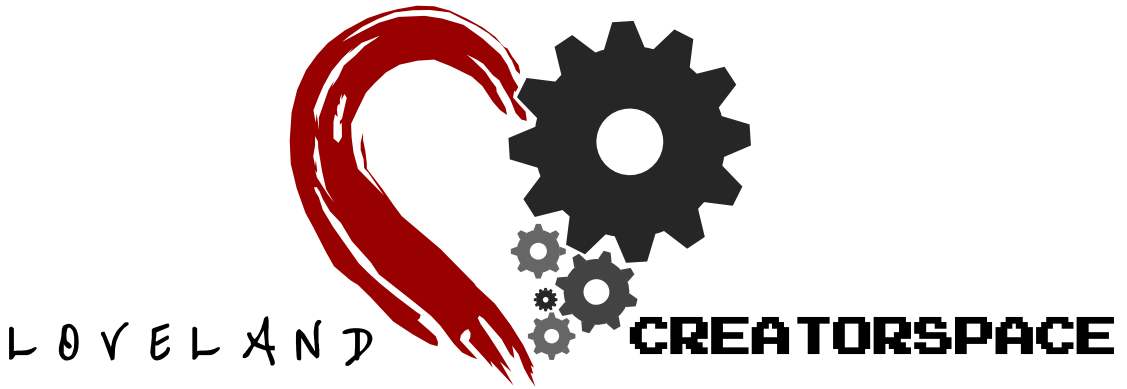
Digital Logic

Build Your Own Logic Gate From Scratch



Overview

- Digital Logic vs. Analog
- Digital Data Representation
- Logic Operations, Truth Tables
- Transistors
- NOT gates, NAND gates, …
- Build a Logic Gate

Digital Logic vs Analog

- All circuits have two (perhaps more) power inputs; 0v and e.g. 5v.
- Signals in analog circuits vary arbitrarily between them
- In digital circuits:
  - Voltage represents data
  - Only the two values 0v and e.g. 5v are used; values in between aren't used
  - Boolean logic; true/false
  - Binary math
  - 0/low/false (0v), 1/high/true (5v)

Logic Operations, Truth Tables

- Logic operations (gates) take a set of inputs, transform them, and produce a set of outputs
- Truth tables define output value(s) for each combination of input(s)

NOT

A	X
0	1
1	0

NAND

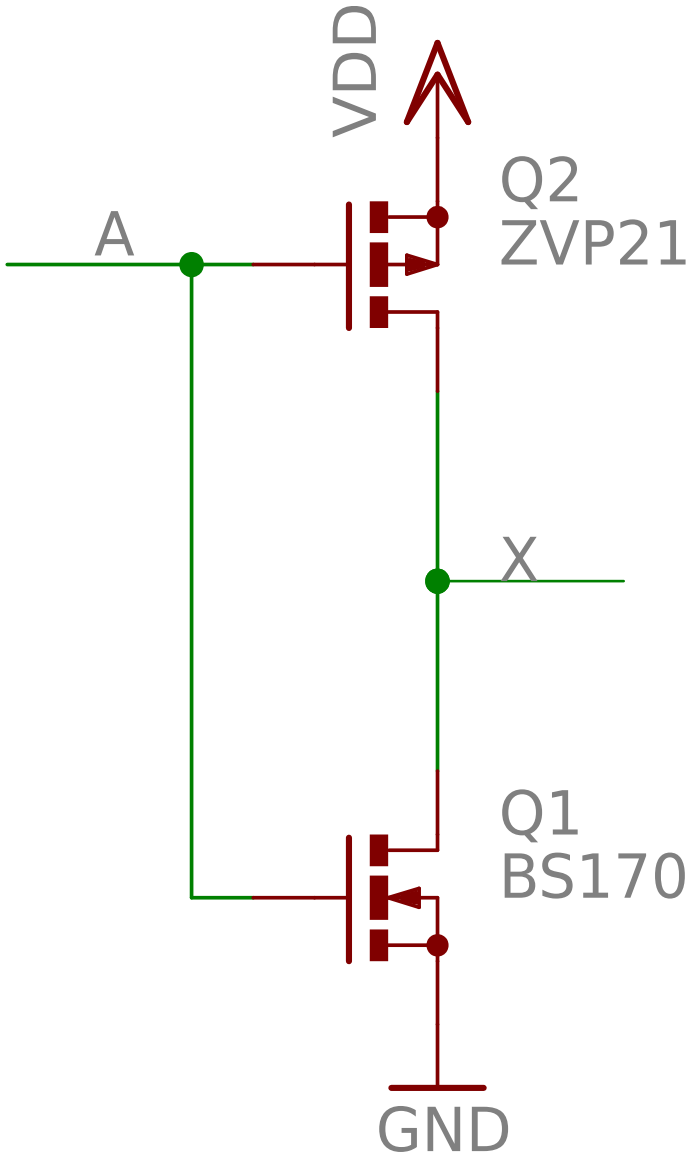
A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

- Also: NOR/AND/OR/XOR/XNOR/...

Transistors

- Many types; Bipolar, BJT, UJT, FET, ...
- CMOS FETs (MOSFETs) used for most modern ICs
- Think of MOSFETS as a simple switch;
  they conduct between 2 terminals (source/drain)
  or not, based on a control *voltage* (at the gate)
- Two types of MOSFET:
  - N-channel conducts if gate input is high
  - P-channel conducts if gate input is low

