B	A or B
0	0	0
0	1	1
1	0	1
1	1	1

A consistent definition of *or* is *max*

$$A + B = \max(A, B)$$

With this definition, you can now evaluate logical *and* when statements are partially true:

(70% true) or (30% true) = max(70%, 30%) = 70%

Logical NOT: NOT has the following truth table:

A	not A
0	1
1	0

A consistent definition of *not* is

$$\sim A = 1 - A$$

With this definition, you can now evaluate logical *not*:

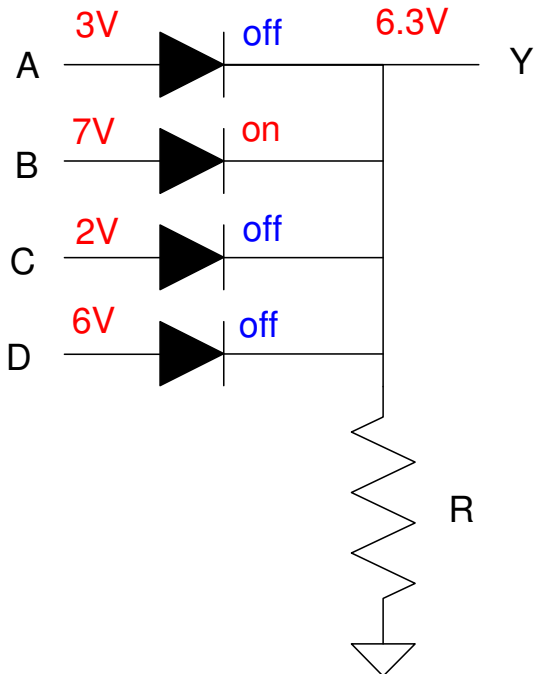
not(70% true) = 30%

Max Circuit: (Logic OR)

- Design a circuit which outputs the maximum of four voltages.
- Design a circuit which computes OR function in Fuzzy Logic

Solution: Use four diodes

- Highest votlage wins

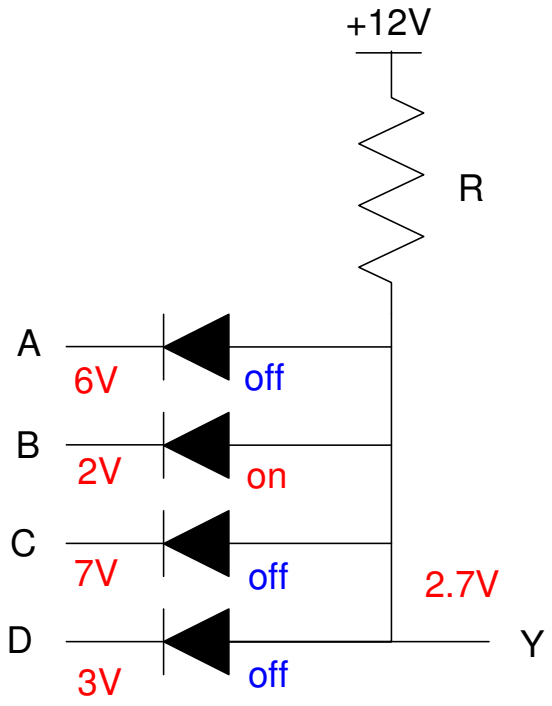


Min Circuit: (Logic AND)

- Design a circuit which outputs the minimum of four voltages.
- Design a circuit which computes the AND function in Fuzzy Logic

