COMPUTER SYSTEMS AND ORGANIZATION

Part 1

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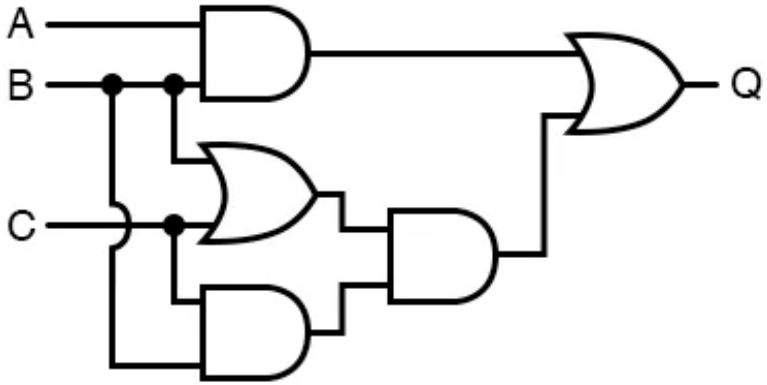
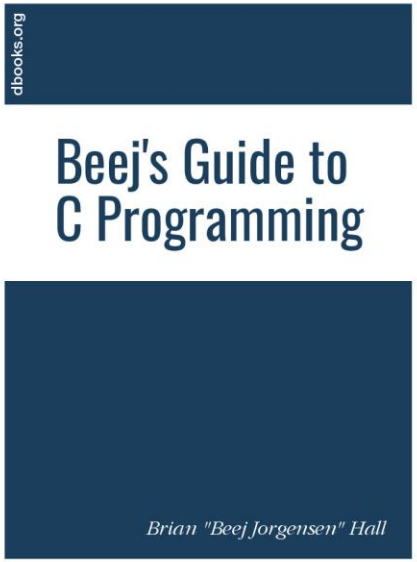
1. Transistor Fundamentals
2. Build Gates from transistors
3. Using a breadboard to build a gate
4. Combine Gates to build logic circuits
5. Express logic circuits as equations

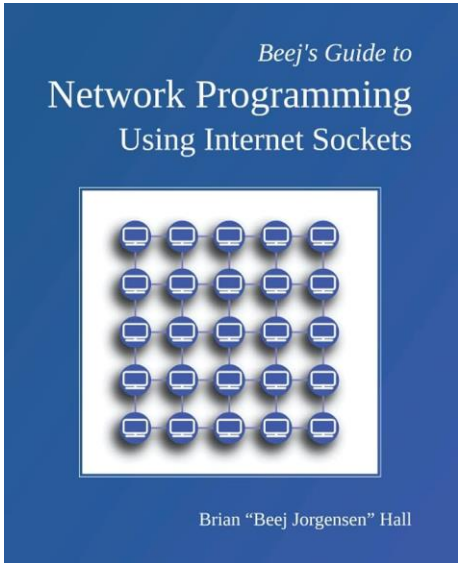
SKILLS

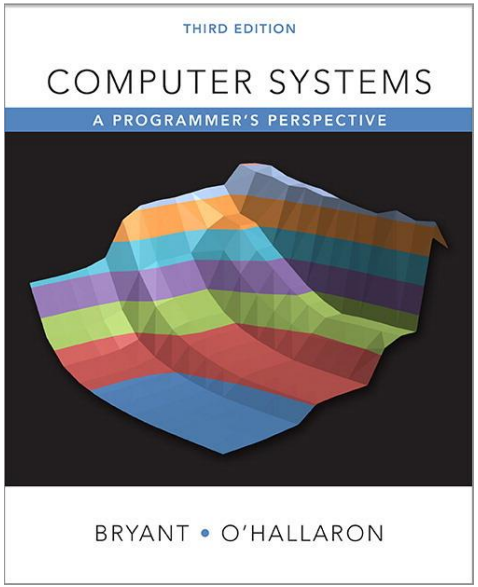
1. By the end of this lecture, you should be able to look at the circuit on the right and tell what it will output given different inputs
2. You should be able to express the circuit as a Boolean logic equation
3. Understand how to combine gates to implement a Boolean logic equation.
4. Combine transistors to implement a gate or logic circuit.

