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LOGIC GATES - BUILDING A SAFETY CIRCUIT

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SEE APPENDIX A, FOR LICENSING & ATTRIBUTION INFORMATION

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WHAT YOU WILL KNOW…

- Prior Knowledge
  - Explain the difference between AND, OR, NOT logic gates
  - Read and fill out a Truth Table
  - Convert a Logical Expression in to Gate Diagram
  - Convert a Logical Expression in to a Truth Table

- What You Will Know & Be Able To Do
  - Identify the components and signals that are used in a Robot work cell safety circuit
  - Prioritize signals and make sure the Emergency Stop really stops
  - Build a logic circuit that integrates signals from sensors and safety devices

NEW WORDS

- Workcell
- Tooling
- Workpeice

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ROBOT WORK CELL SAFETY

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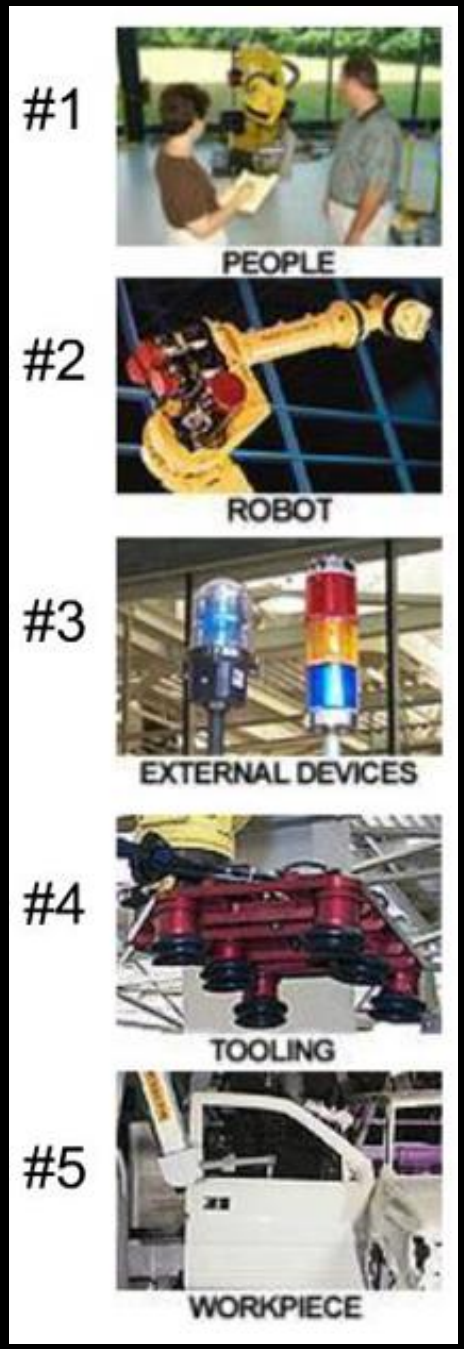
What needs to be safe?

- People are always the #1
- Prioritized Safety
  - People
  - Robot
  - Work Cell
  - Tooling
  - Workpeice



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Devices that feed a safety logic circuit

- Emergency Stop Buttons
- Deadman Switch
- Hard Stop or Limit Switch's
- Light Curtain, Pressure Pads, Cameras, etc
- Interlocks (Keys and Lockouts)
- Interlocks (gates and doors)
-

EMERGENCY'S

- This signal needs to be the **highest priority**…
- Needs to override any other signals
- Needs to be immediate

Emergency Stop Buttons

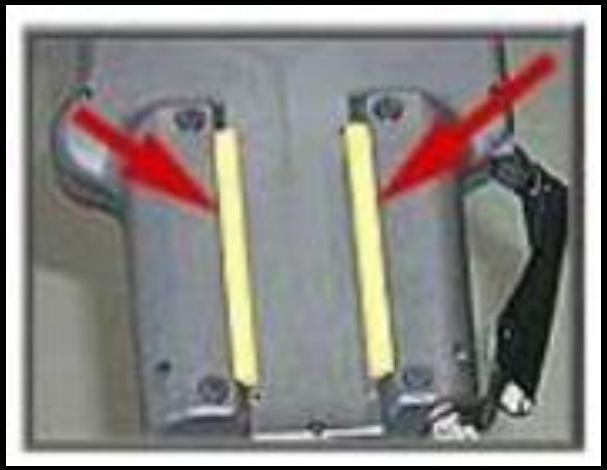
The Emergency Stop button is used in emergency situations to stop robot motion. It controls the operation of a circuit which overrides all other robot controls, removes drive power from the actuators, and causes all moving parts to stop. When the Emergency Stop button is pushed, "dynamic" braking is employed on all joints and all electrical brakes are engaged. Both the Standard Operator Panel and the Teach Pendant are equipped with Emergency Stop buttons.

DEADMAN

- Next in priority after Emergency Stop
- If this switch is released, the robot needs to stop any motion

DEADMAN Switch

The DEADMAN switch, a pair of handles located on the back of the Teach Pendant, is a control switch that is used in conjunction with other factors to supply servo power. Gripping the DEADMAN switch correctly (middle detent position) while the Teach Pendant is ON will ensure personal safety. When the robot is energized, and the DEADMAN switch is released or gripped harder, servo power is deactivated and robot brakes are applied.