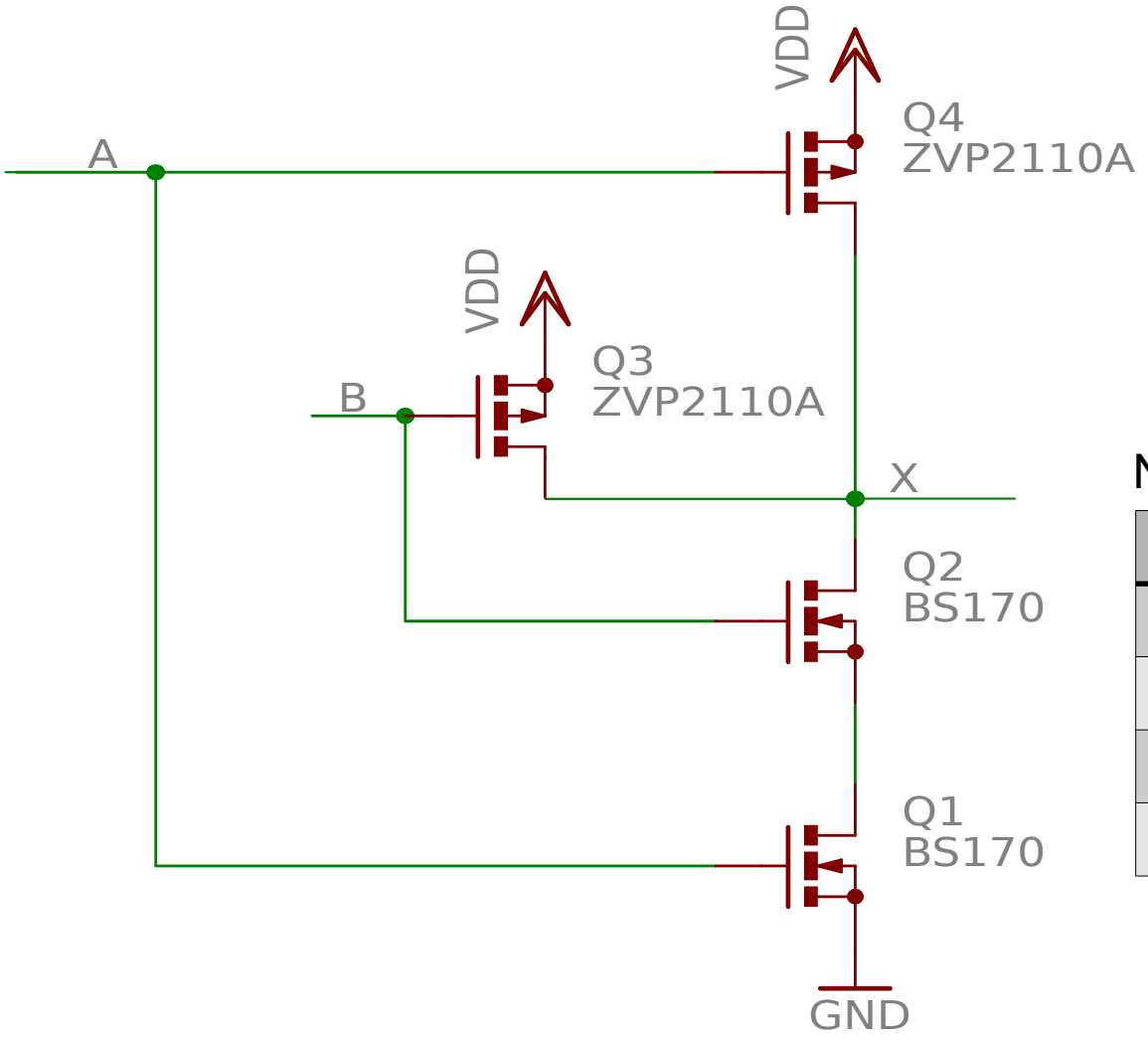
NOT schematic



NOT

A	X
0	1
1	0

NAND schematic



NAND

A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

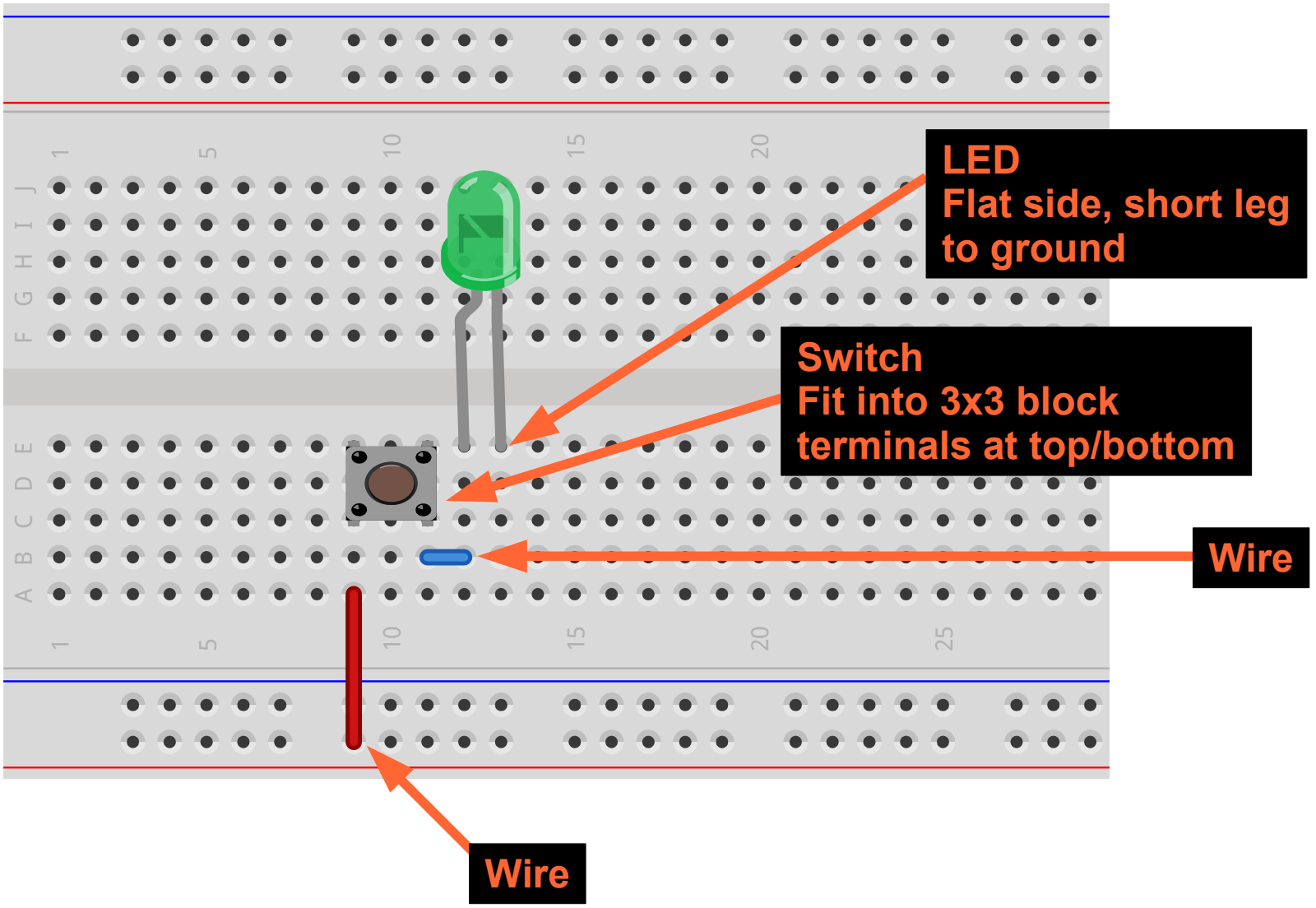
Questions

Build A Logic Gate!

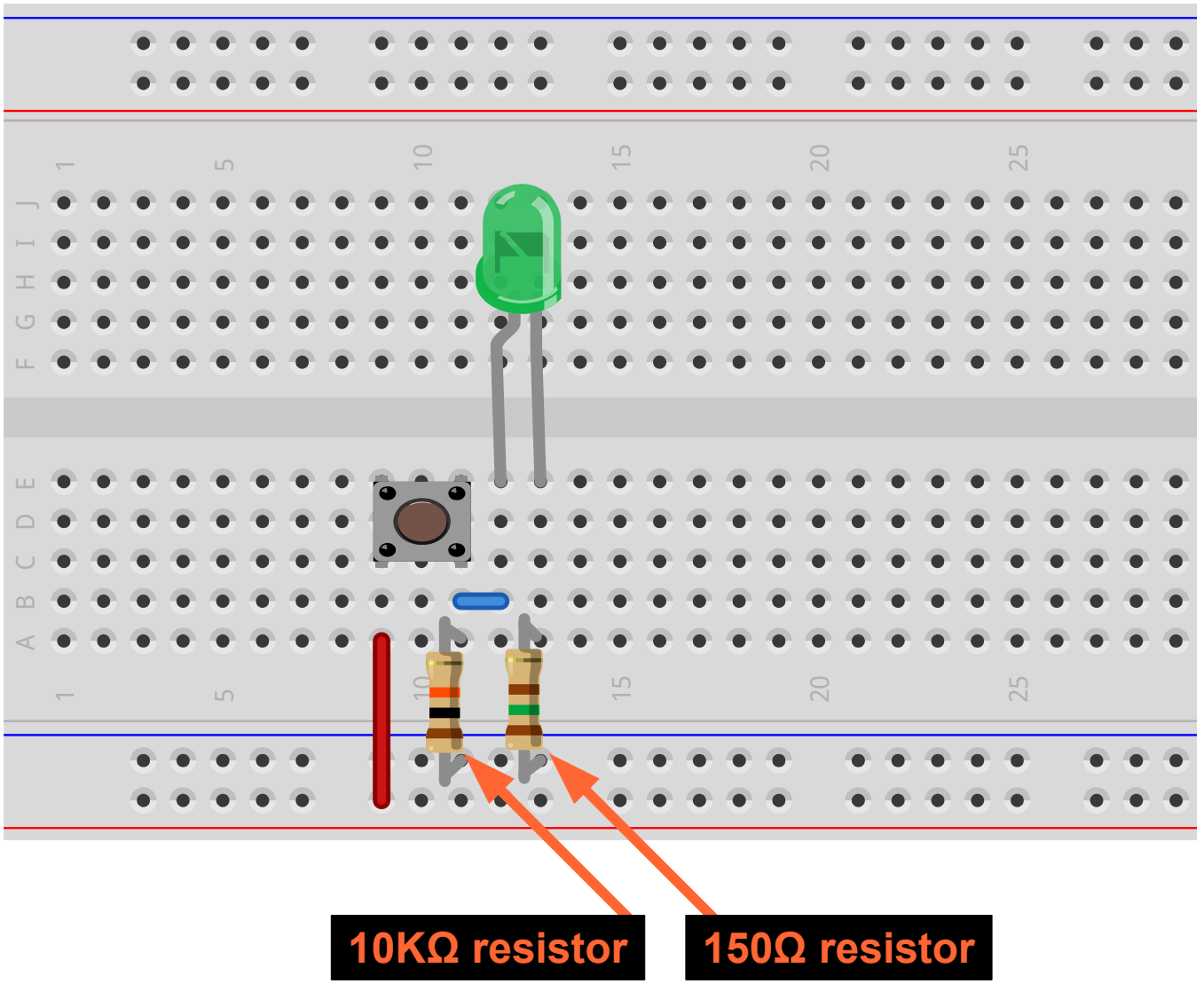
You will need:

- Bag of components
- Breadboard
- USB power supply
- Modified USB cable

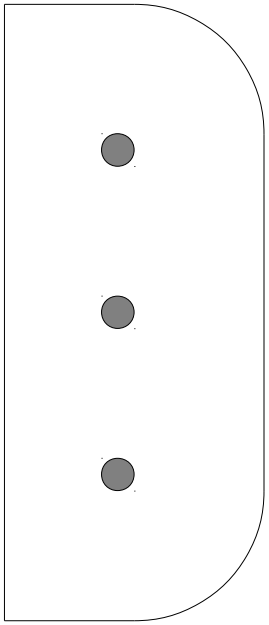
NOT gate - Step 1



NOT gate - Step 2

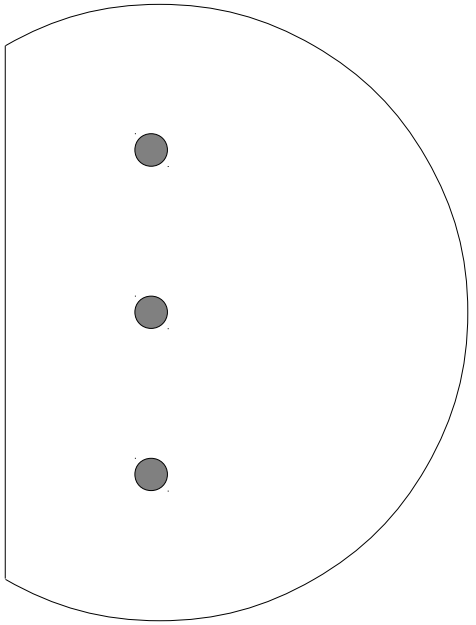


Transistor Packages



E-line package

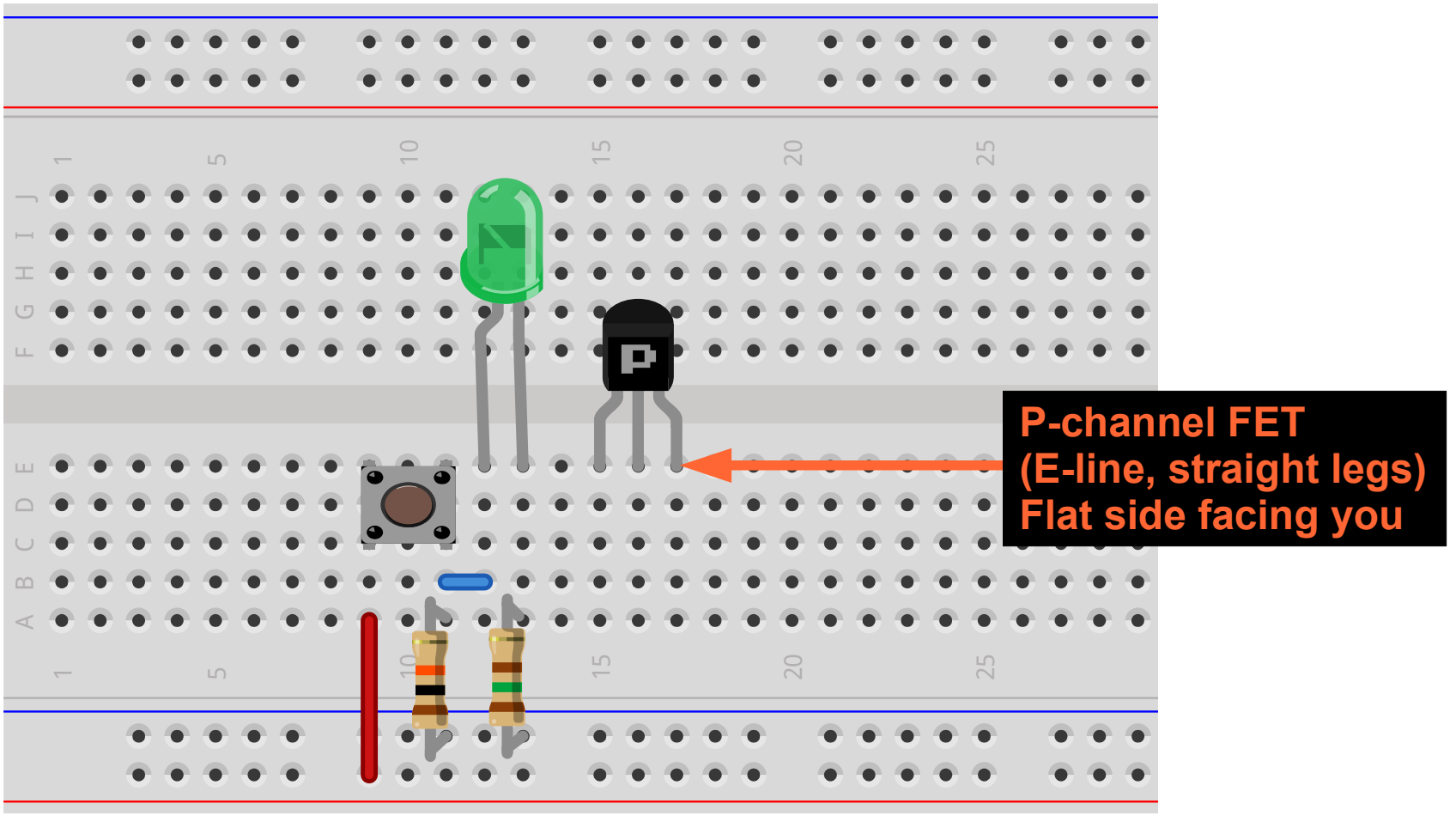
Used by our P-channel device
(straight legs)



