

# From transistors to arithmetic

Let's build a computer together



Steve Wetzel

<https://wetzel.dev/reference/transistors/>

# Goals

- Explain binary, transistors, and NAND gates
- Physically build a NAND gate from transistors
- Digitally build an adder from NANDs
- Show a physical adder

# What is a transistor?

- A transistor is an electronic switch
- Cell of all electronics
- The iPhone 11 has 8.5 billion transistors.
  - more transistors than there are people on Earth

# Binary

- Decimal has 10 digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9)
- Binary has 2 digits (0, 1)
- Count until you run out of digits, then increment next digit and reset current



# Binary

00	000000000	08	00001000
01	000000001	09	00001001
02	000000010	10	00001010
03	000000011	11	00001011
04	00000100	12	00001100
05	00000101	13	00001101
06	00000110	14	00001110
07	00000111	15	00001111

Adding

$$\begin{array}{r} 1 \\ 28 \\ +14 \\ \hline 42 \end{array}$$

$$\begin{array}{r} 111 \\ 00011100 \\ +00001110 \\ \hline 00101010 \end{array}$$

# Logic Gates

NOT



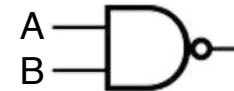
A	Output
0	1
1	0

AND



A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

NAND



A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0

OR



A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

NOR



A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

XOR

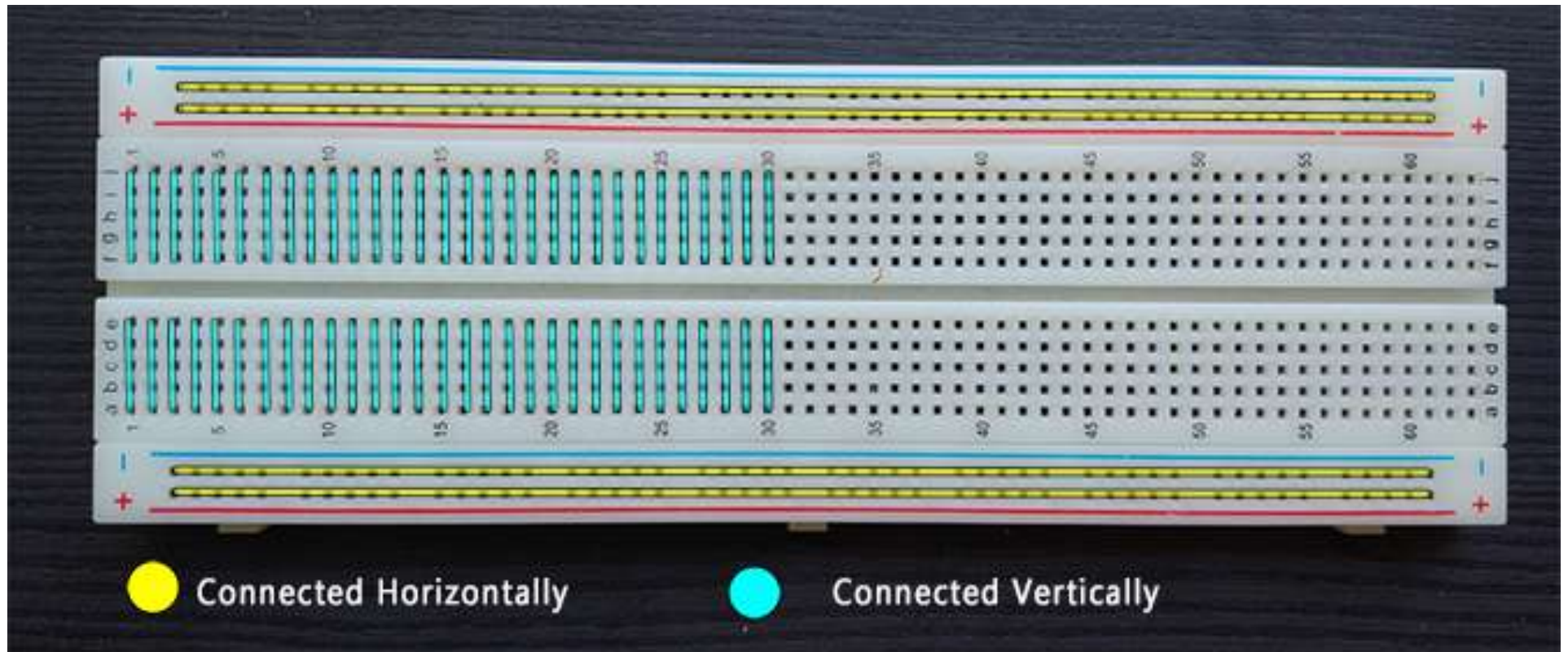


A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0



# Components

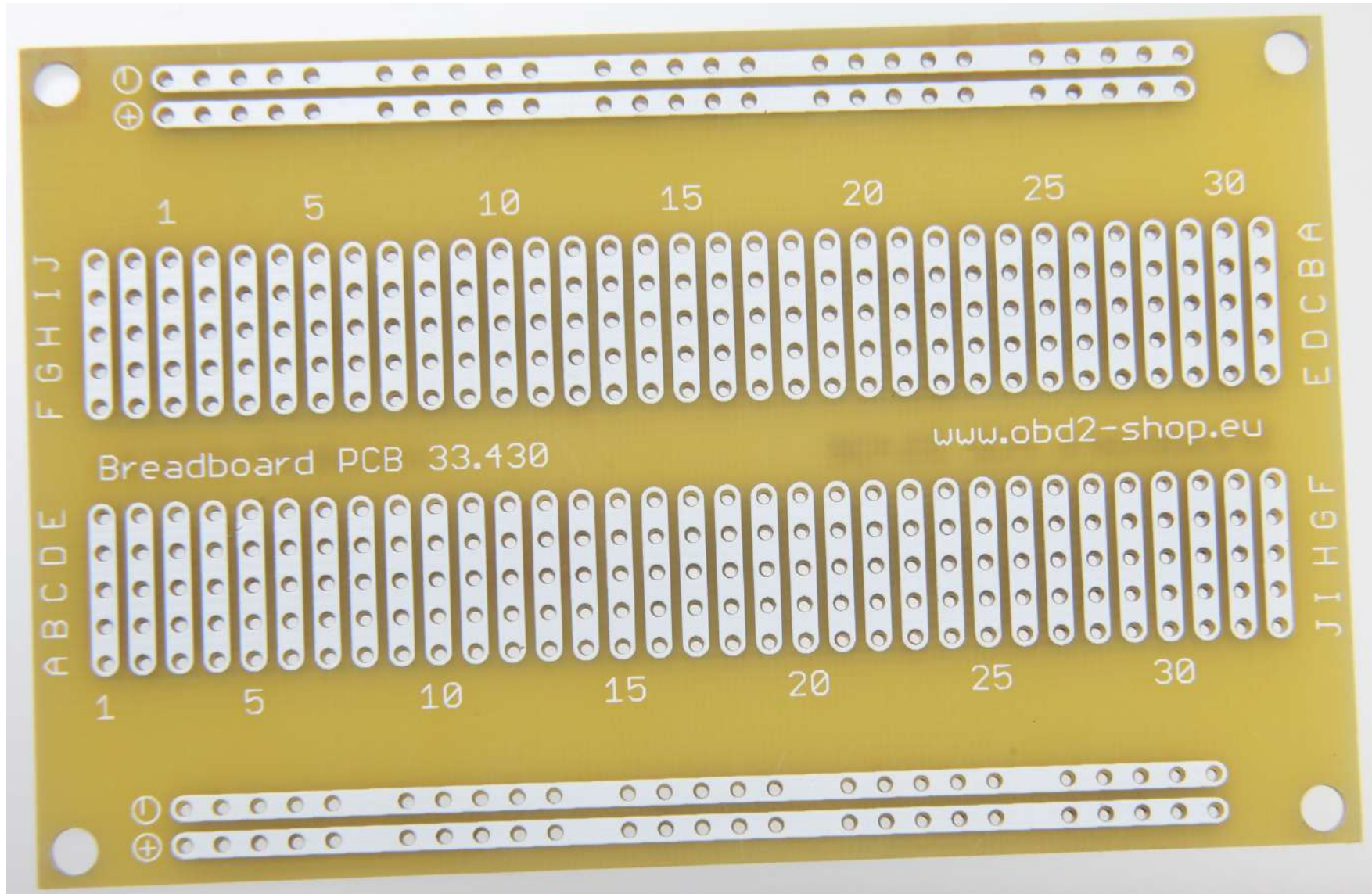
# Breadboard



# Breadboard

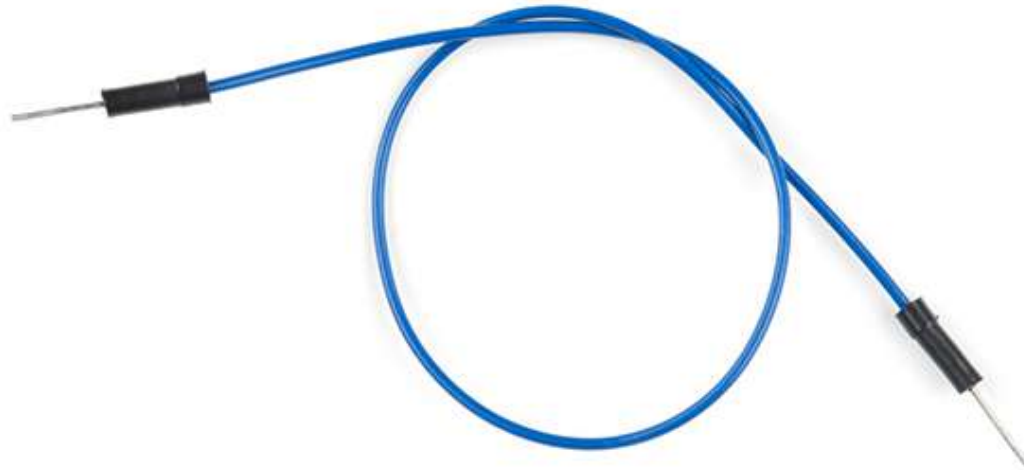


# Breadboard





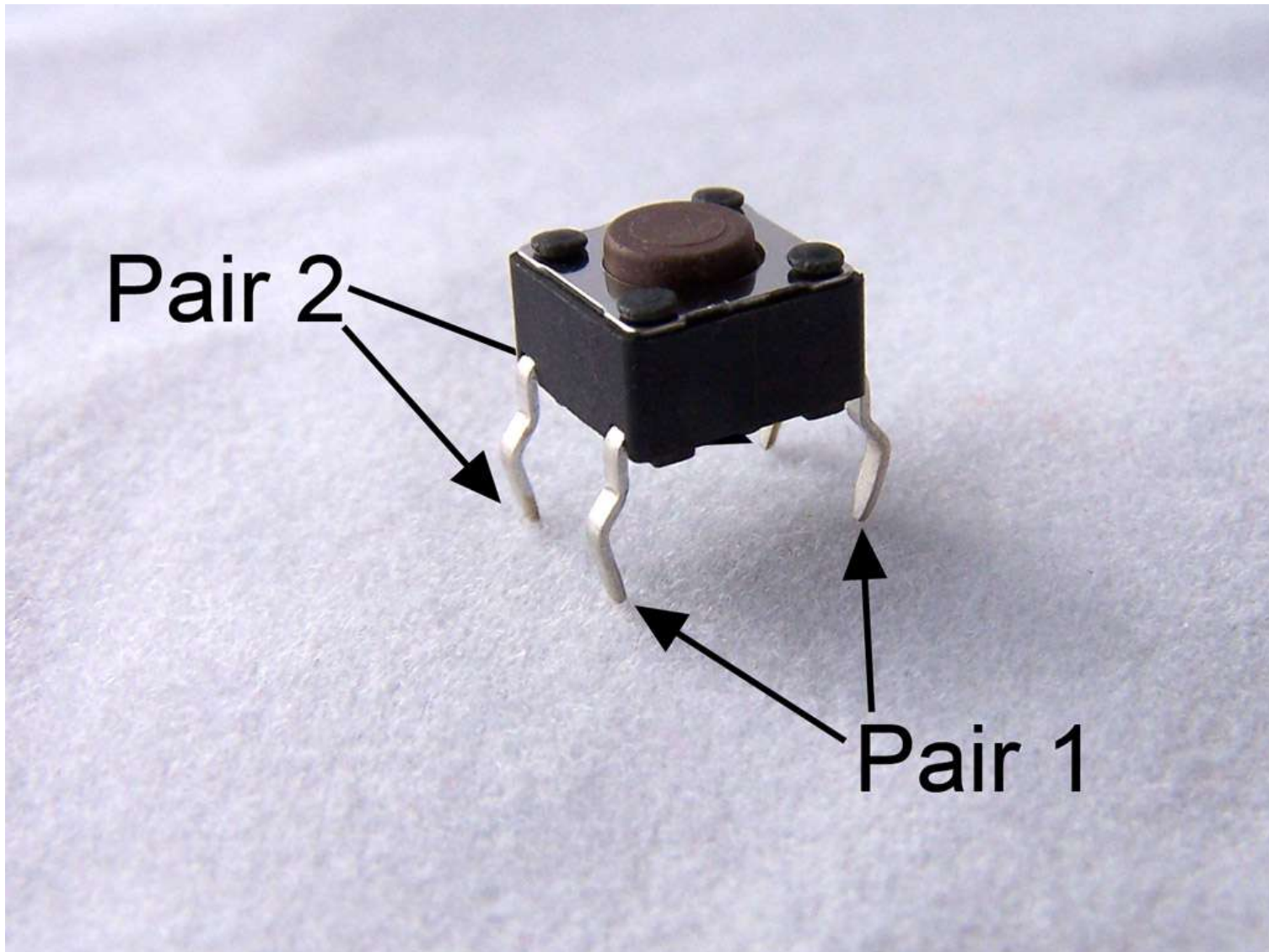
# Jumper Wire



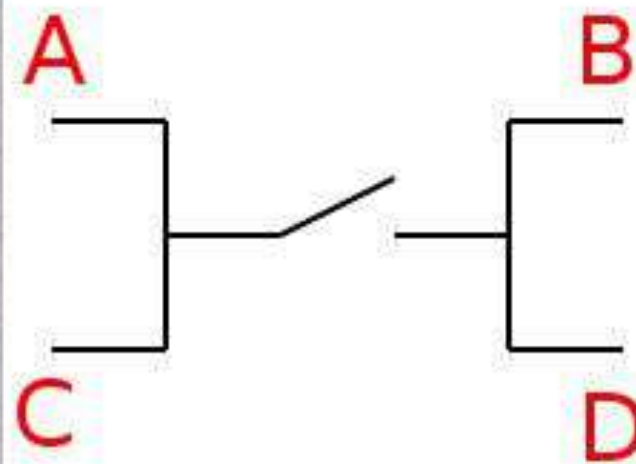
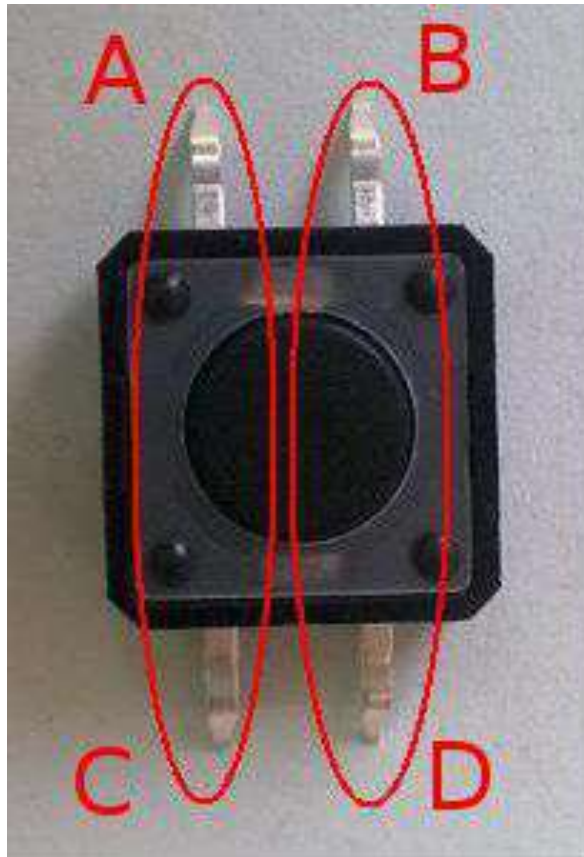
# Resistors