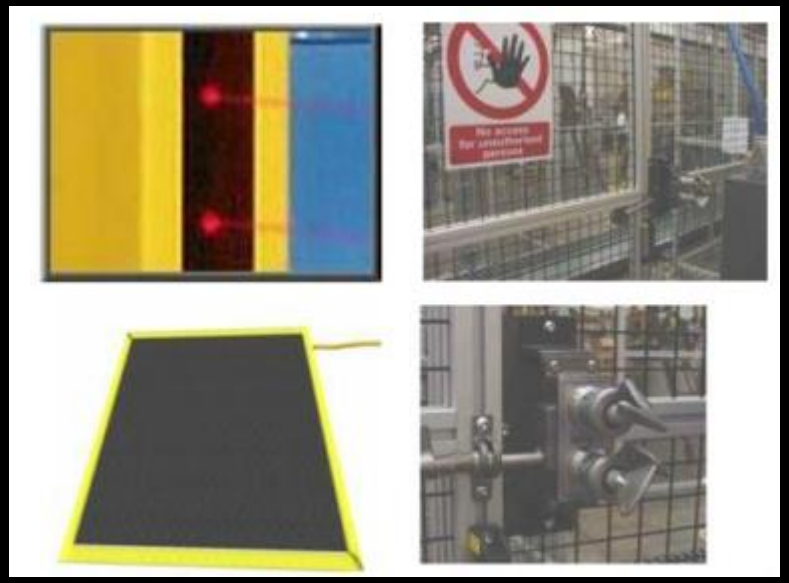


Things that detect humans...

- Light Curtains
- Pressure Pads
- Motion Sensors
- Cameras

Light Curtains

Light Curtains are beams of light set up to travel from transmitter to receiver. This light protects personnel or unwanted objects from entering the restricted work envelope, the work area of the robot. When an interruption of the path of light to the receiver occurs, deactivation of servo power to the robot takes place, brakes are applied, and the robot comes to a stop.

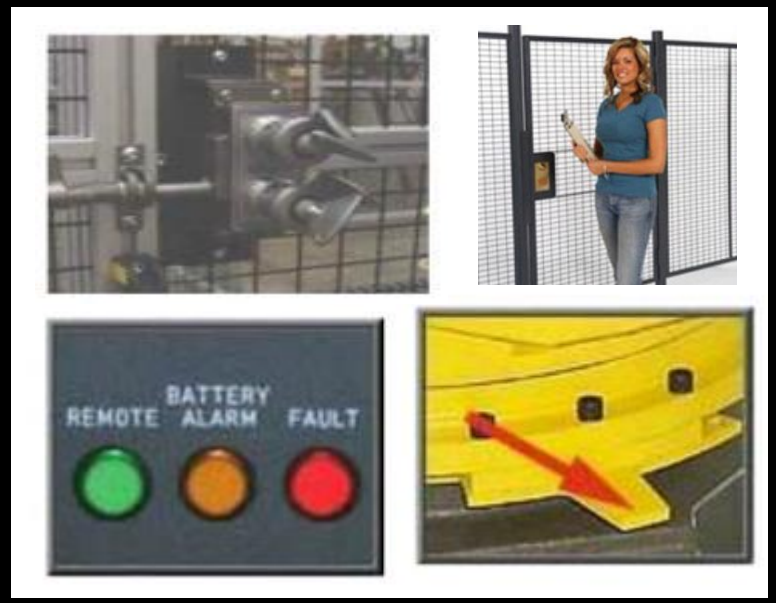


INTERLOCKS

- Control Panels with Keys
- Gates with Keys
- Gates with Switches
- Limit Switches

Interlocks

Interlocks are any arrangement where the operation of one control or mechanism brings about, or prevents, the initiation of operations of another. These may include safety fences, light curtains, mats, operator controls, etc.



BOOTUP, DIAGNOSTICS, STATUS

- Power good signal
- Motor diagnostic pass
- Memory and processor diagnostic pass
- I/O signals in correct state (user defined)
- All safety signals in their "safe" state (see above)