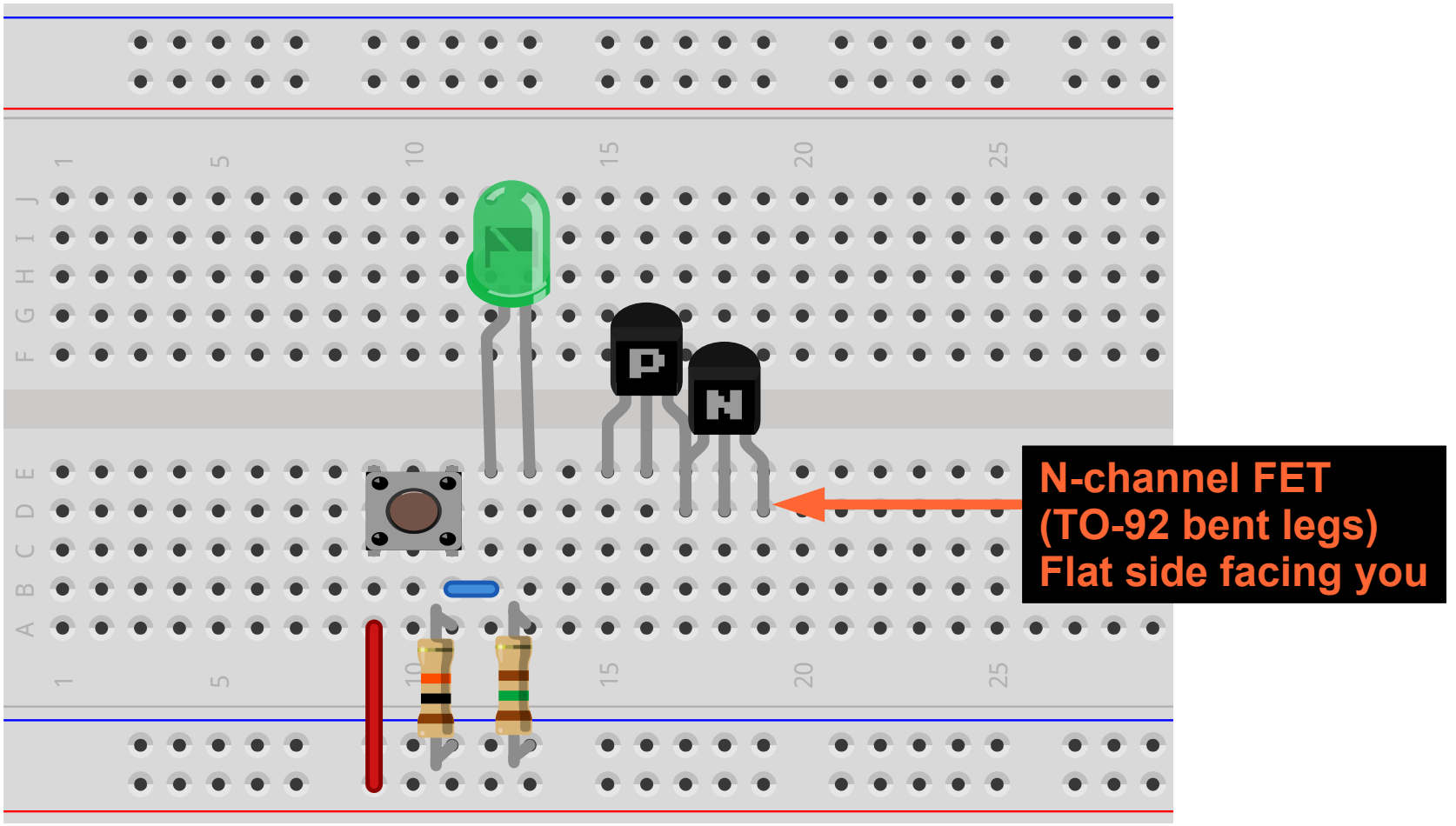
TO-92 package

Used by our N-channel device
(bent legs)