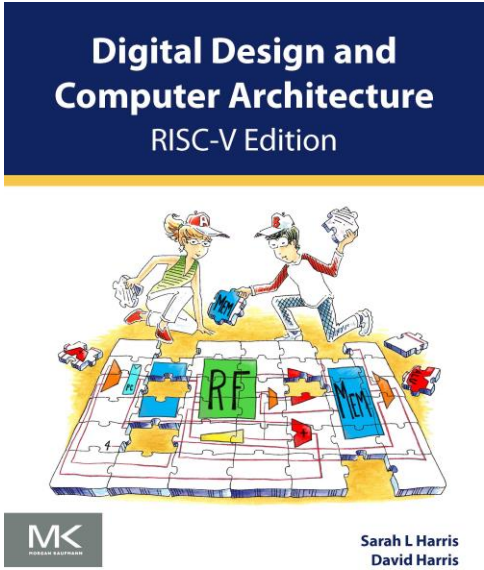


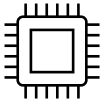
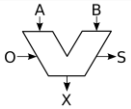
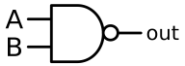
RESOURCES


dbooks.org
Beej's Guide to
C Programming
Brian "Beej Jorgensen" Hall


Beej's Guide to
Network Programming
Using Internet Sockets
Brian "Beej Jorgensen" Hall


THIRD EDITION
COMPUTER SYSTEMS
A PROGRAMMER'S PERSPECTIVE
BRYANT • O'HALLARON

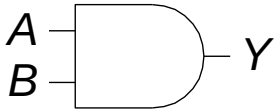

Digital Design and
Computer Architecture
RISC-V Edition
RF
MEM
Sarah L Harris
David Harris

Application Software 	C
Operating system 	Linux
Architecture 	Risc-V
Micro Architecture 	Data path, Stages
Gates 	Nand, NOR, NOT ..
Devices 	Field Effect Transistors
Physics 	Electrons

WHAT ARE LOGIC GATES

- Logic gates are circuits that perform logic functions
    - such as AND, OR, (NOT) , etc
- Logic gates have different symbols and their behavior is normally described using a truth table.

AND

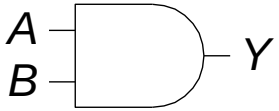


$Y = AB$

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

BUILD AN AND GATE FROM SWITCHES

AND



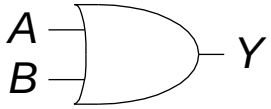
$Y = AB$

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

Draw an example

CHALLENGE BUILD AN OR GATE FROM SWITCHES

OR



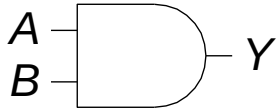
$Y = A + B$

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

Draw an example

INTRODUCING THE IDEA OF VDD AND GND

AND



$Y = AB$

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

VDD
(+5V)