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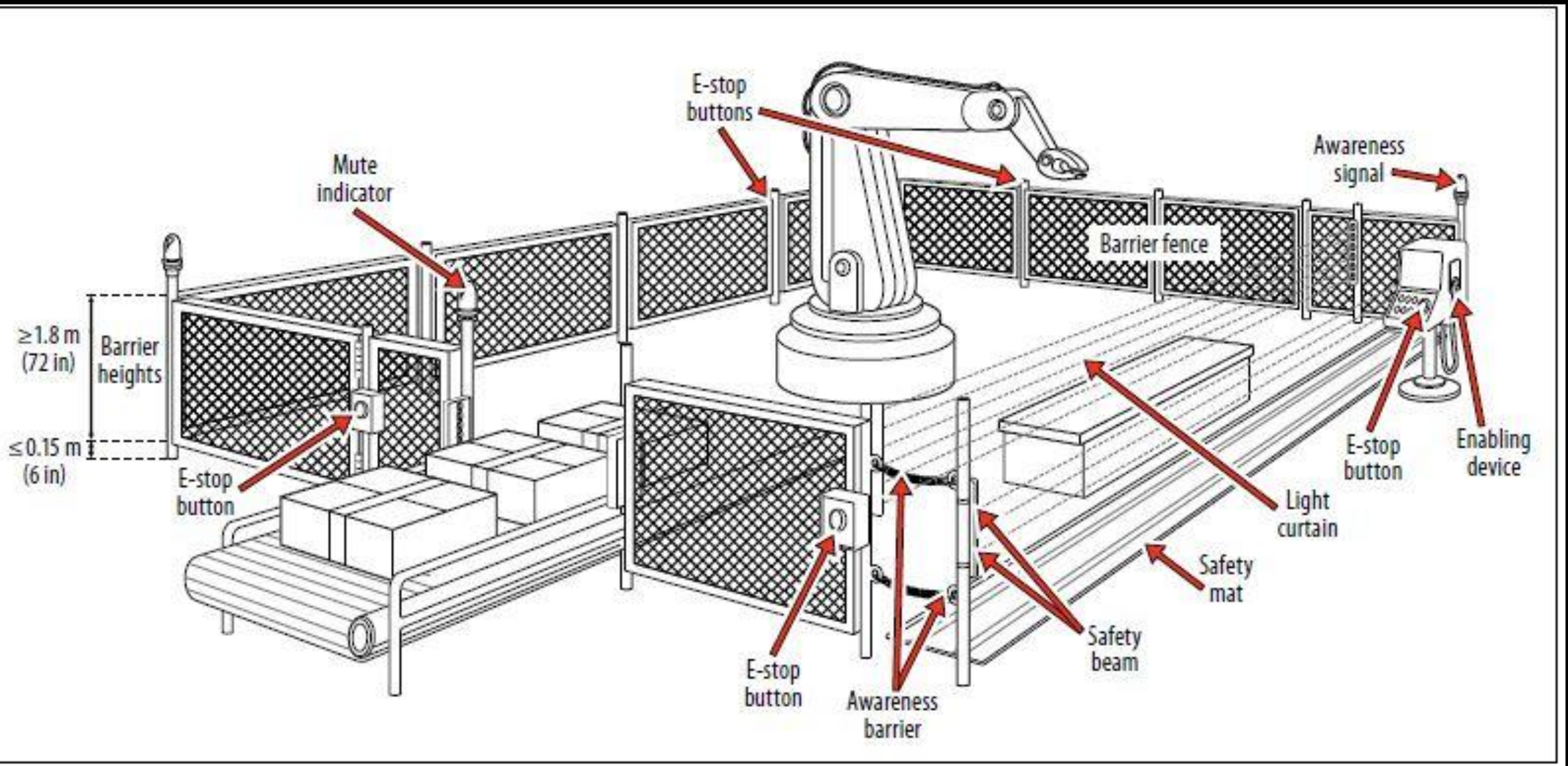
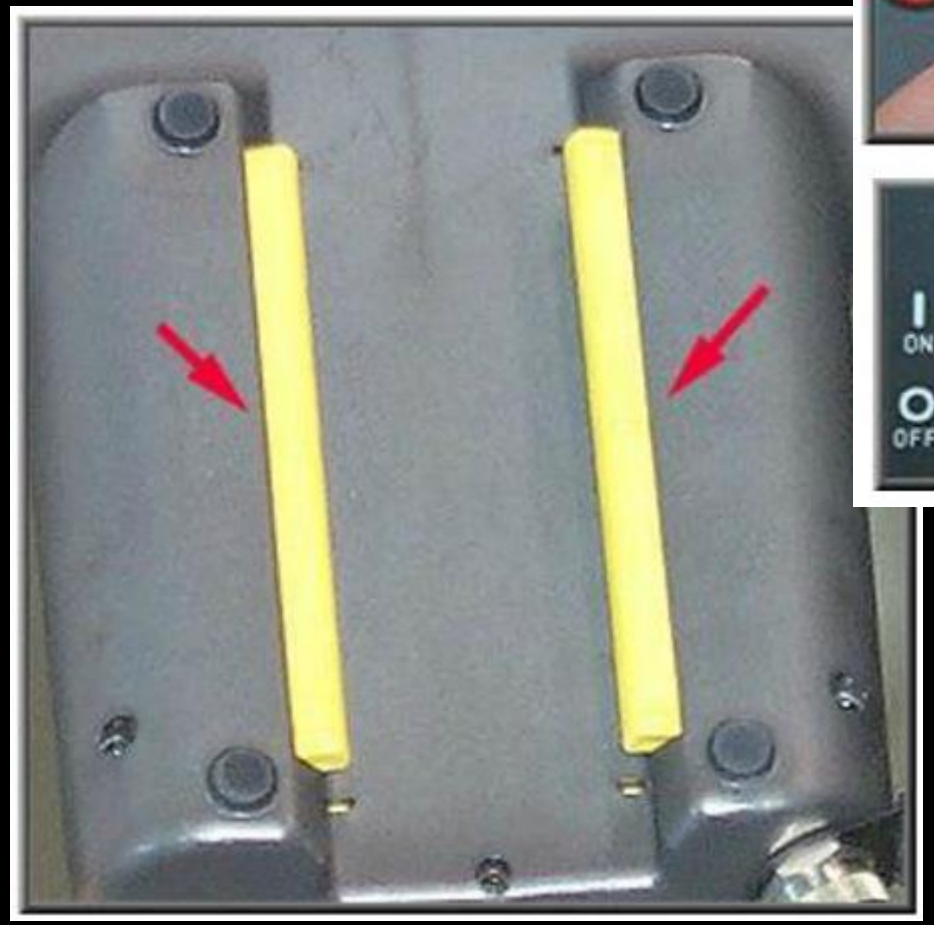
ORGANIZING PRIORITY

ROBOT WORK CELL



LET'S ORGANIZE THE SIGNALS



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BINARY LOGIC FUNCTION

F(var) = expression

Operators (+, •, ‘)

Variables

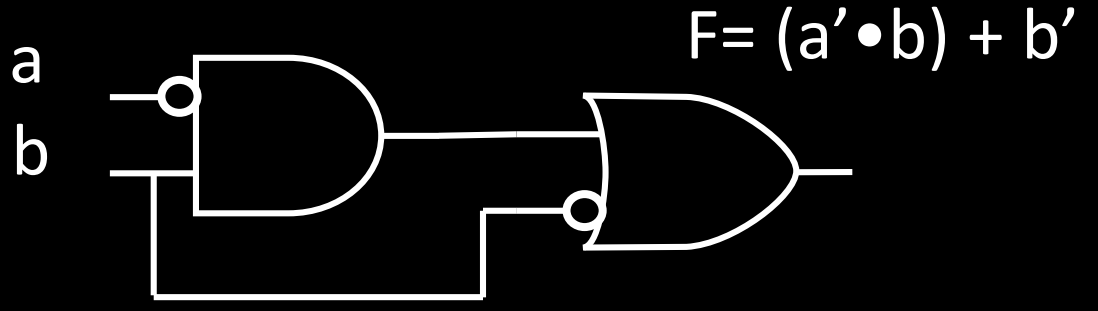
Constants (0, 1)