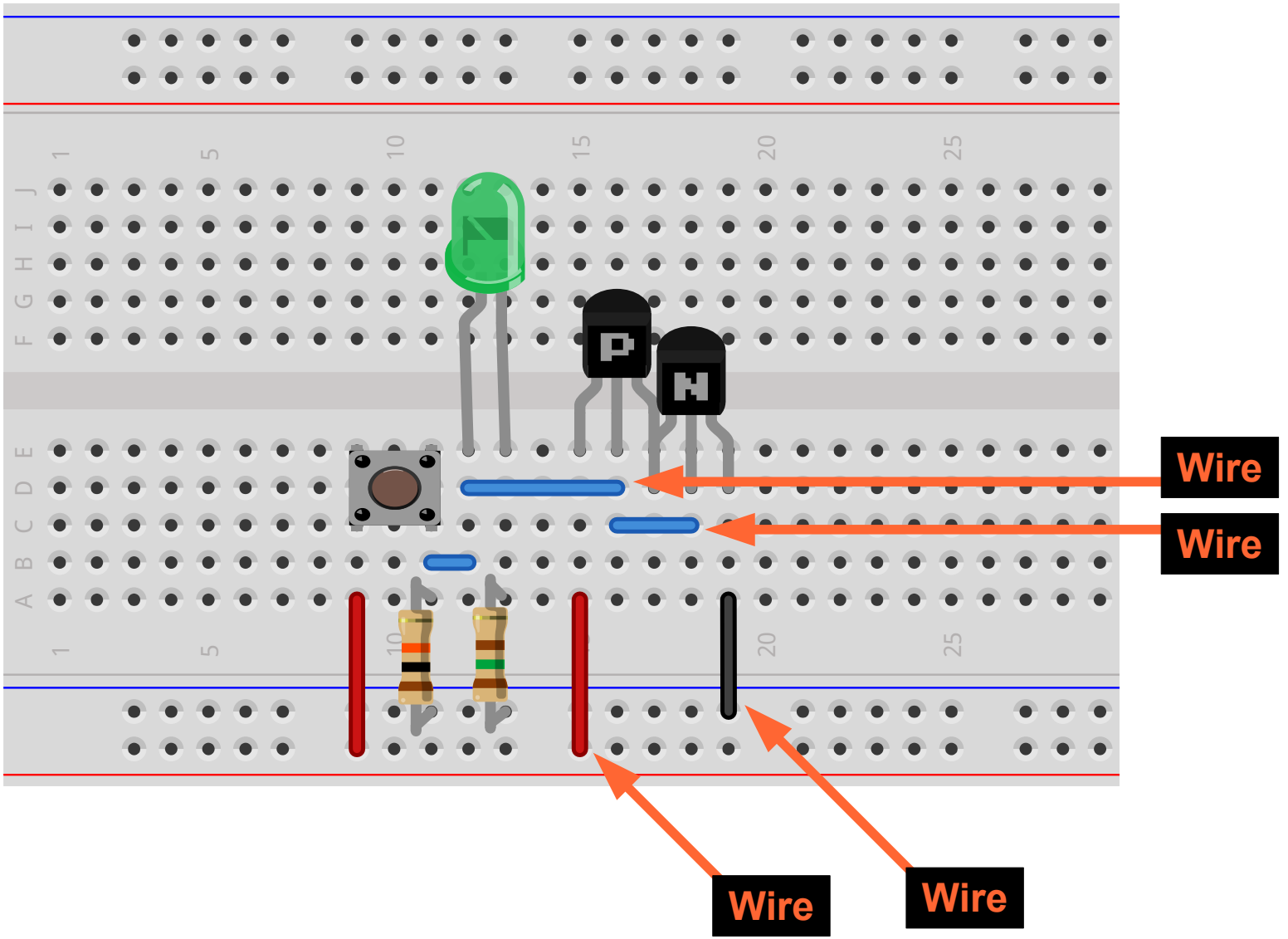
NOT gate - Step 3



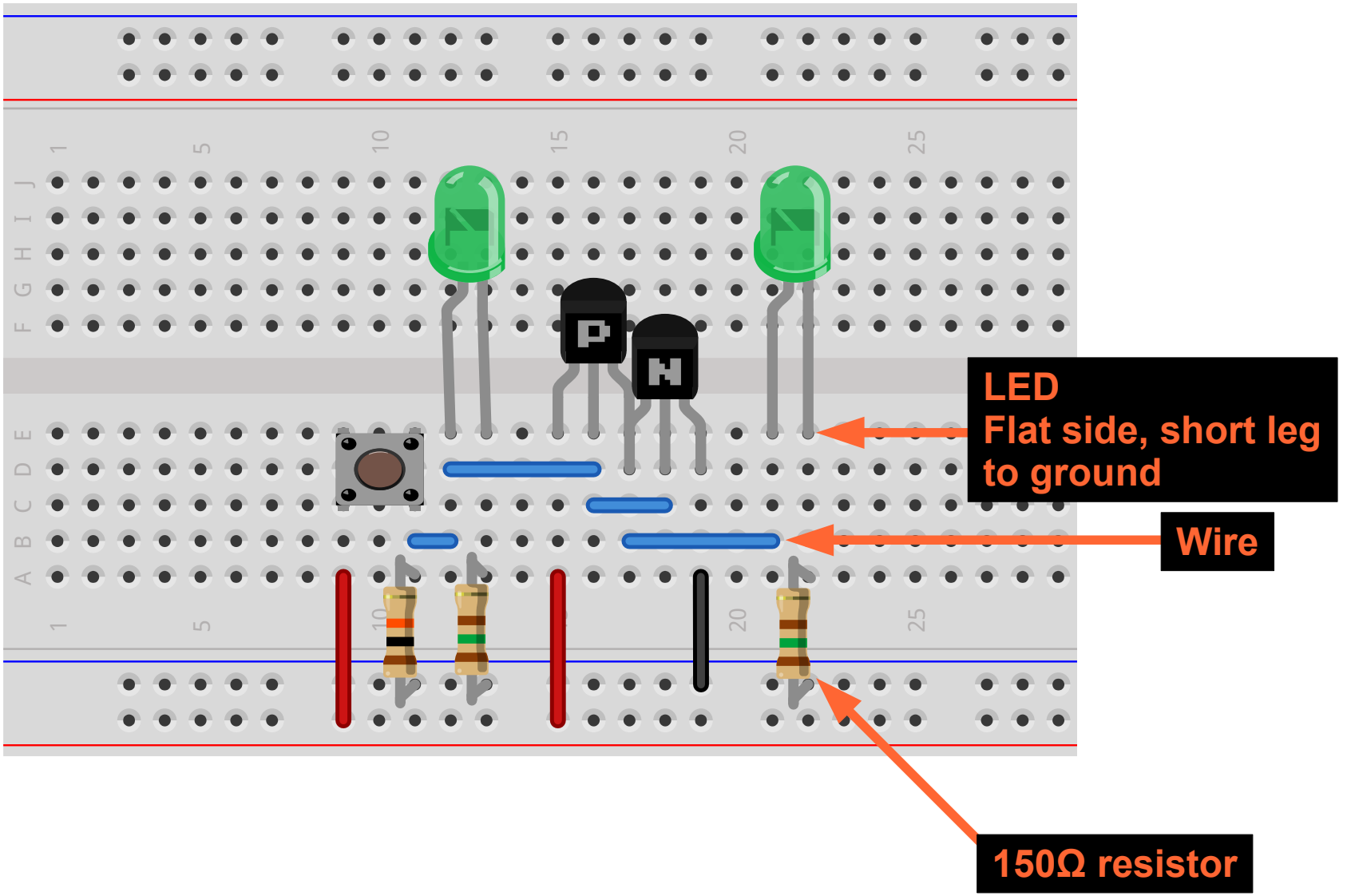
NOT gate - Step 4



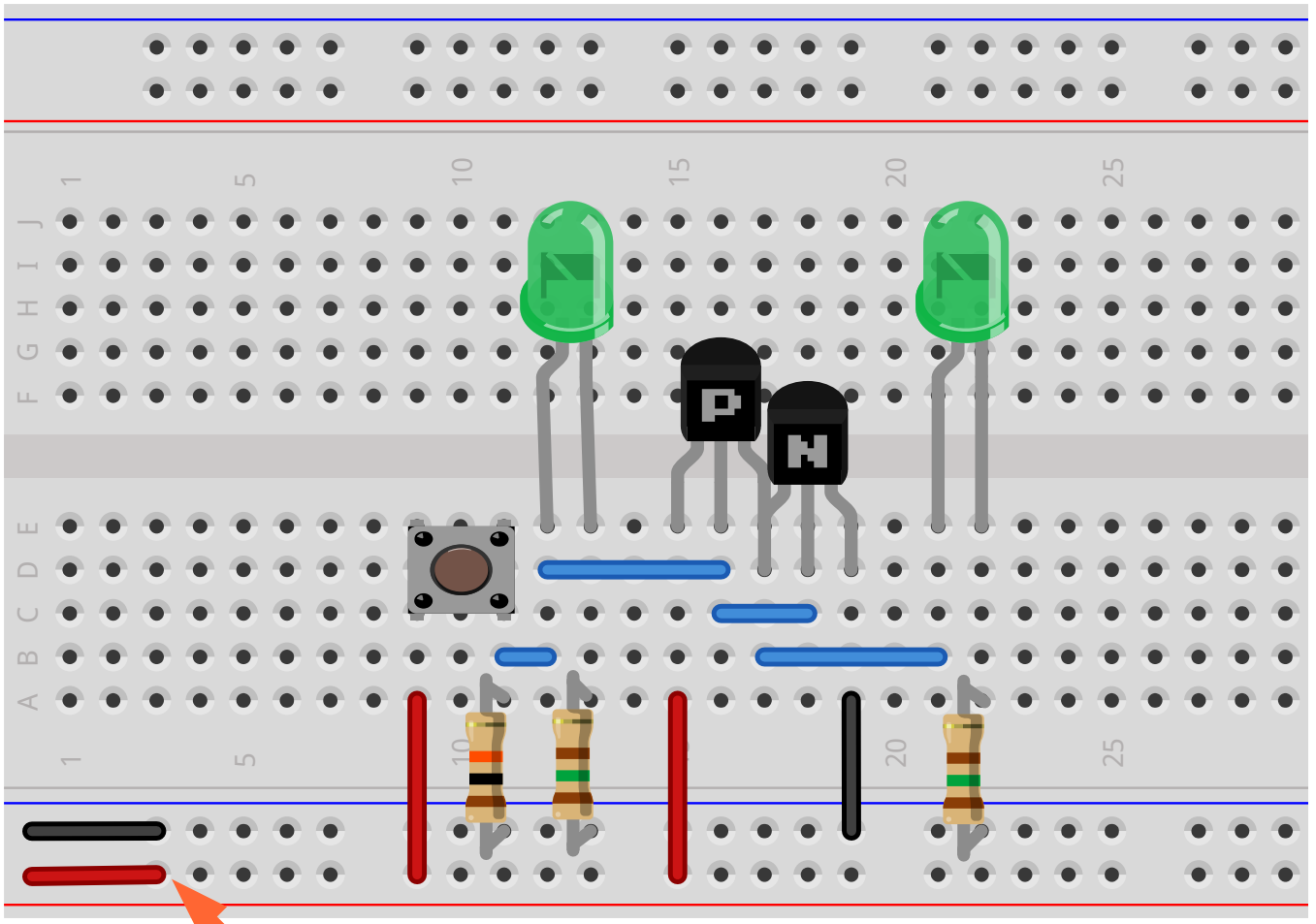
NOT gate - Step 5



NOT gate - Step 6



NOT gate - Power!



NOT gate – Test

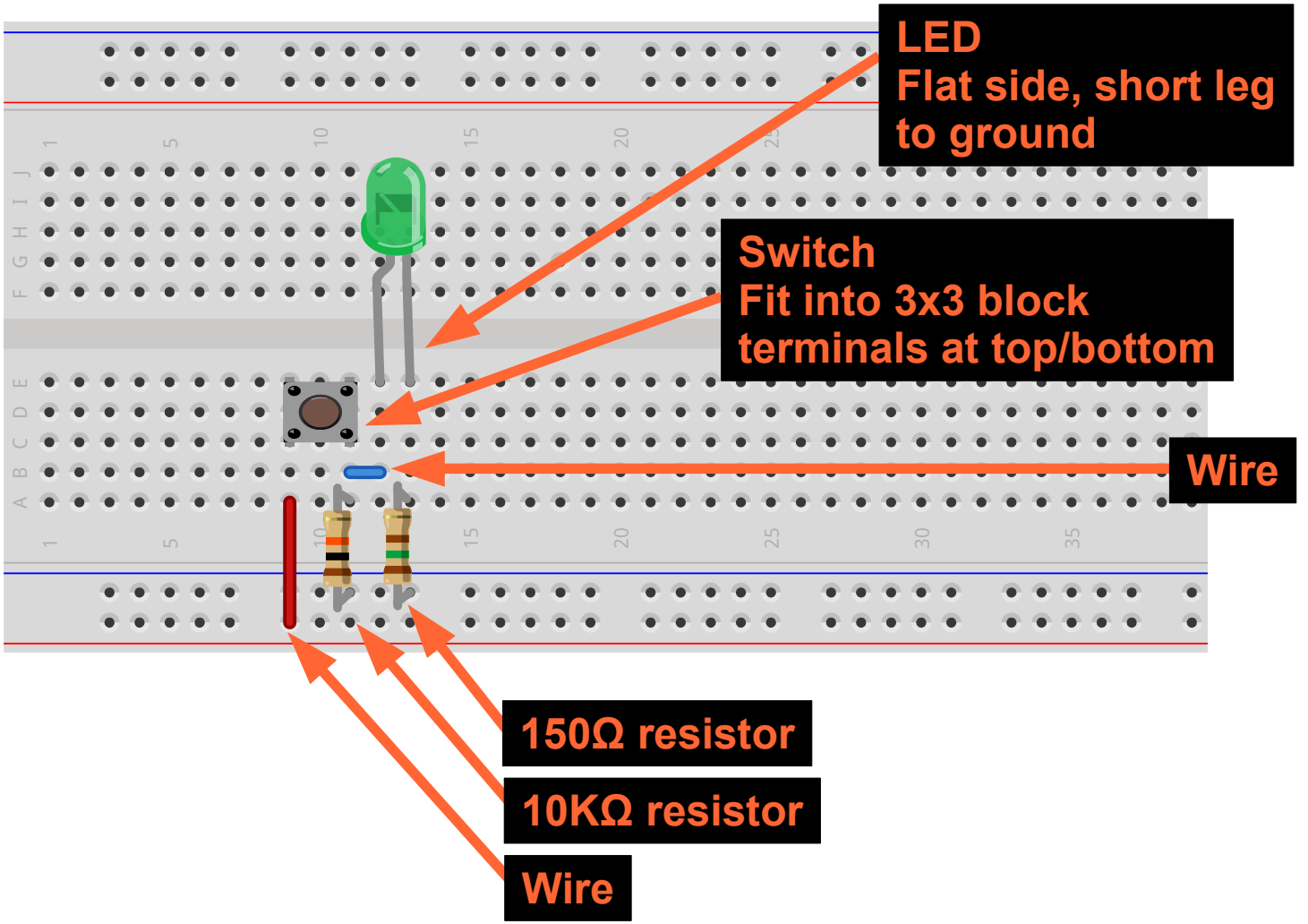
- Press and release the button to test the NOT gate
- Verify that the input and output match the truth table