GND

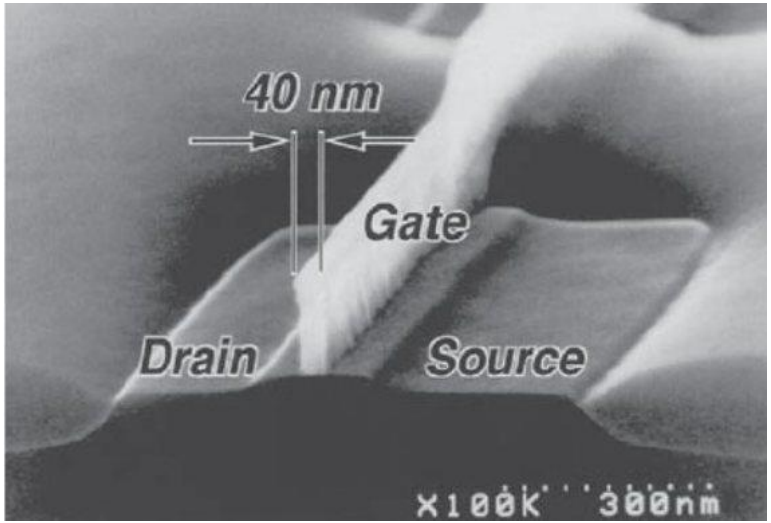
Draw an example

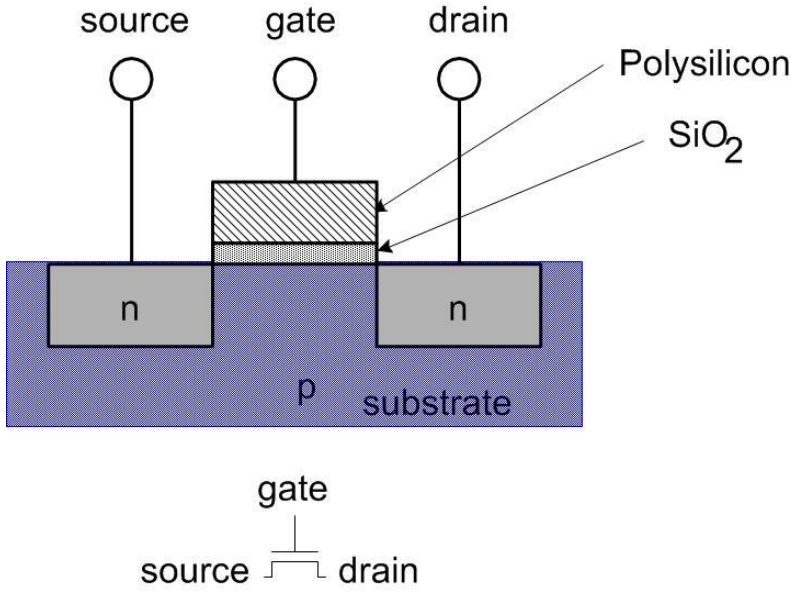
BUT WE DON'T WANT TO MANUALLY OPEN AND CLOSE SWITCHES.