Groupings (parenthesis)

This is a set of Binary variables
Defines the set of “Inputs”

Ex: F(a,b) = (a’•b) + b’

F(a,b,c) = a•((b+c’)+(b’+c))

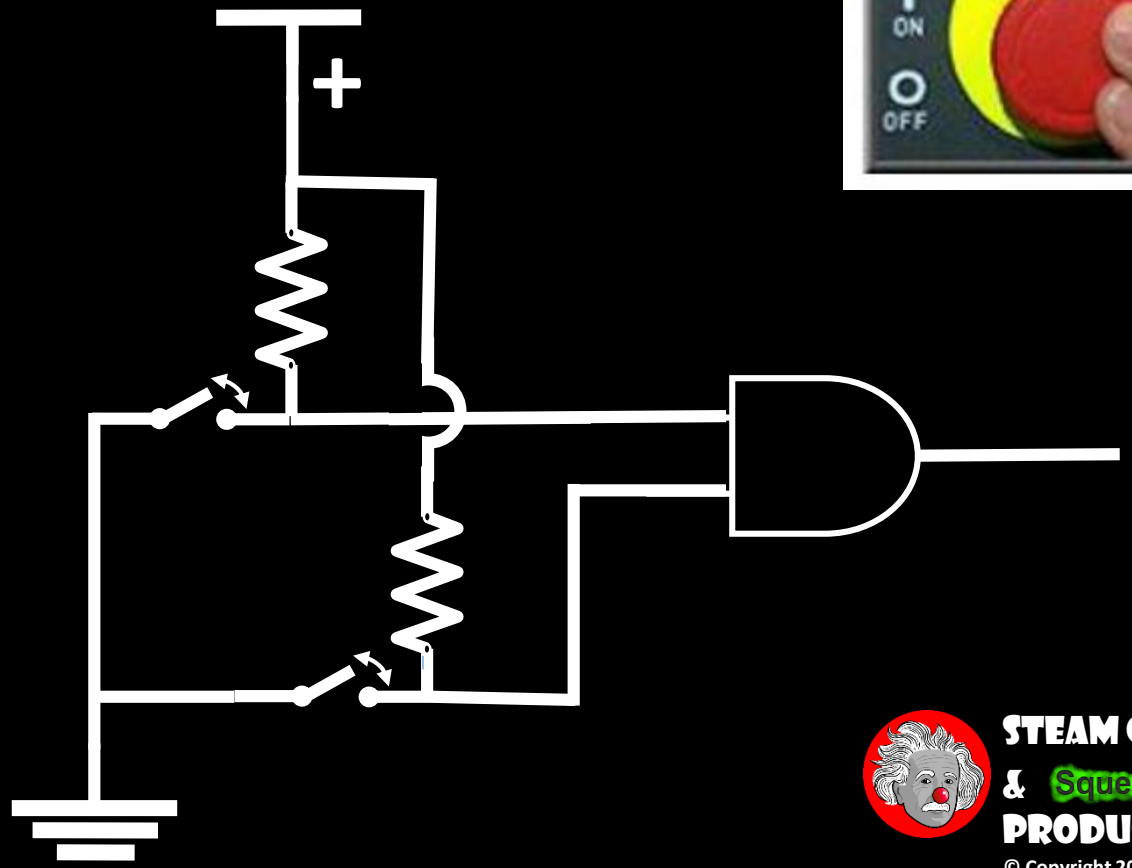


EMERGENCY STOP

- If any of the E-Stop buttons are pushed, then the AND gate is OFF