# Momentary Push Button Switch

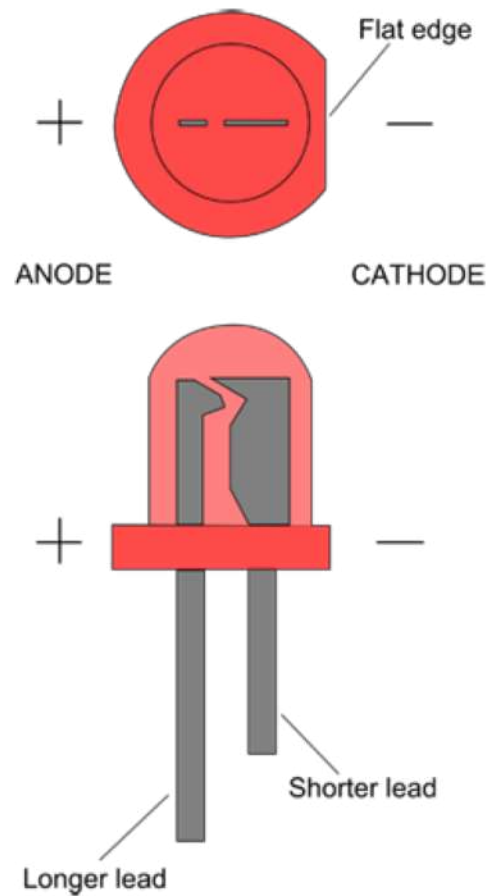


# Momentary Push Button Switch

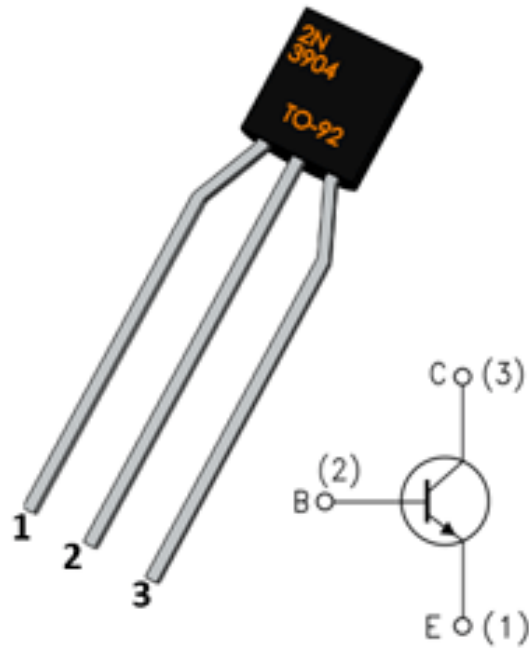




# Light Emitting Diode



# Transistors



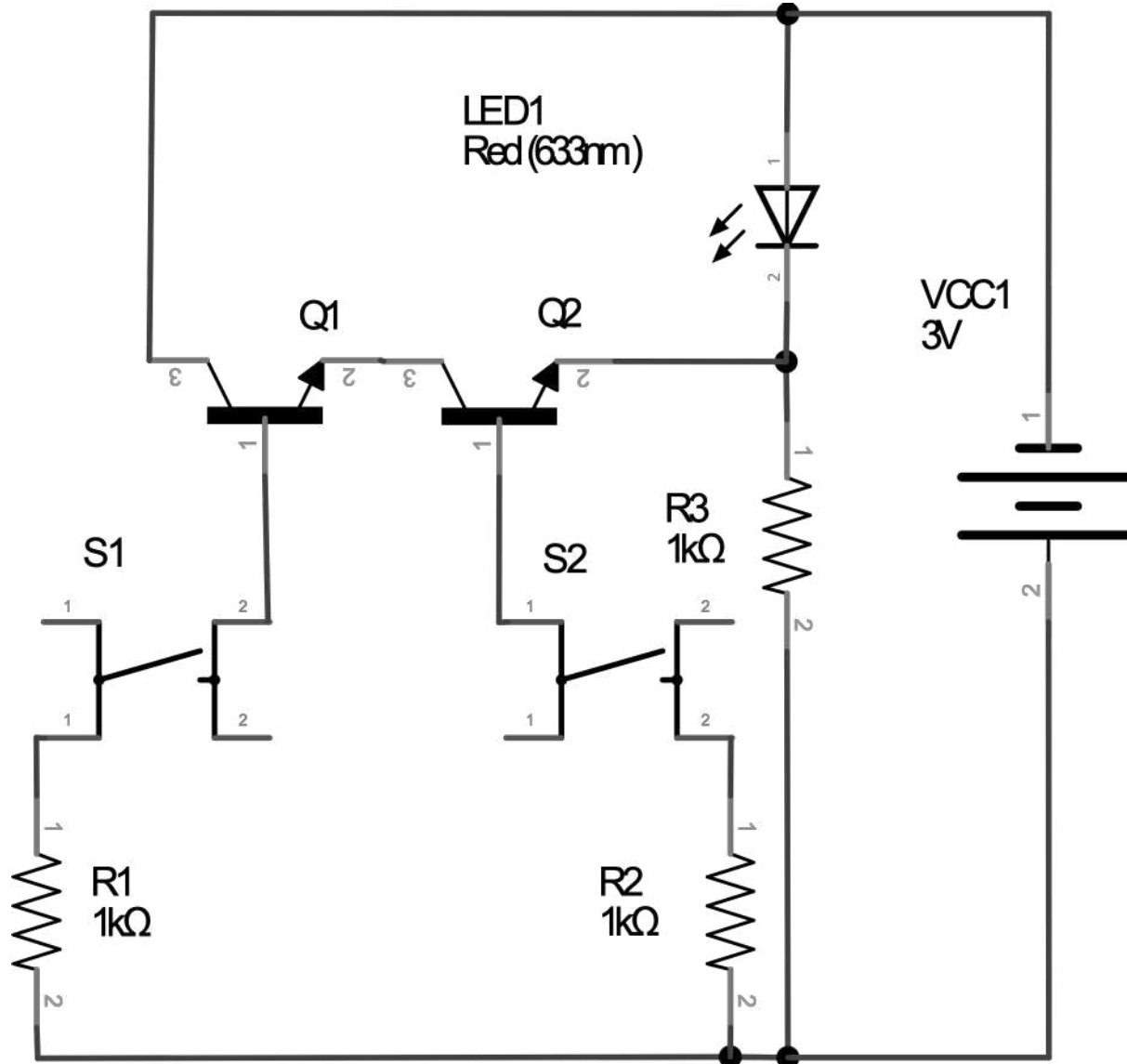
2N3904	
1	Emitter
2	Base