OUR END GOAL IS DO MATH WITH ELECTRICITY

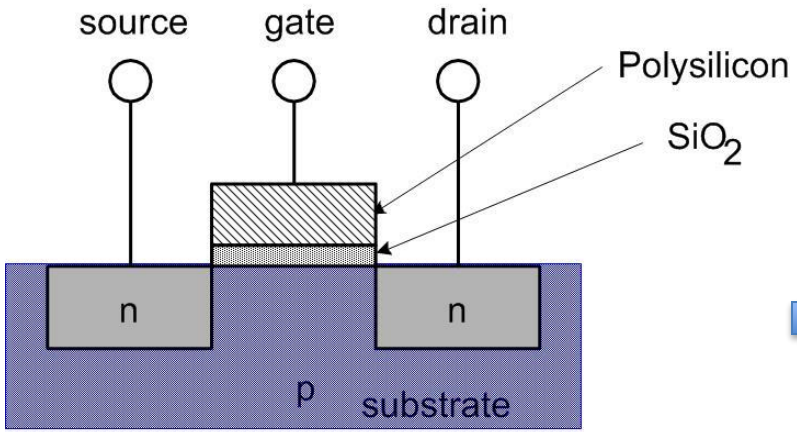
WE NEED A SWITCH THAT WE CAN OPEN AND CLOSE WITH ELECTRICITY

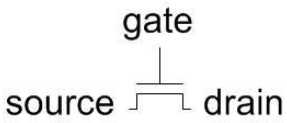
TRANSISTOR

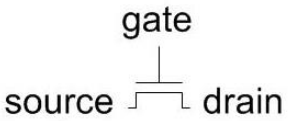

40 nm
Gate
Drain
Source
X100K 300nm


source
gate
drain
Polysilicon
SiO2
n
n
p
substrate
gate
source
drain

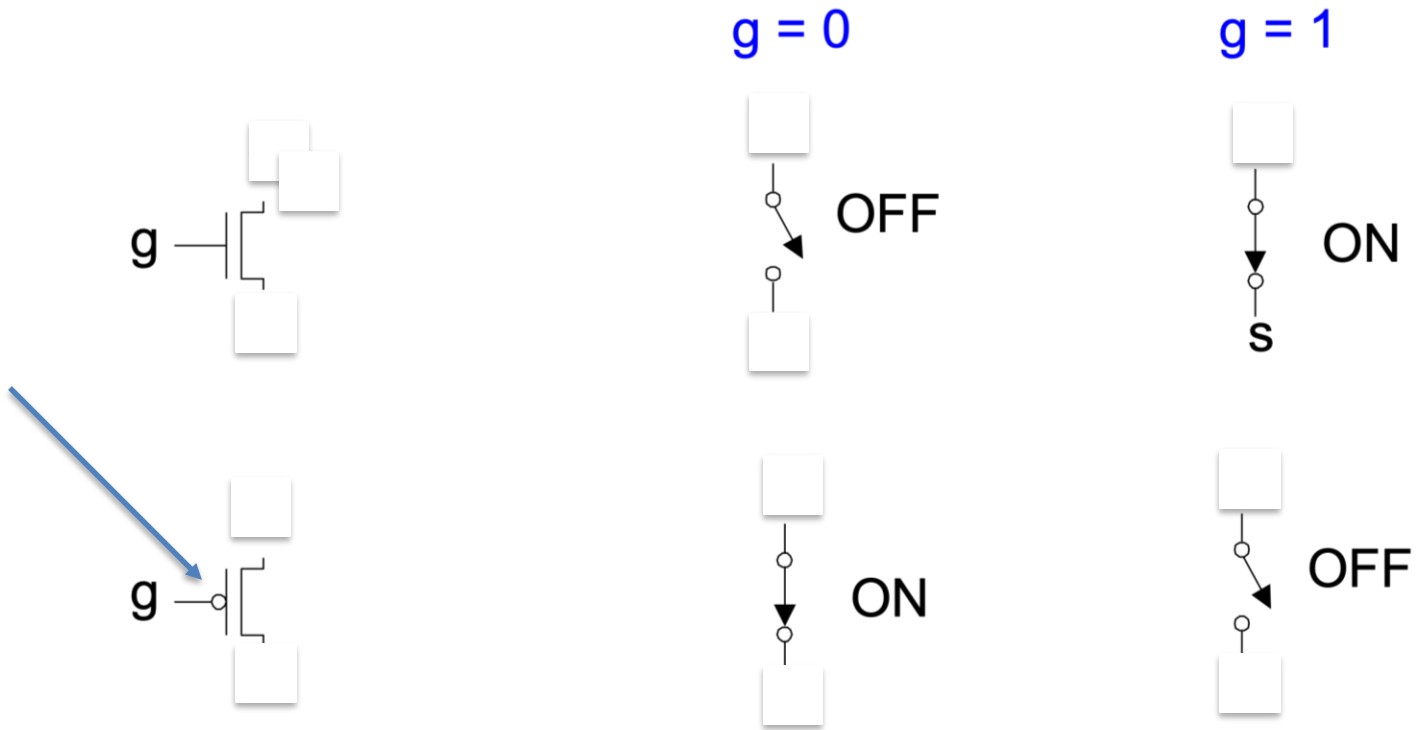
WE'LL FOCUS ON THE BEHIVOR







THINKING OF TRANSISTORS AS SWITCHES



HOW CAN WE COMBINE SWITCHES TO IMPLEMENT LOGIC

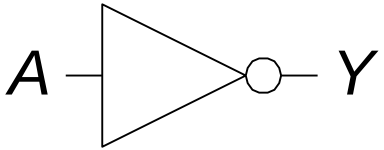
CAN WE USE TRANSISTORS TO BUILD GATES

Questions we need to answer

- What are logic gates?
- How do logic gates work?
- Are there different types of gates?