2-Input AND

A	B	F=A·B
0	0	0
0	1	0
1	0	0
1	1	1

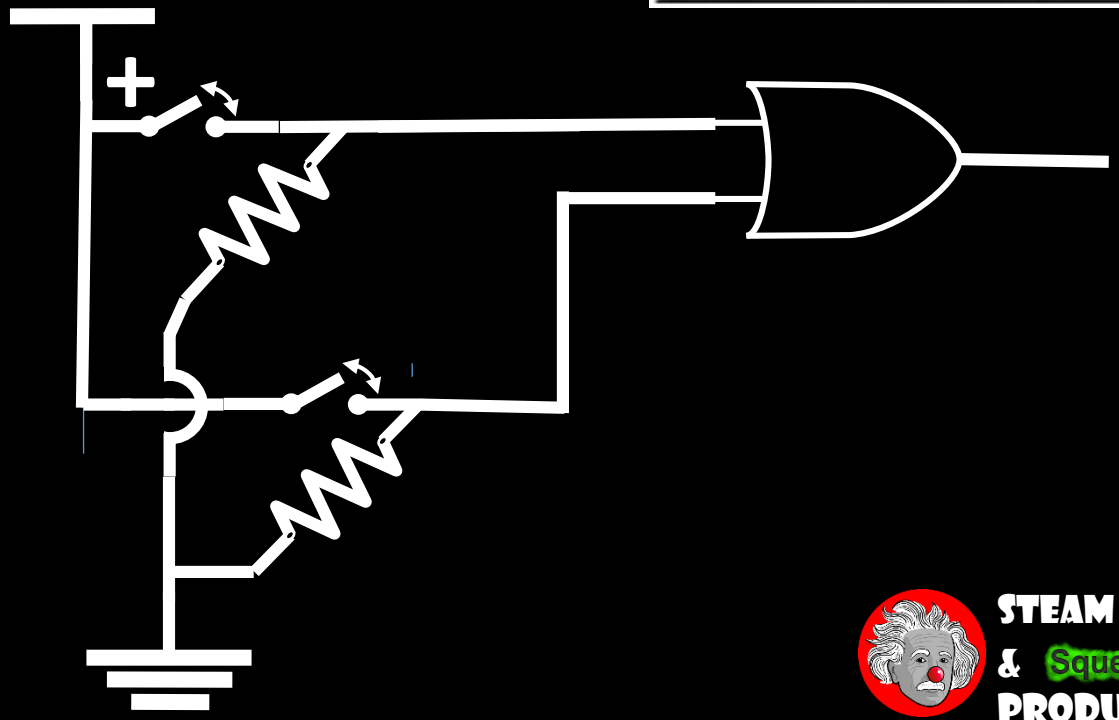


Deadman Switch

- If the Deadman Switch is pushed, then the OR gate is ON

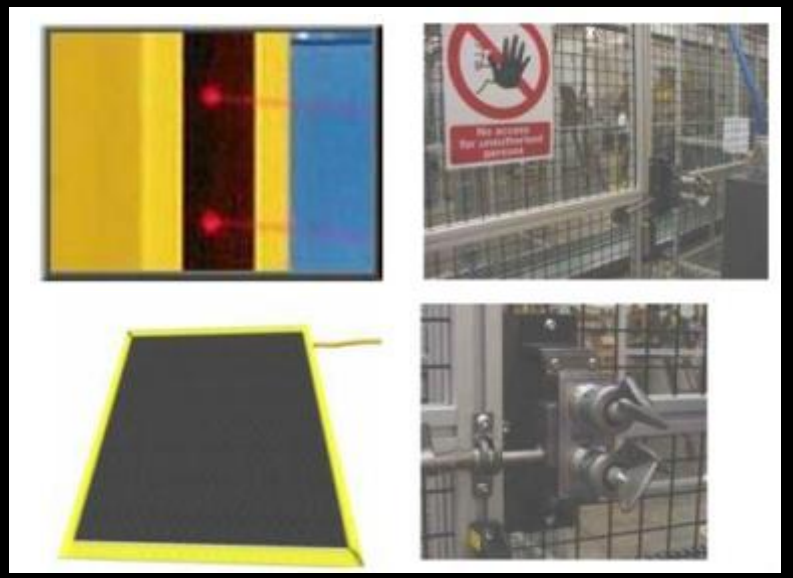
2-Input OR