3	Collector

# Assembly

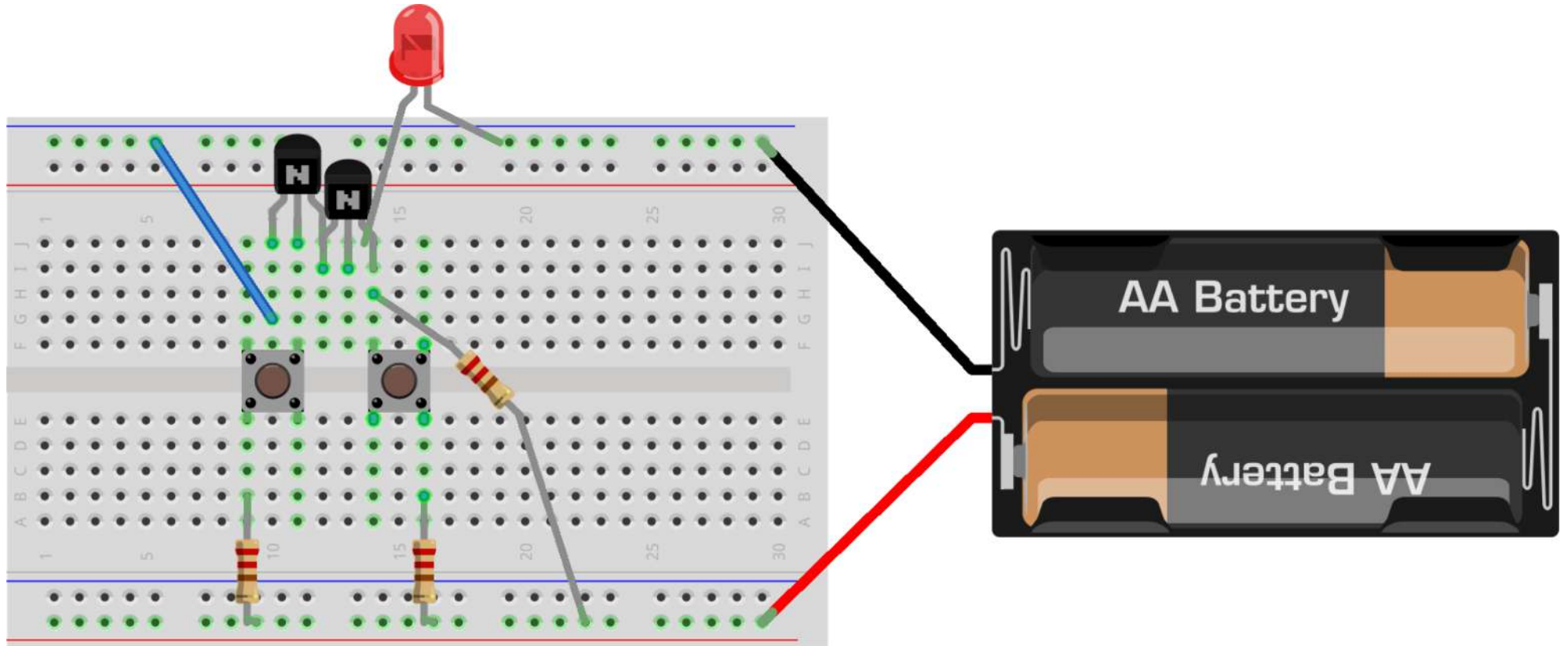
# Pro Tips

- Don't put batteries in until end
- Push the components in firmly
- You can bend the pins a bit to make things fit
- Other spots in same row will work
  - But it's easier to follow number