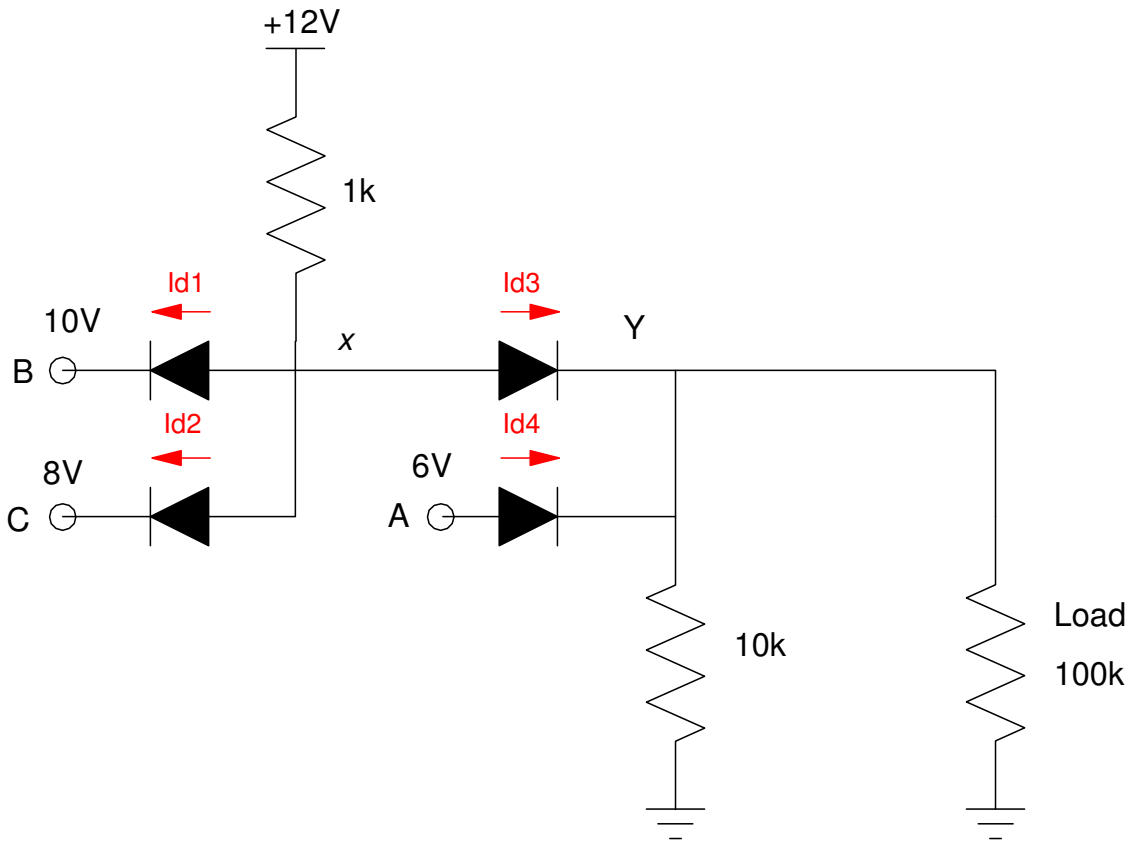
Solution: Use four diodes

- Lowest voltage wins



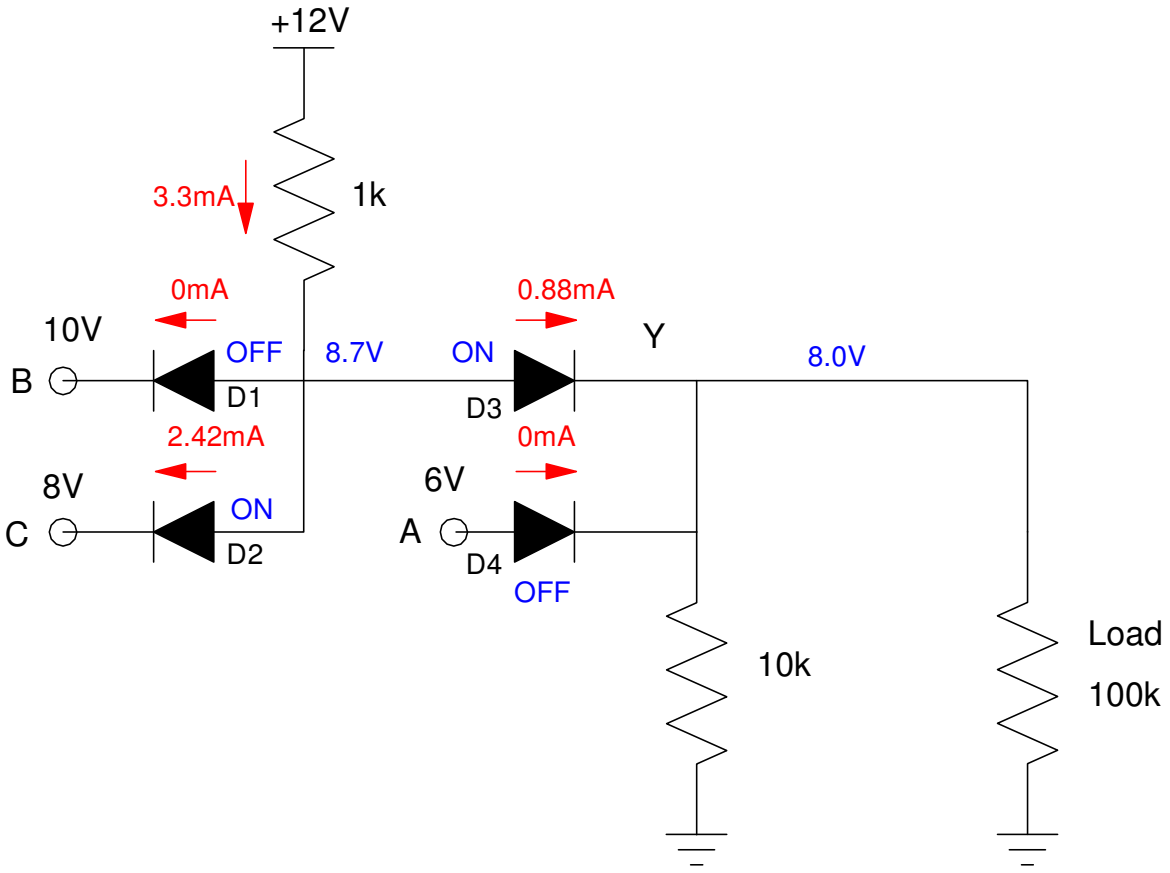
Min / Max Circuits:

- Inputs: A, B, C. 0-10V signals, capable of 10mA.
- Outputs: Y, capable of driving a 100k load (0.1mA @ 10V)
- Relationship: Y = max(A, min(B,C)) = A + BC (using Fuzzy Logic)



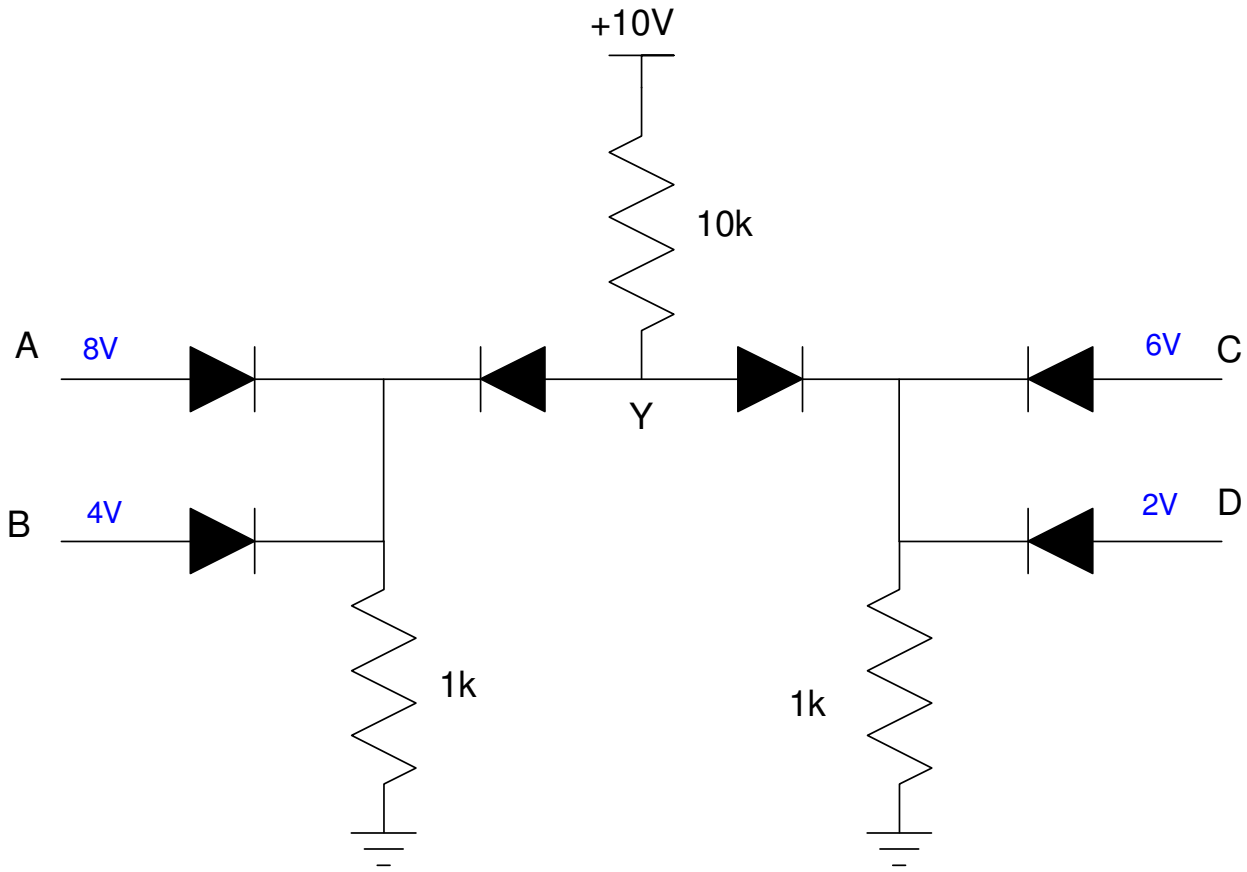
This results in Y = 8.0V (X - 0.7V drop across diode D3). The currents are then

- Id1 = 0mA (diode is off)
- Id4 = 0mA (diode is off)
- Id3 = 0.88mA
- Id2 = 2.42mA .