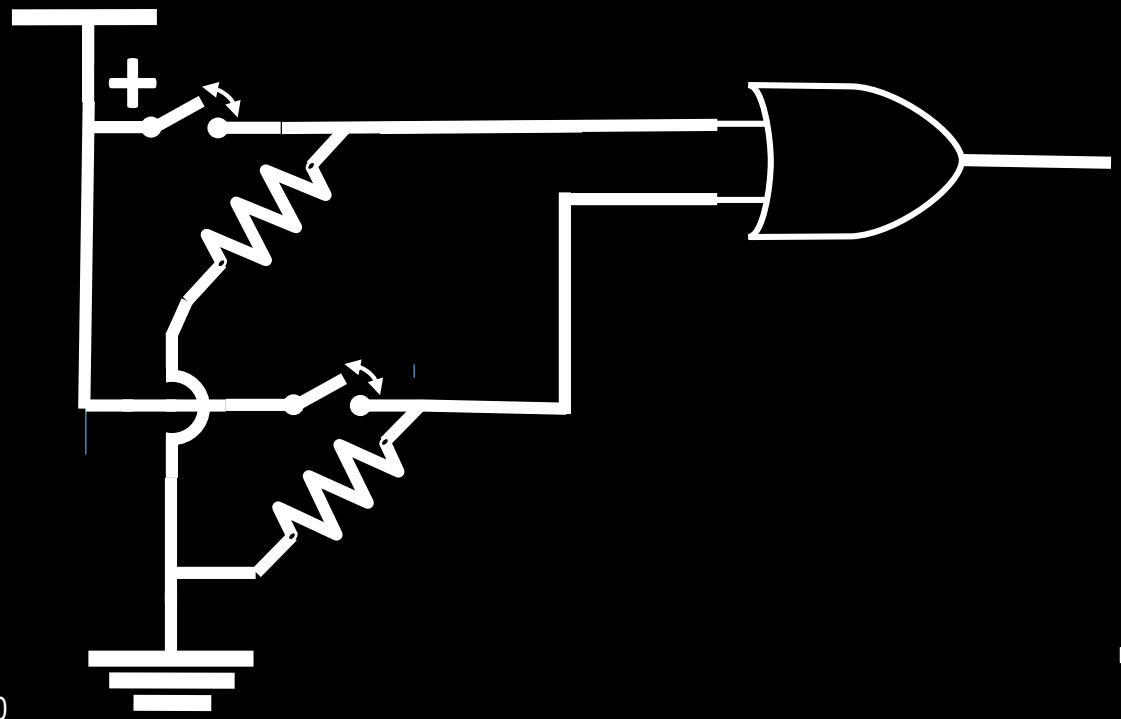
A	B	F=A+B
0	0	0
0	1	1
1	0	1
1	1	1

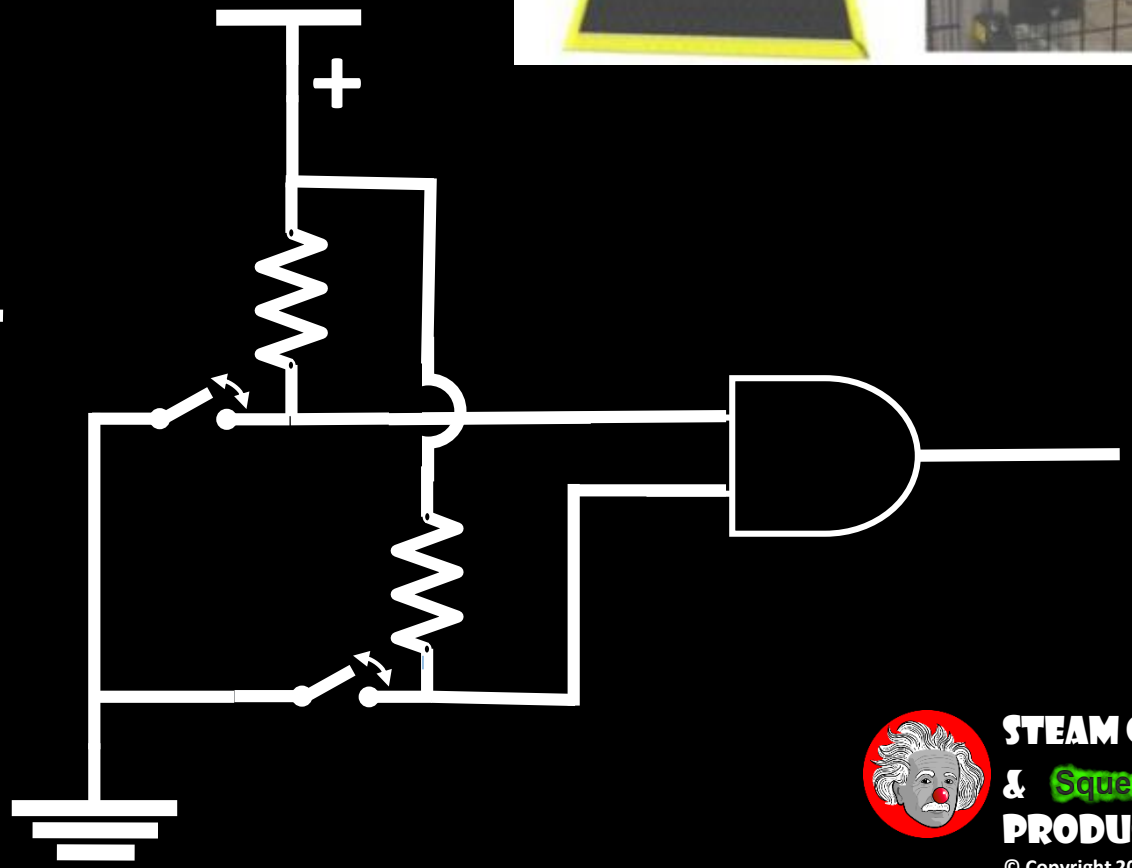


Other Sensors

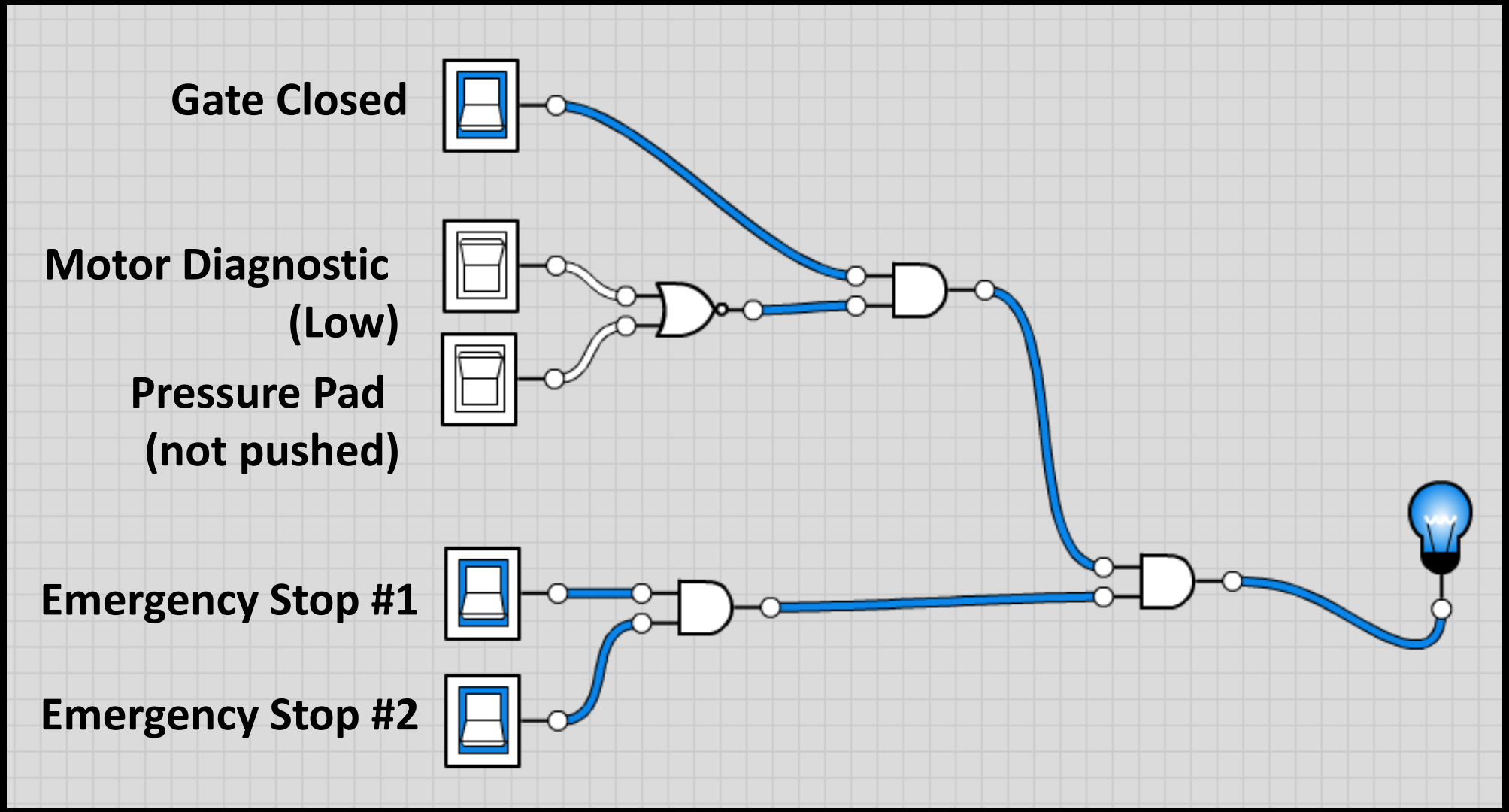
- Depending on the Sensor, the logic will be asserted HIGH or LOW