# NAND Circuit

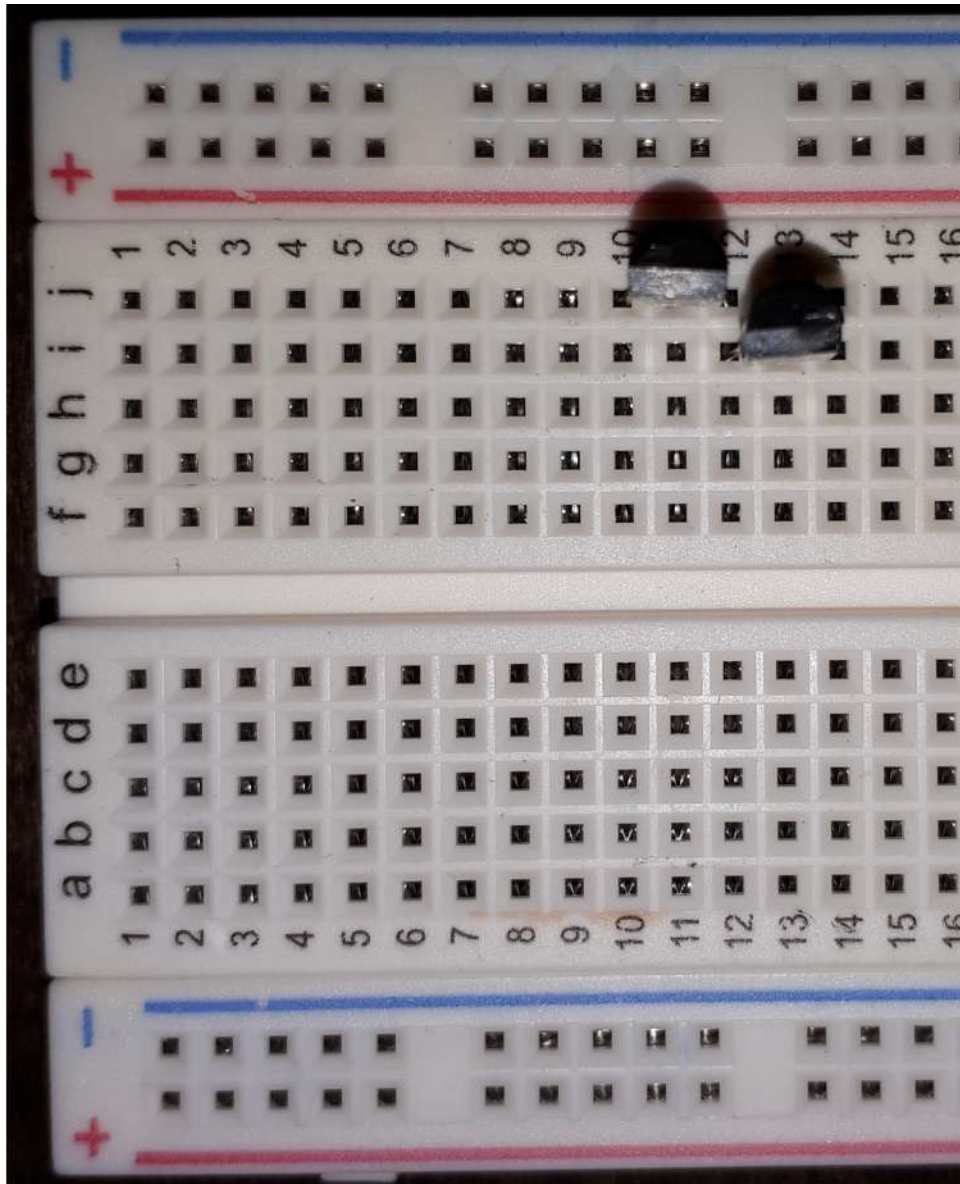


# NAND Circuit



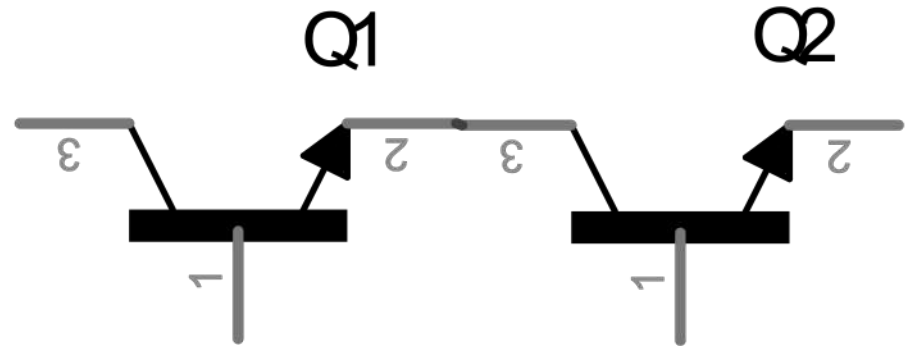
fritzing