Handout

Determine the voltages and currents. Assume ideal silicon diodes.



Average Circuit:

Problem: Design a circuit which computes the average of four voltages.

Solution: This is a linear function

$$Y = \frac{1}{4}(A + B + C + D)$$

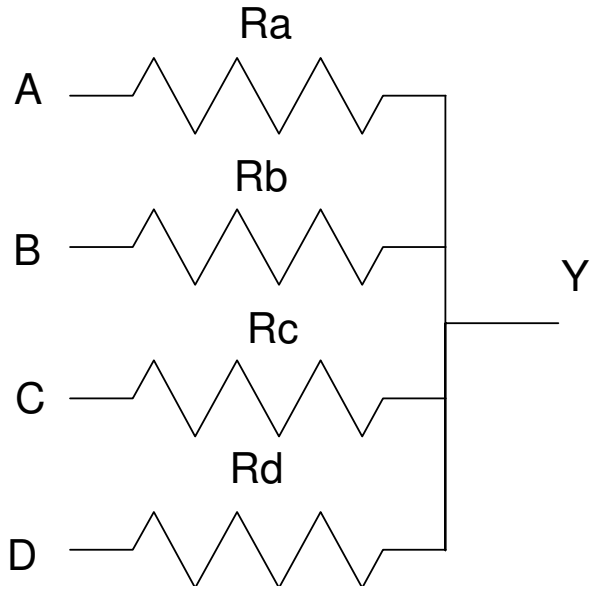
You don't need electronics (nonlinear elements)

- Solve using resistors
- Circuits I problem

Ra = Rb = Rc = Rd = R:

$$\left(\frac{Y-A}{R}\right) + \left(\frac{Y-B}{R}\right) + \left(\frac{Y-C}{R}\right) + \left(\frac{Y-D}{R}\right) = 0$$

$$Y = \frac{1}{4}(A + B + C + D)$$



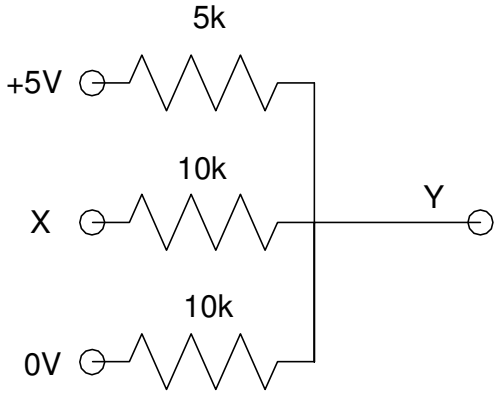
Weighted Average

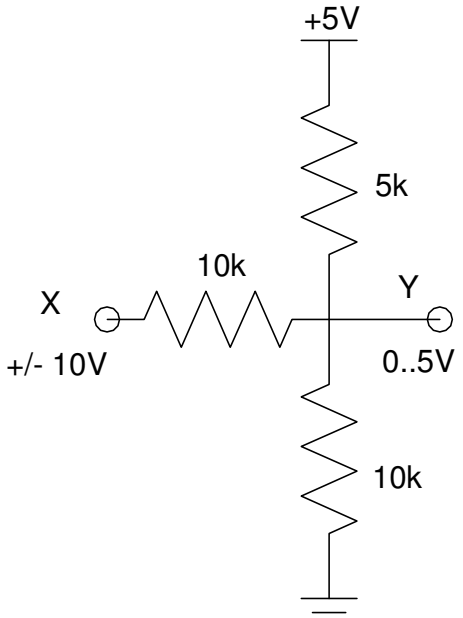
- To weight an input with X, divide R by X
- Smaler R means higher weighting

Example:

$$Y = \frac{1}{4}X + 2.5 = \left(\frac{1}{4}\right)(1 \cdot X + 2 \cdot 5V + 1 \cdot 0V)$$

Weights are {1, 2, 1}





Summary

With diodes, you can determine

- The maximum of N voltages, or
- The minimum of N voltages

With this, you can implement fuzzy logic

- But... you lose 0.7V for each AND / OR gate