CREATE A LOGIC CIRCUIT FOR YOUR INPUTS



https://logic.ly/demo/

REFERENCE SLIDES

Basic AND & OR Logic Operators

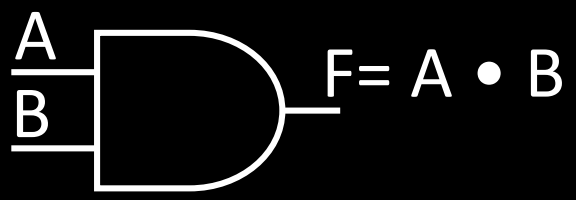
1-bit logic AND resembles binary multiplication:

$0 \bullet 0 = 0$

$0 \bullet 1 = 0$

$1 \bullet 0 = 0$

$1 \bullet 1 = 1$



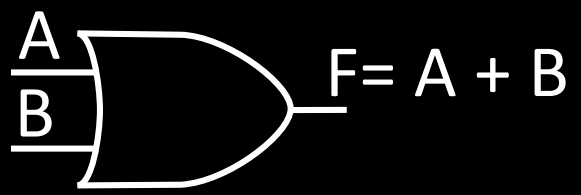
1-bit logic OR resembles binary addition, except for one operation:

$0 + 0 = 0$

$0 + 1 = 1$

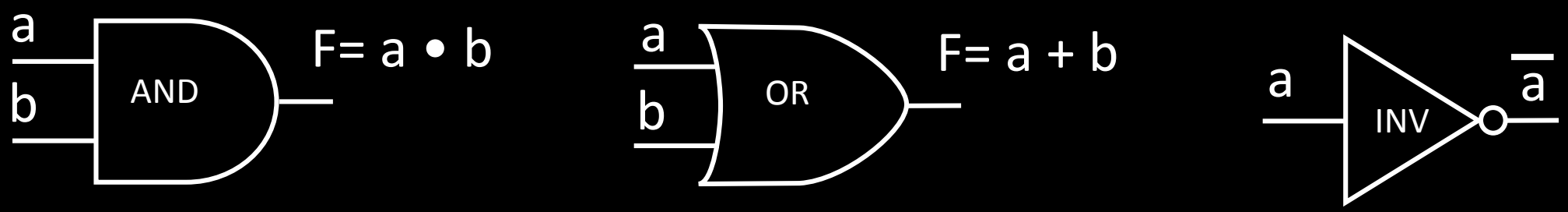
$1 + 0 = 1$

$1 + 1 = 1$ ($\neq 10_2$)

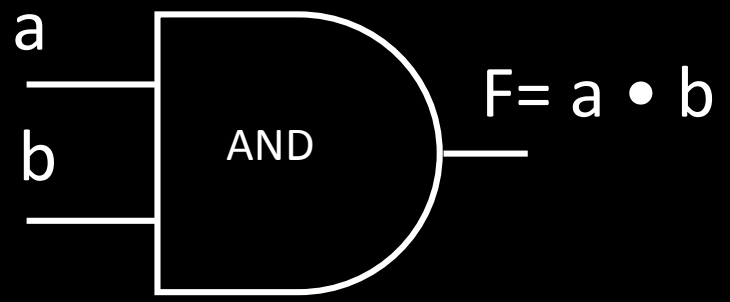


Logic Gates

- Logic gates are abstractions of electronic circuit components that operate on one or more input signals to produce an output signal



AND GATE



- This AND gate has two inputs and an output
- Output is zero unless both Inputs are 1's

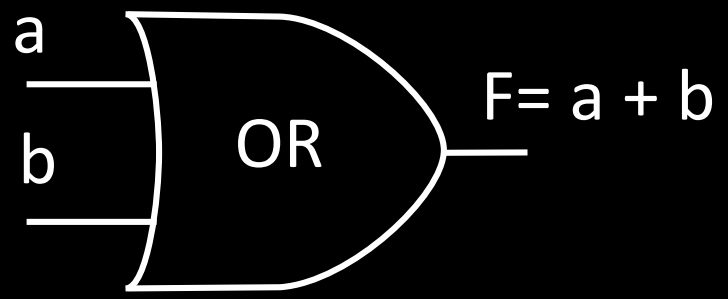
The AND operation is mathematically defined as the product of two Boolean values

2-Input AND

A	B	F=A•B
0	0	0
0	1	0
1	0	0
1	1	1

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

OR GATE



- This OR gate has two inputs and an output
- Output is 1 if any of the Inputs are 1's

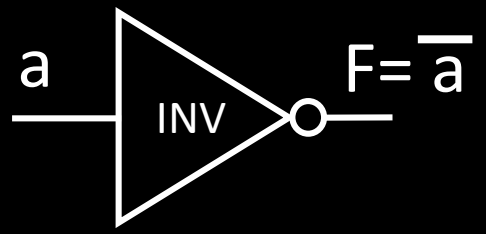
The OR operation is mathematically defined as the summation of two Boolean values

2-Input OR

A	B	F=A+B
0	0	0
0	1	1
1	0	1
1	1	1

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

NOT (INVERTER) GATE



- This NOT gate has one input and one output
- This is an “inverter” function
- Output is 1 if the Input is 0, and 0 if the Input is 1