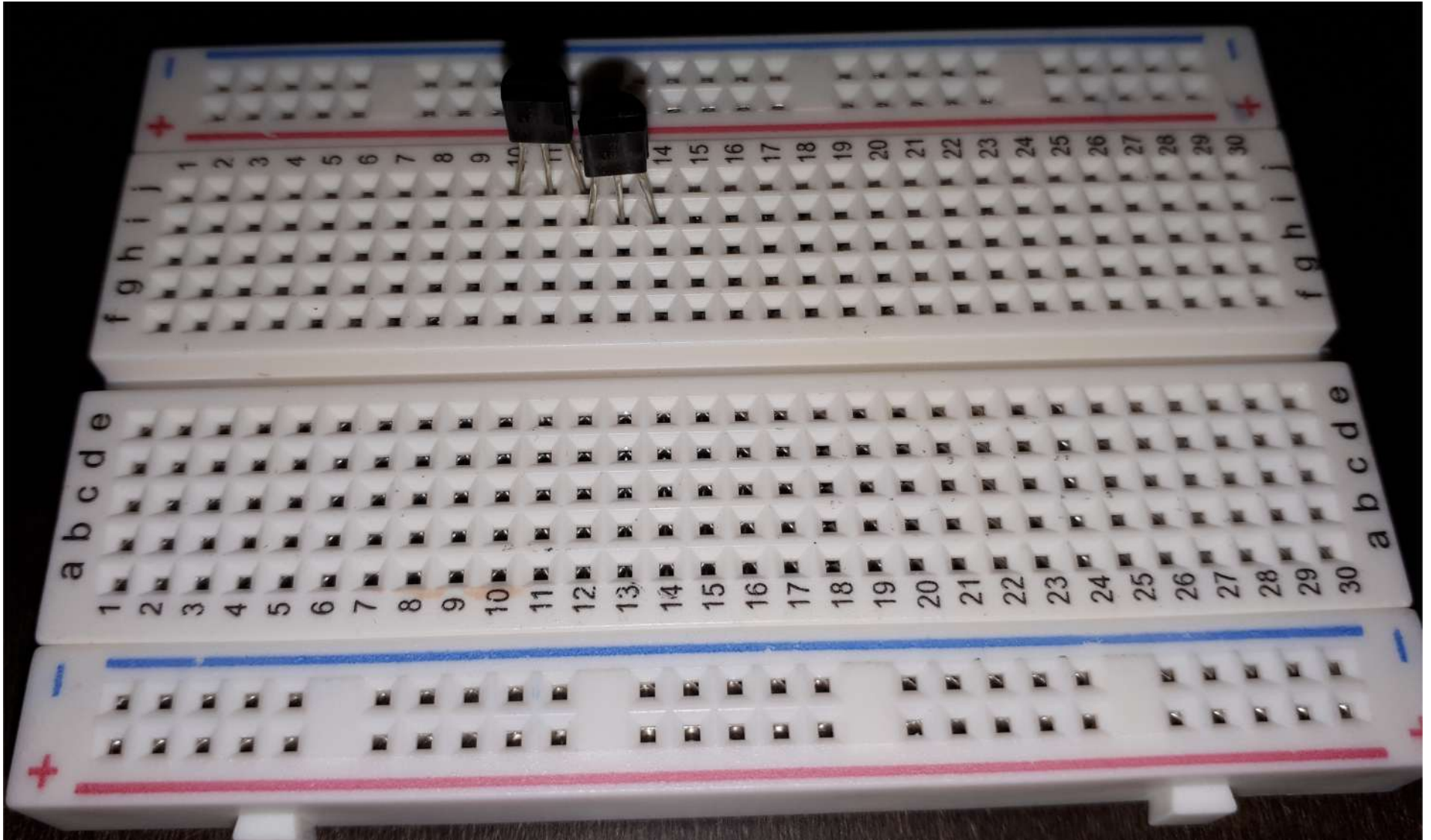


T1: j10, j11, j12

T2: i12, i13, i14

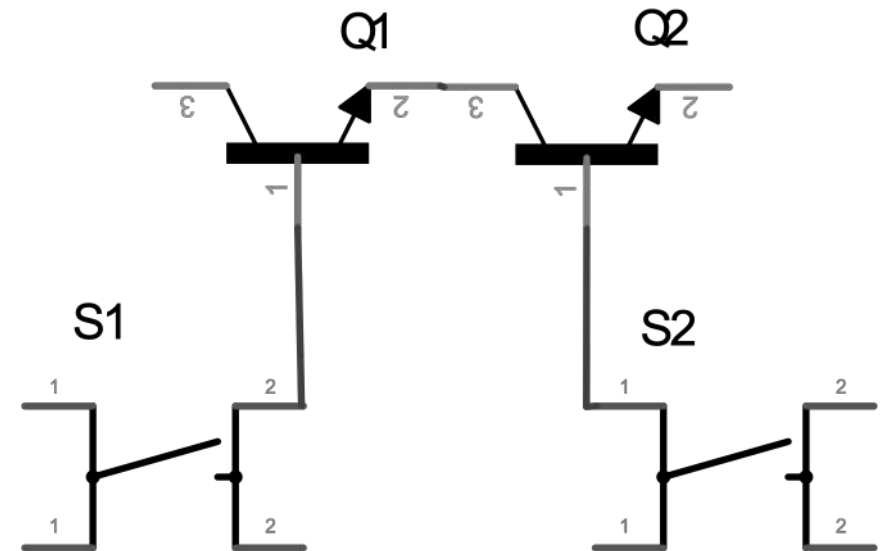
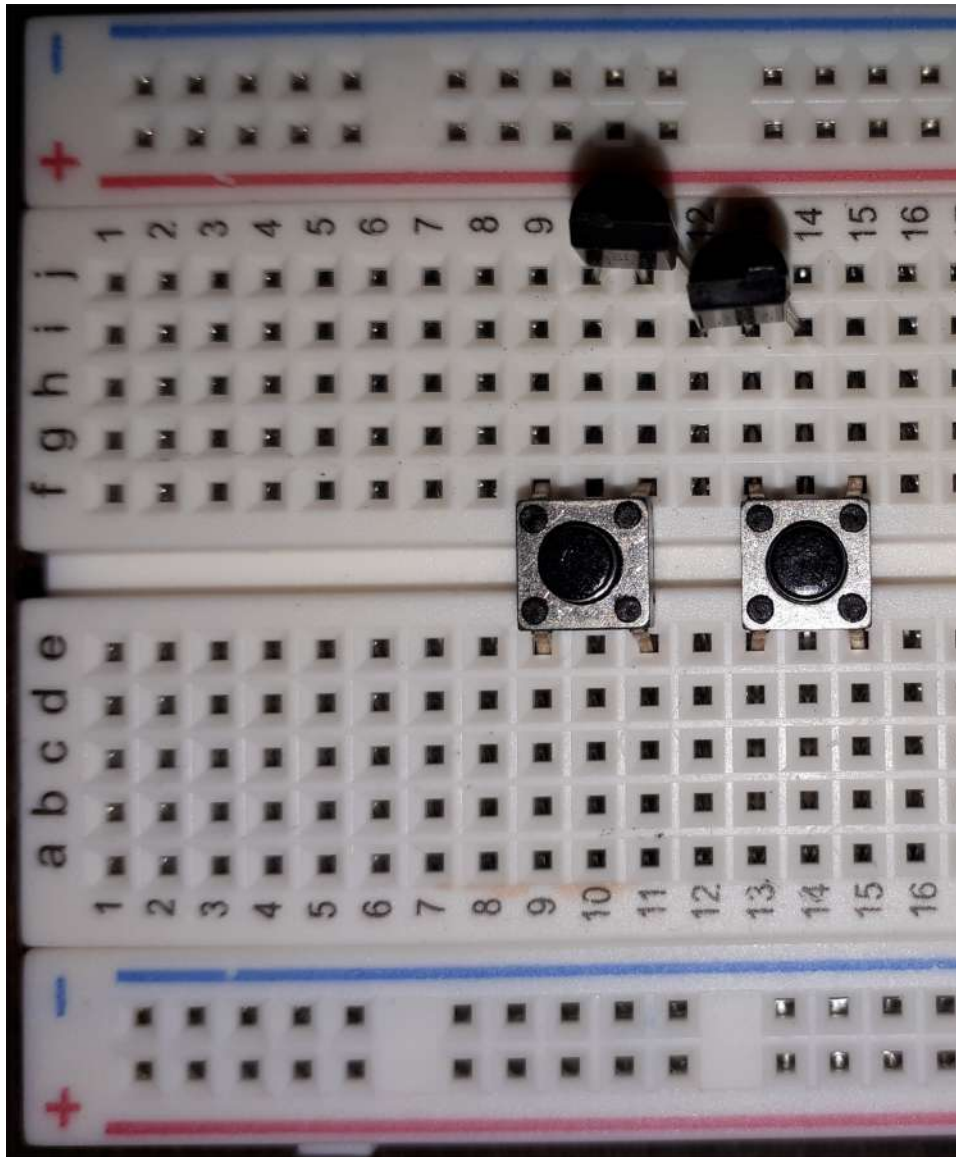