NOT

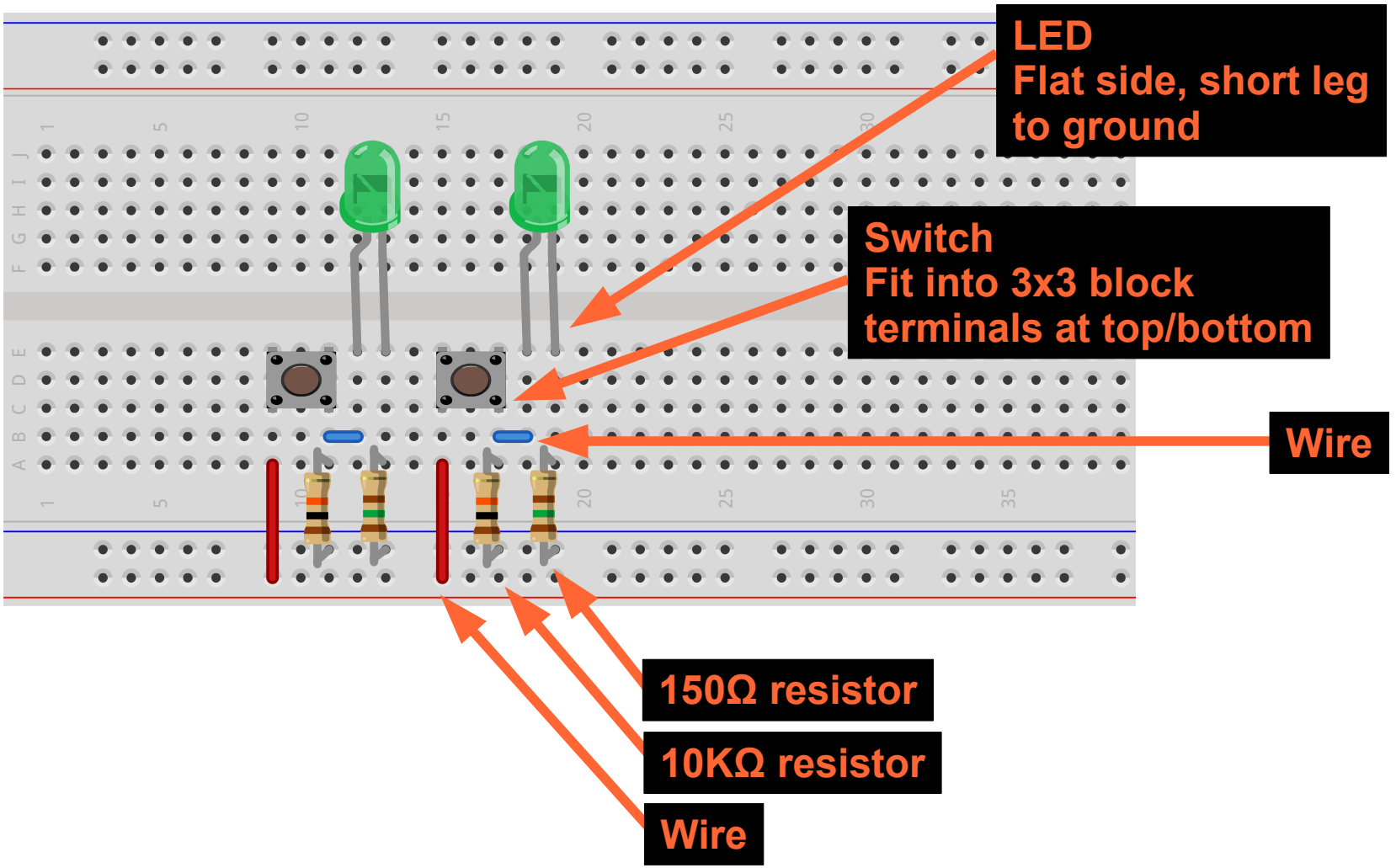
A	X
0	1
1	0

Questions

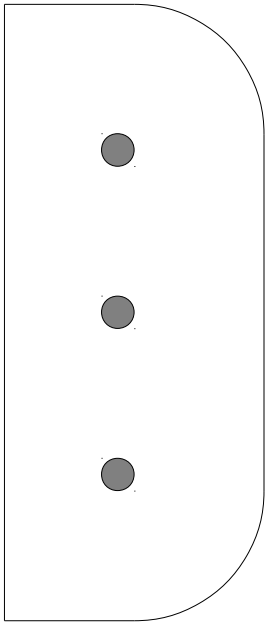
NAND gate – Step 1



NAND gate – Step 2

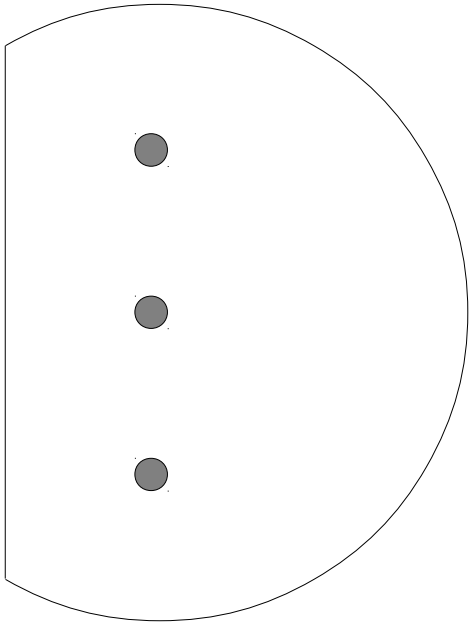


Transistor Packages



E-line package

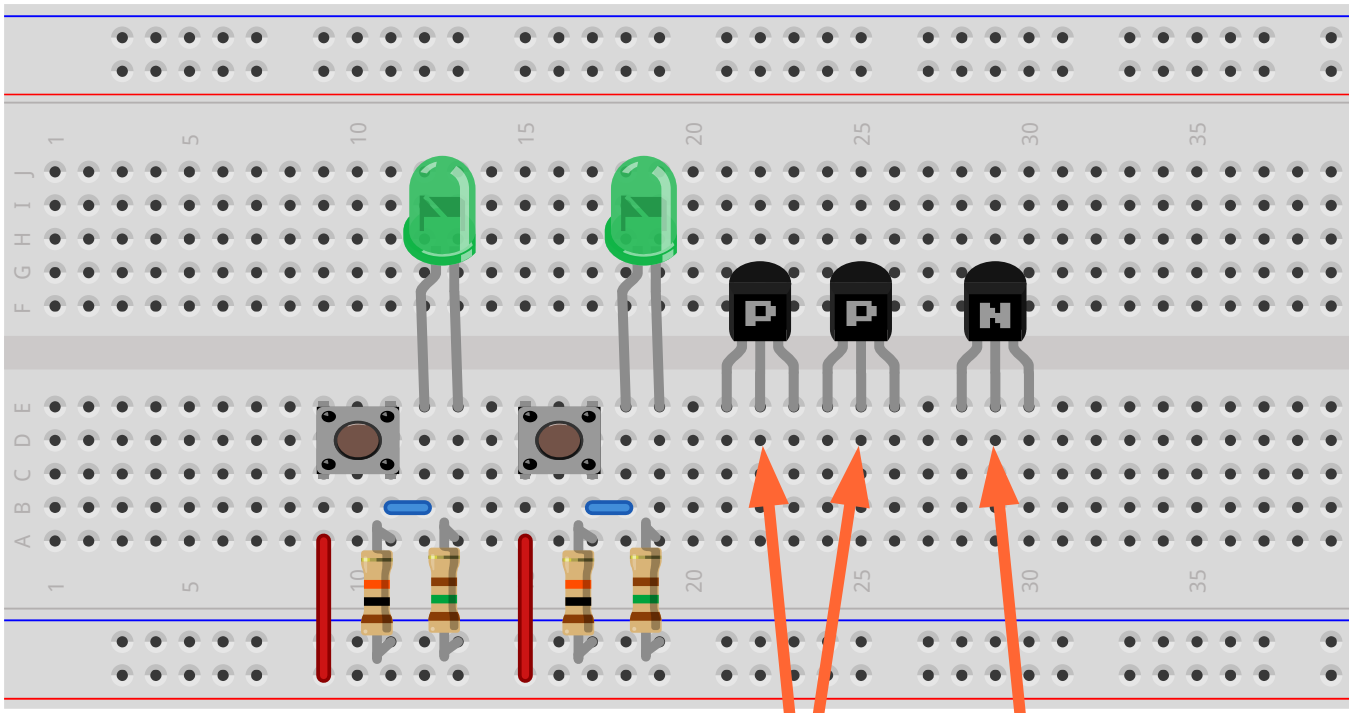
Used by our P-channel device
(straight legs)