SINGLE INPUT VS TWO INPUT GATES

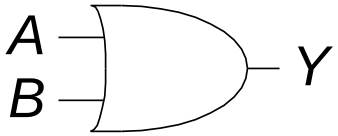
NOT



$Y = \overline{A}$

A	Y
0	1
1	0

OR

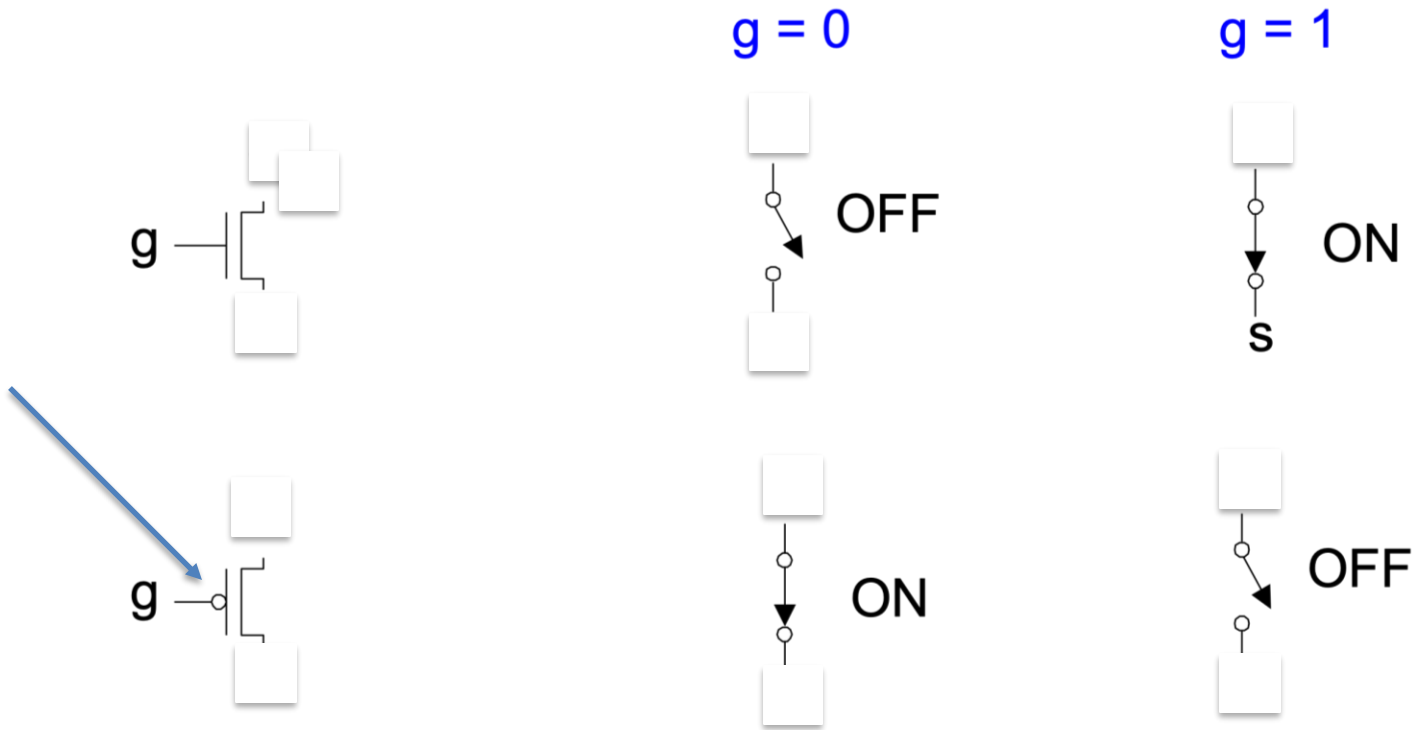


$Y = A + B$

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

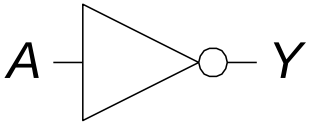
BUILD AN AND GATE FROM TRANSISTORS

THINKING OF TRANSISTORS AS SWITCHES



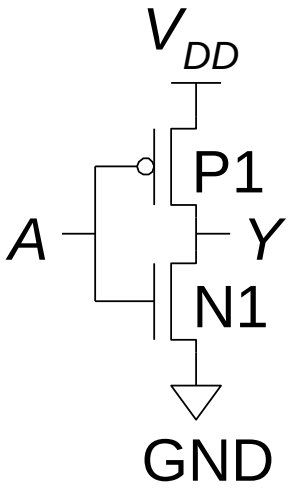
NOT GATE

NOT



$Y = \overline{A}$

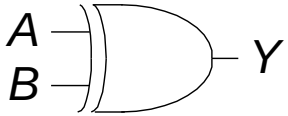
A	Y
0	1
1	0



A	P1	N1	Y
0			
1			

MORE LOGIC GATES

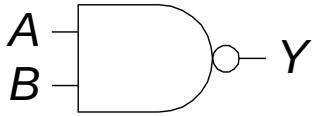
XOR



$Y = A \oplus B$

A	B	Y
0	0	
0	1	
1	0	
1	1	

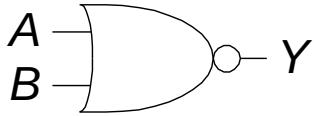
NAND



$Y = \overline{AB}$

A	B	Y
0	0	
0	1	
1	0	
1	1	

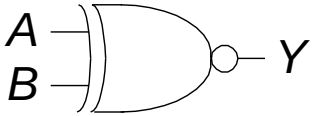
NOR



$Y = \overline{A + B}$