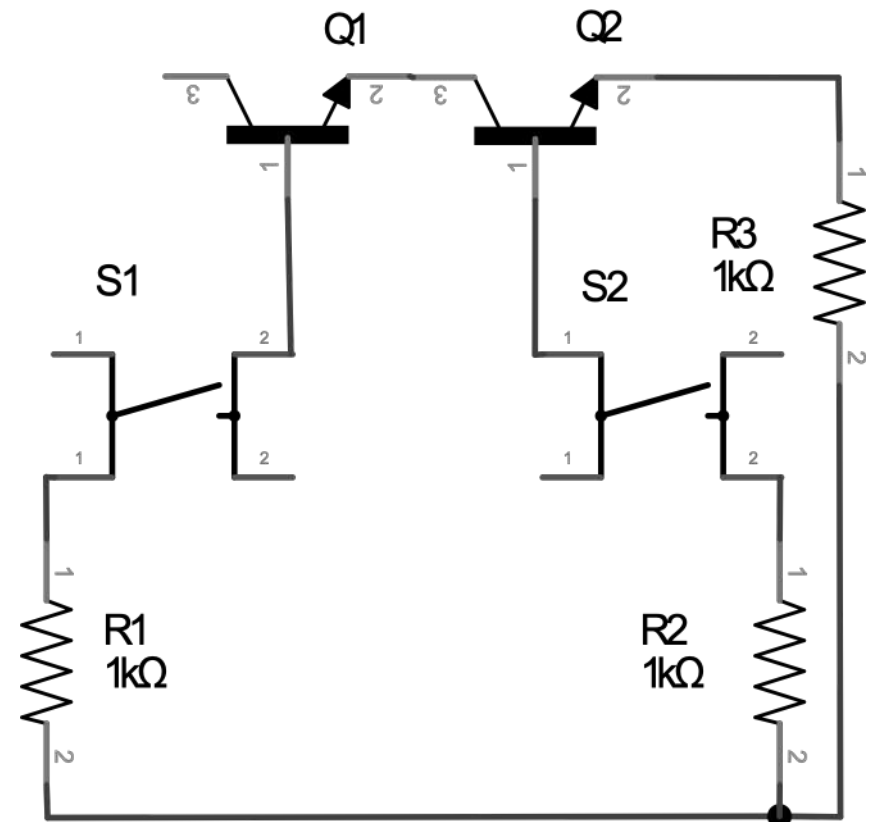
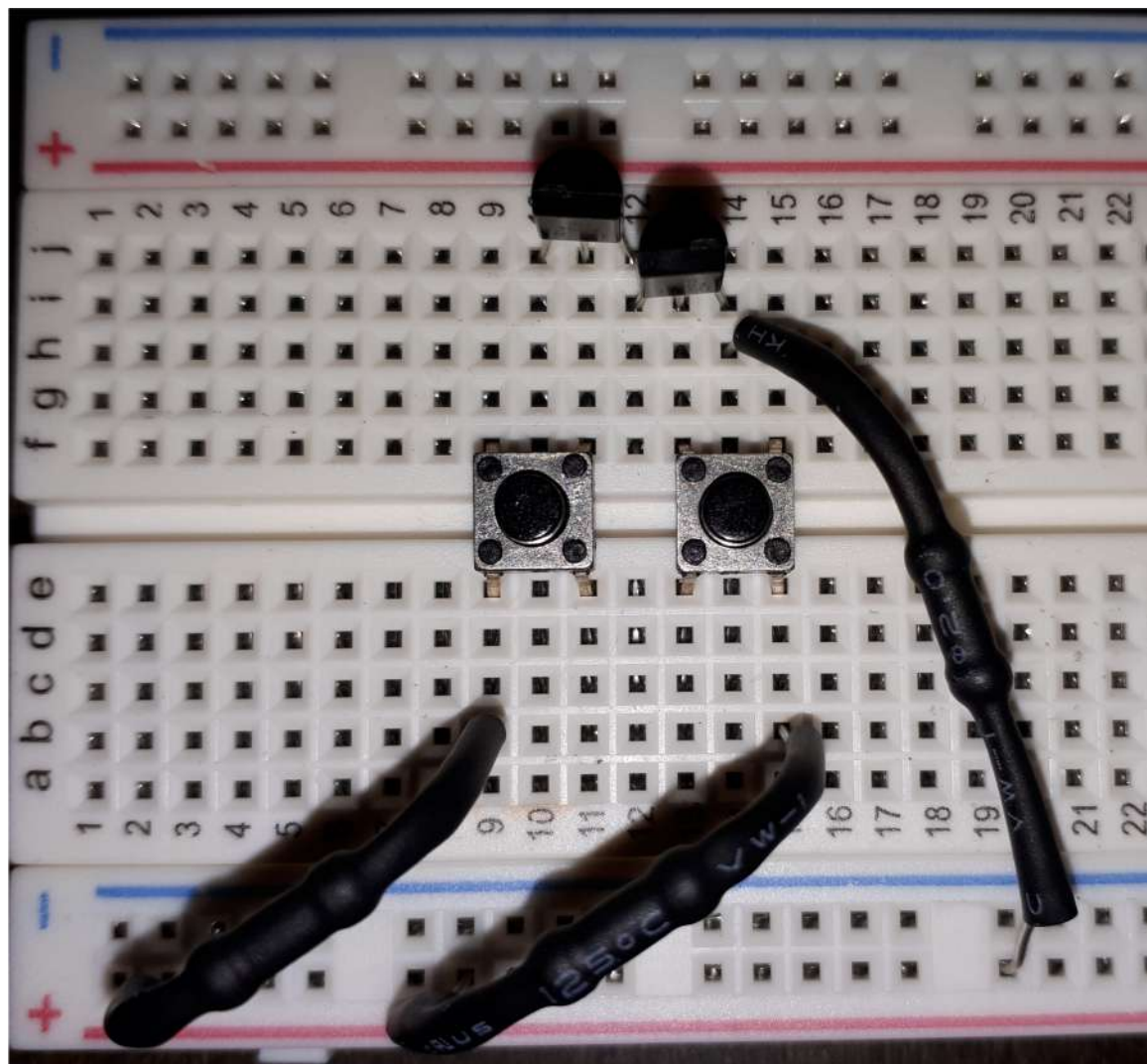
T1: j10, j11, j12