TO-92 package

Used by our N-channel device
(bent legs)

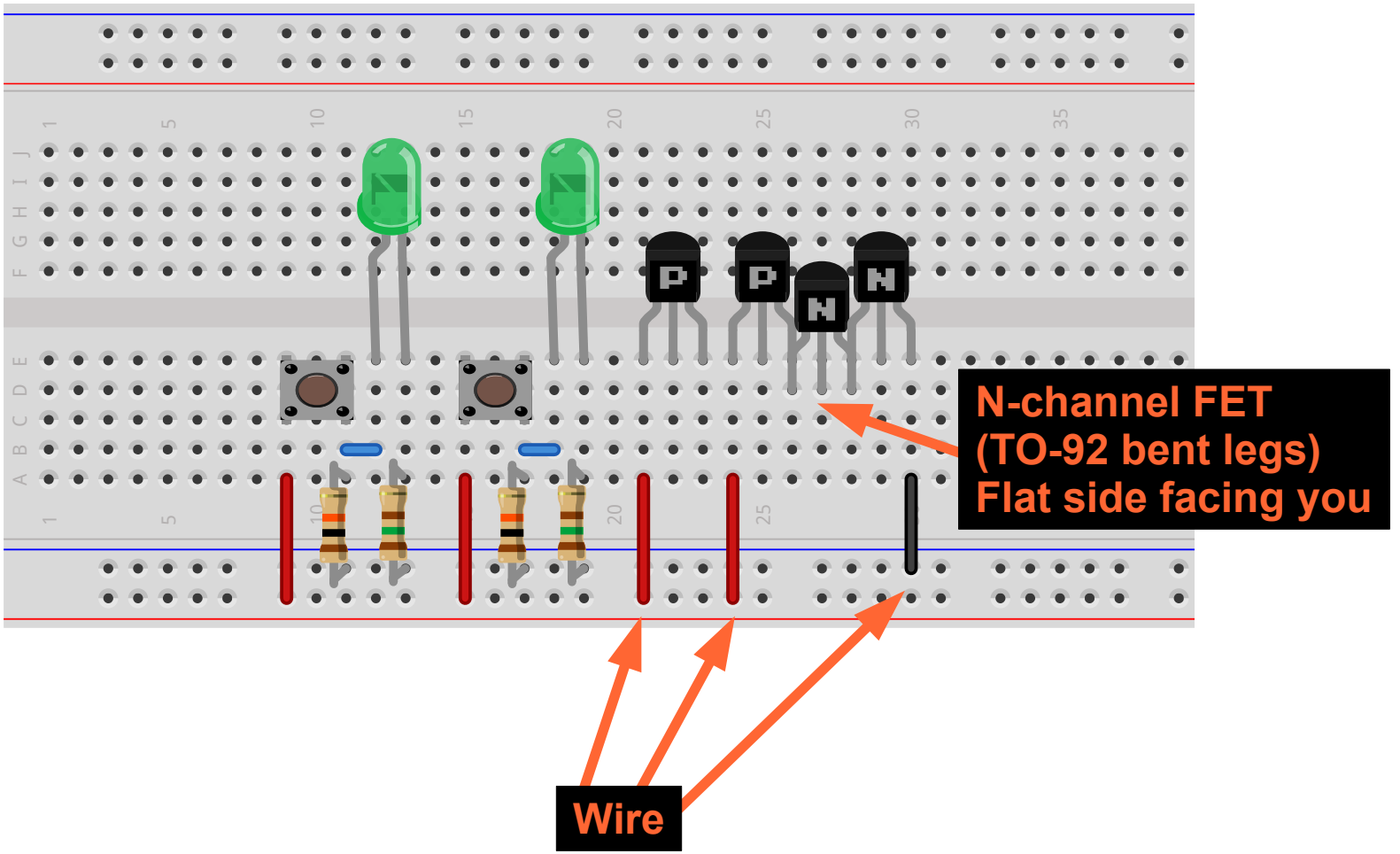
NAND gate – Step 3



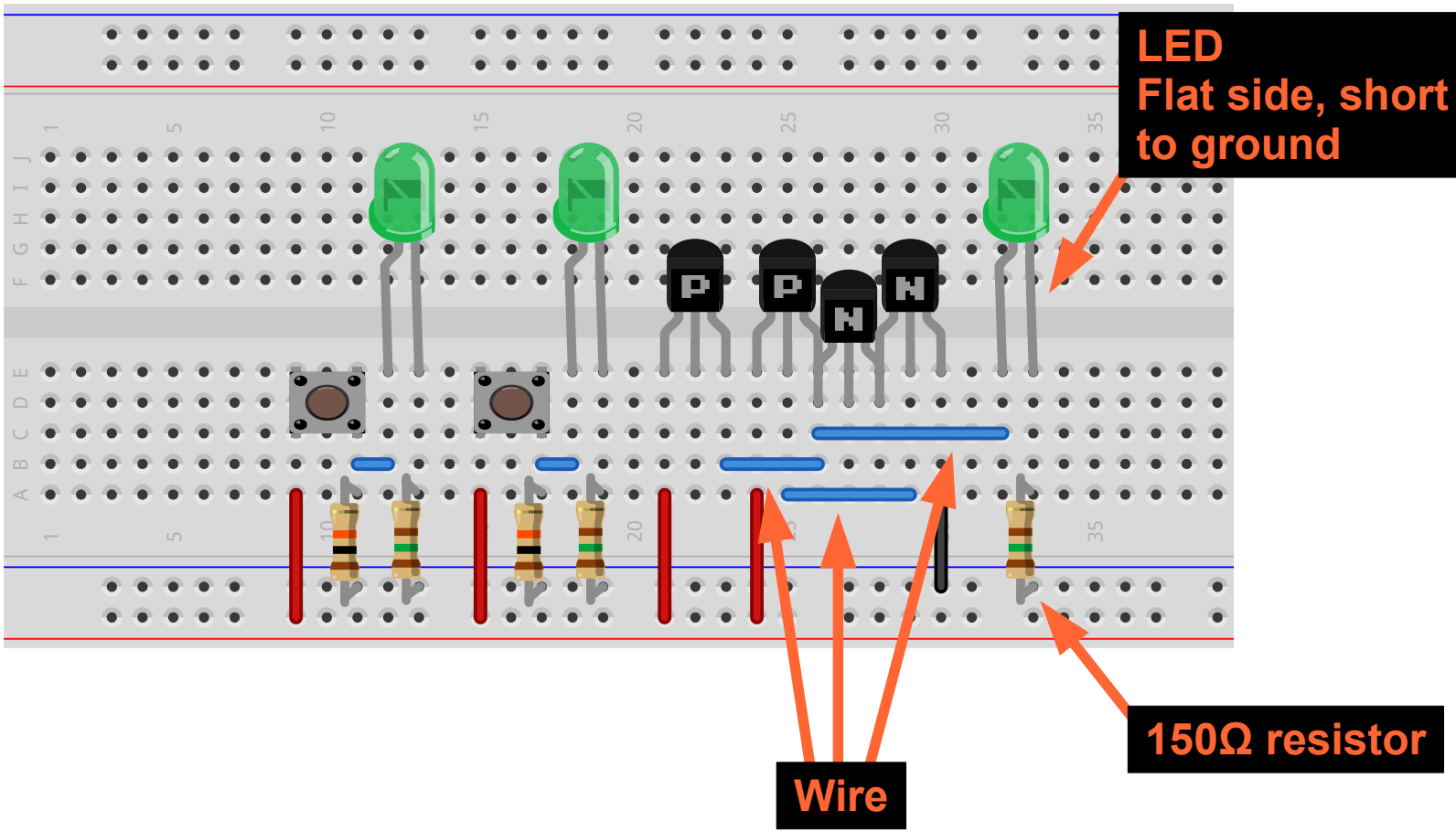
P-channel FET
(E-line, straight legs)
Flat side facing you