(Inverter)
NOT

a	F= $\overline{a}$
0	1
1	0

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

TRUTH TABLES FOR LOGIC OPERATORS

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

2-Input AND

A	B	F=A·B
0	0	0
0	1	0
1	0	0
1	1	1

2-Input OR

A	B	F=A+B
0	0	0
0	1	1
1	0	1
1	1	1

NOT

A	F=A'
0	1
1	0

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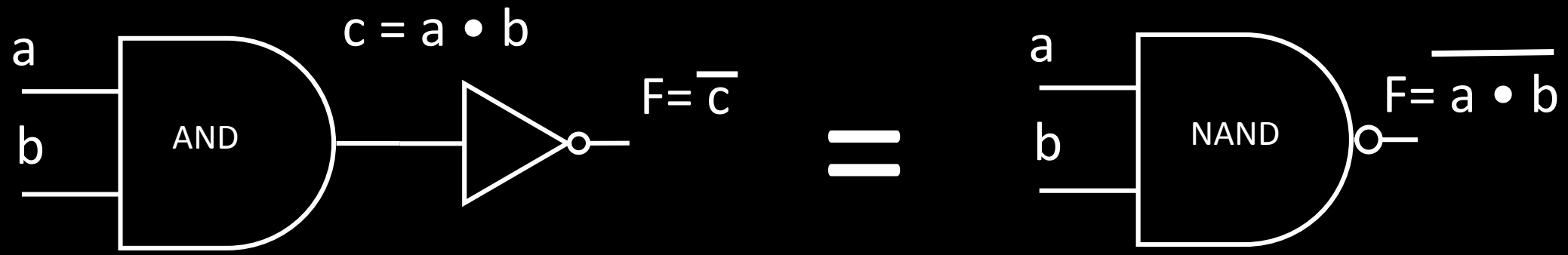
AND GATE + INVERTER

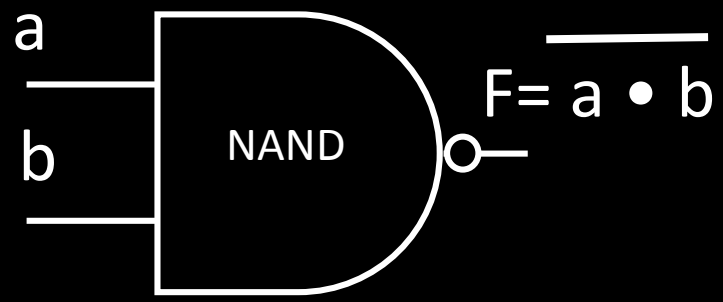
- This NAND gate has two inputs and an output
- Output is 1 unless both Inputs are 1's, then it's 0

2-Input NAND

A	B	F=A•B
0	0	1
0	1	1
1	0	1
1	0	1
1	1	0



NAND GATE



- This NAND gate has two inputs and an output
- Output is 1 unless both Inputs are 1's, then it's 0

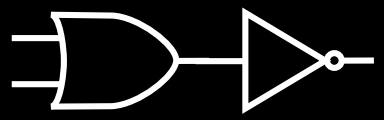
The NAND operation is mathematically defined as the product of two Boolean values

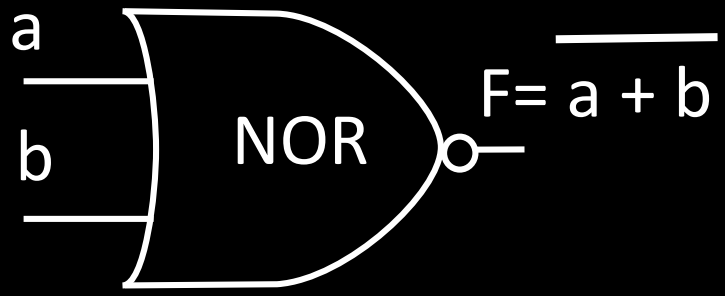
2-Input NAND

A	B	$F=\overline{A \bullet B}$
0	0	1
0	1	1
1	0	1
1	1	0

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

NOR GATE





- This NOR gate has two inputs and an output
- Output is 0 if any of the Inputs are 1's

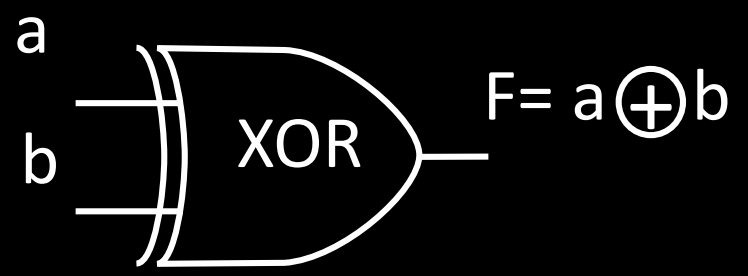
The NOR operation is mathematically defined as the summation of two Boolean values

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

2-Input NOR

A	B	$F=\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

XOR Gate



- This XOR gate has two inputs and an output
- Output is 1 if the Inputs are different

The XOR operation is mathematically defined as the summation of two Boolean values if they are different

2-Input XOR

A	B	F=A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

Truth table: tabular form that uniquely represents the relationship between the input variables of a function and its output

Check out this Logic Link

- Learning about Logic Gates and Circuits
  - https://logic.ly/lessons/

APPENDIX

Appendix A: License & Attribution

- This interpretation is primarily the Intellectual Property of Jim Burnham, Top STEAM Clown, at STEAMClown.org
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- My best attempt to properly attribute, or reference any other sources or work I have used are listed in Appendix B

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Appendix B: Attribution for Sources Used

- Power Point Logic Gates Symbols – Oliver Mannay
- Slide Share Logic Gates
- PPT from Michigan Tech EE 4271