A	B	Y
0	0	
0	1	
1	0	
1	1	

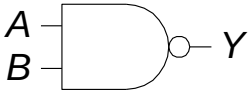
XNOR



$Y = \overline{A \oplus B}$

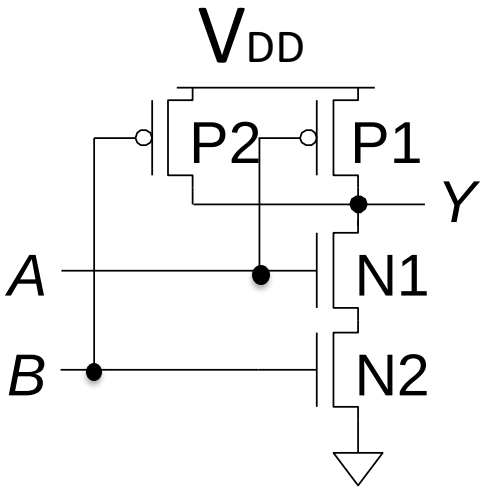
A	B	Y
0	0	
0	1	
1	0	
1	1	

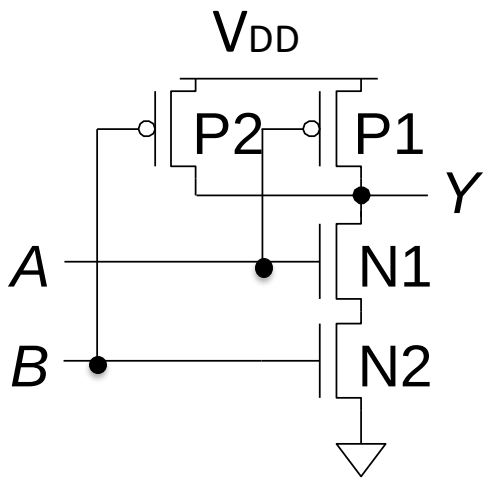
NAND



$Y = \overline{AB}$

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

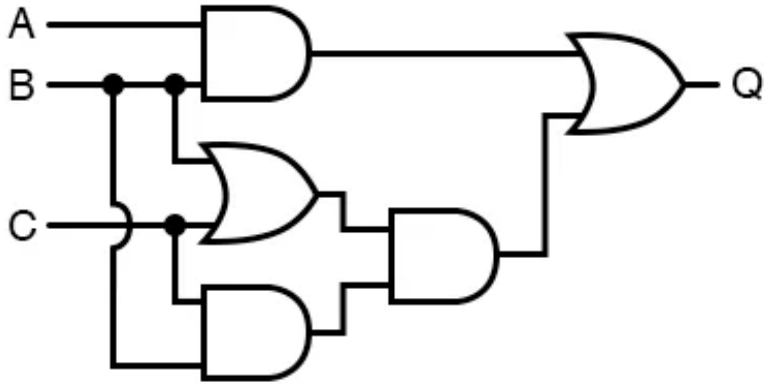




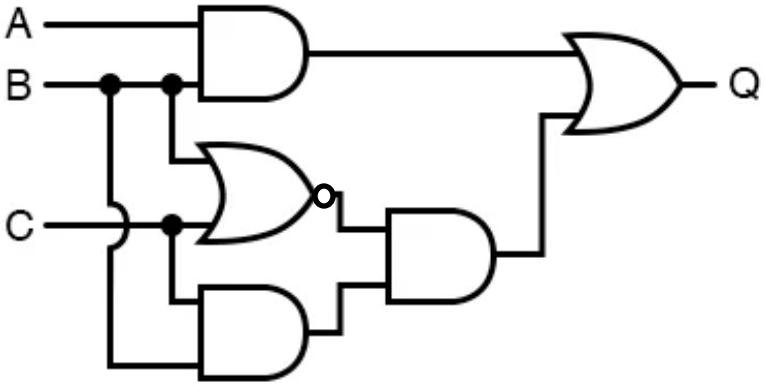
A	*B*	P1	P2	N1	N2	*Y*
0	0					
0	1					
1	0					
1	1					

A	*B*	C	Q
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

WHAT IS THE OUTPUT OF THIS CIRCUIT?

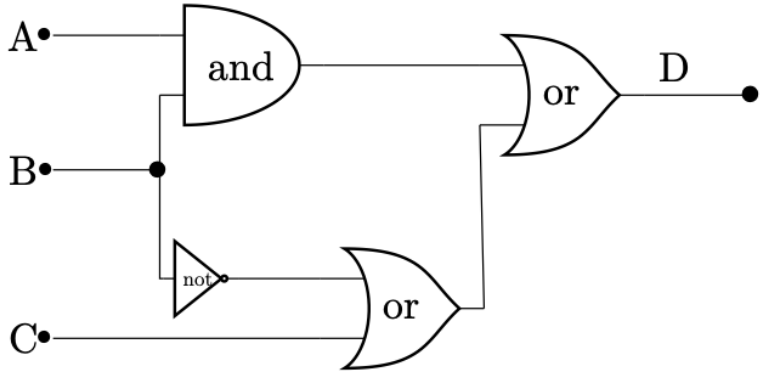


EXPRESS CIRCUIT AS AN EQUATION



Write the equation representing the circuit. Note I replaced the OR with a NOR.

EXAM QUESTION



Fill in the following truth table for this circuit:

A	B	C	D
0	0	0	
0	0	1	
0	1	0	
0	1	1	

SPRING 2022
Midterm 1

7. (2 points) Consider the following ~~push-pull~~ network. Which gate does it implement? (Hint: write out the truth table.)

Pull up pull down

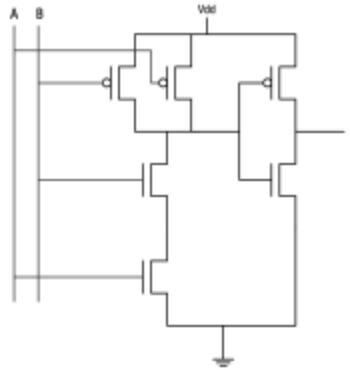


Figure 1: Push-Pull Network, output is the unlabeled wire on the right.

- ○ AND
- ○ OR
- ○ NAND
- ○ XOR
- ○ NOR
- ○ None of the above

CREATIVE QUESTIONS

NAND GATES ARE TURNING COMPLETE

It is possible to implement every other gate by using NAND. You can implement the complete CPU using only NAND gates. What a beautiful building block right ☺

Use a NAND gate to implement the following gates:

NOT

1. AND
2. OR
3. NOR
4. XOR

Hint: Start by asking NOT what a NAND gate can do for you but what you can do with a NAND gate.