N-channel FET
(TO-92 bent legs)
Flat side facing you

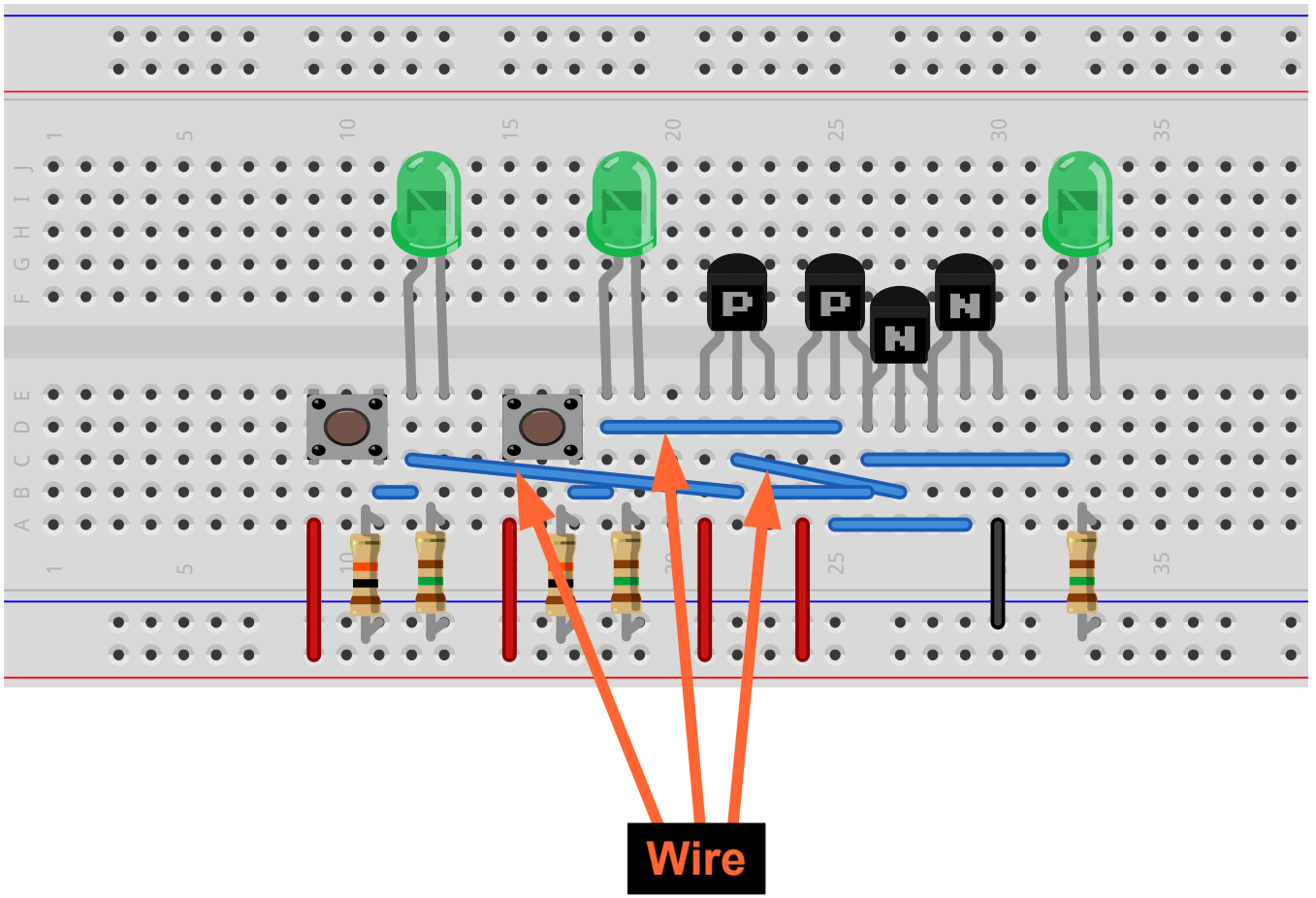
NAND gate – Step 4



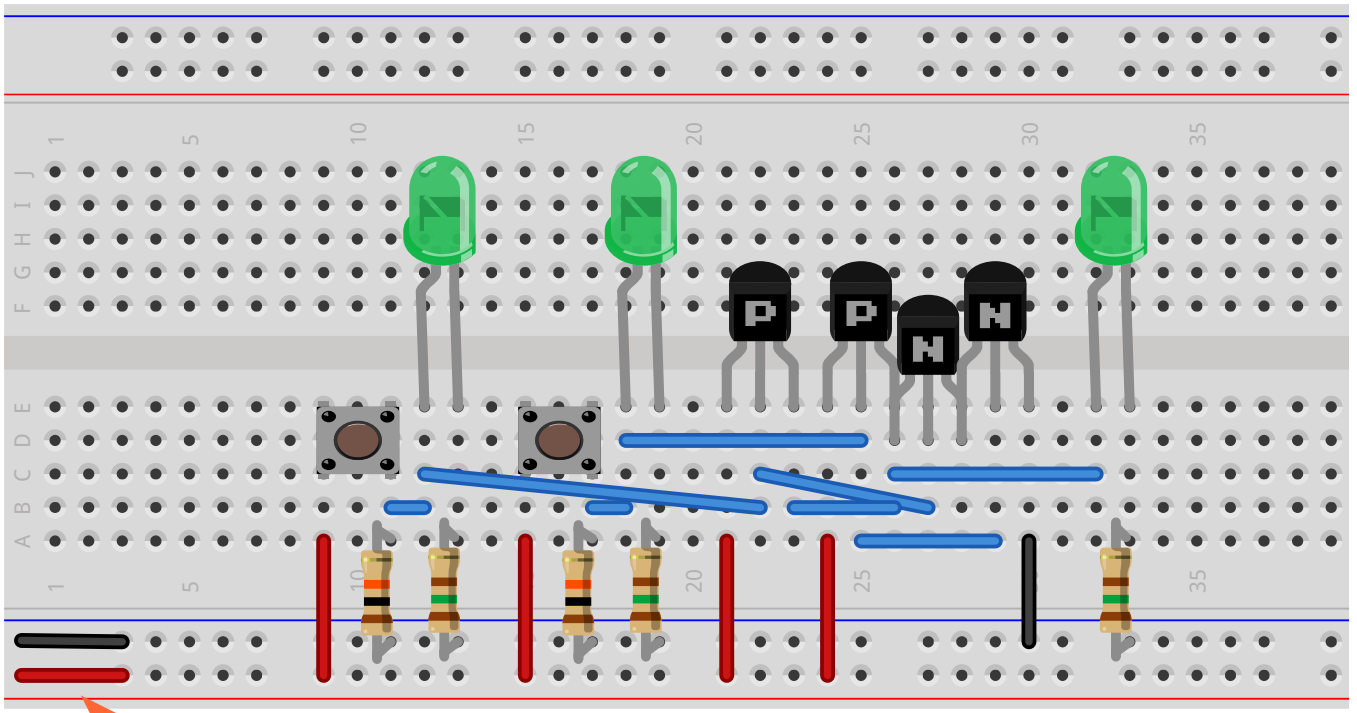
NAND gate – Step 5



NAND gate – Step 6



NAND gate – Power!



NAND gate – Test

- Press and release the buttons to test the NAND gate
- Verify that the inputs and output match the truth table

NAND

A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

Questions