T2: i12, i13, i14



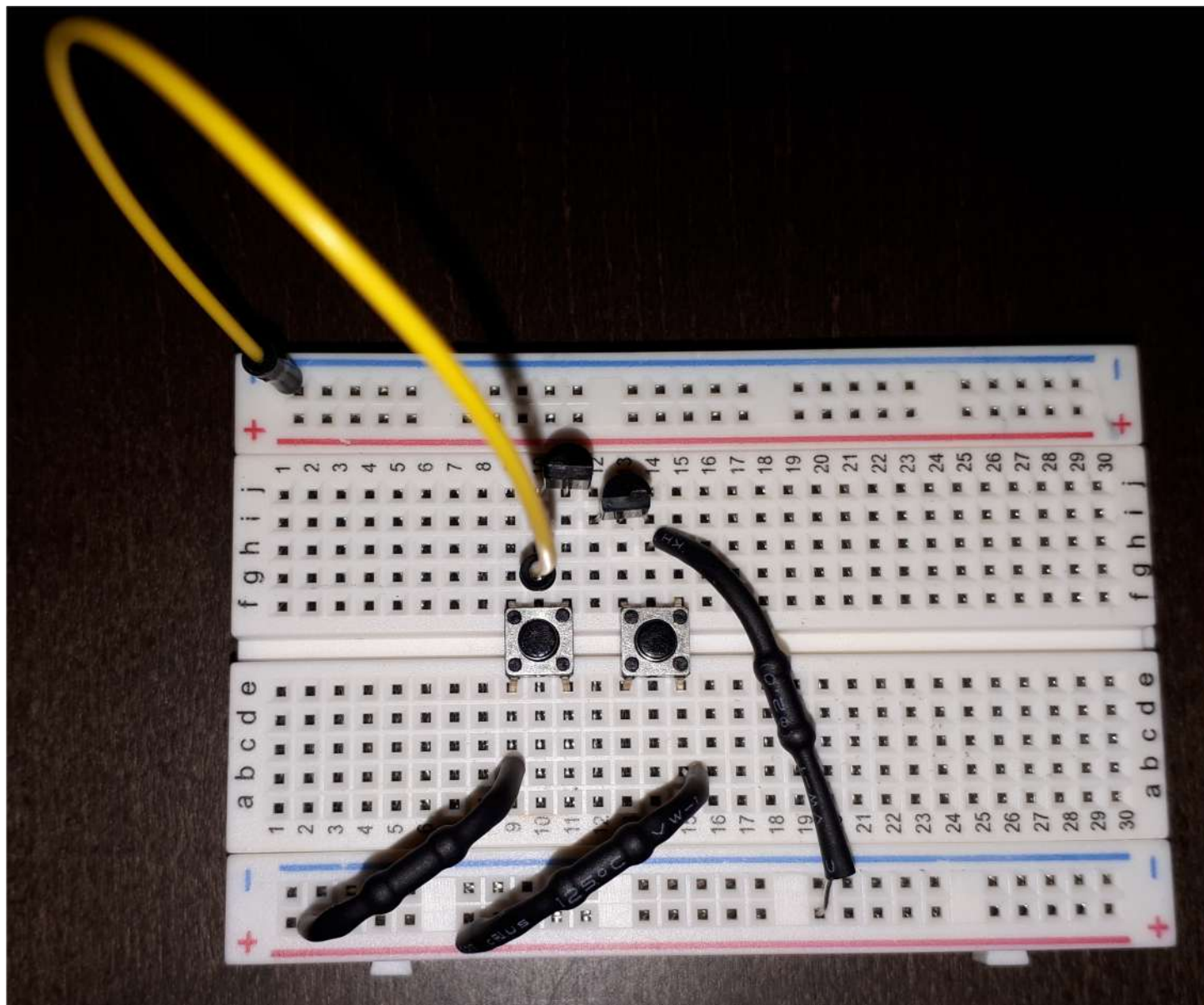
B1: e9, f9, e11, f11

B2: e13, f13, e15, f15

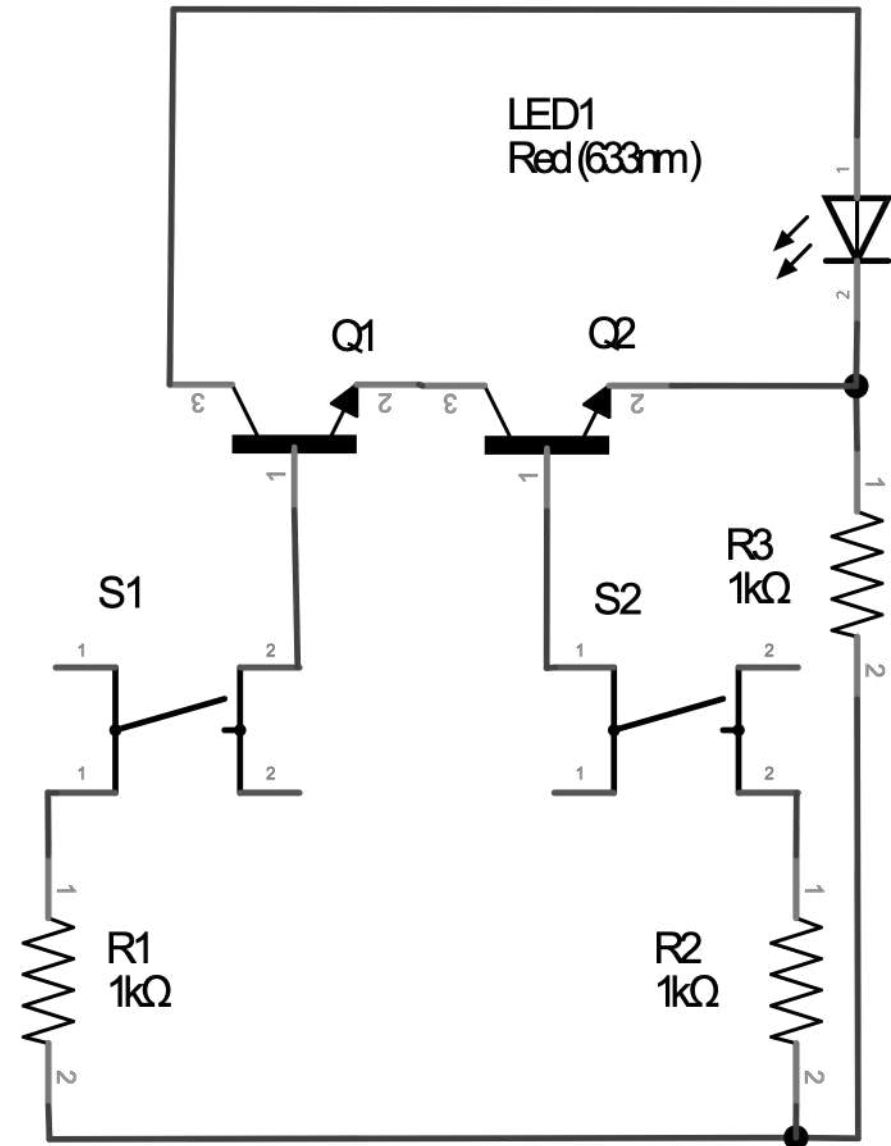


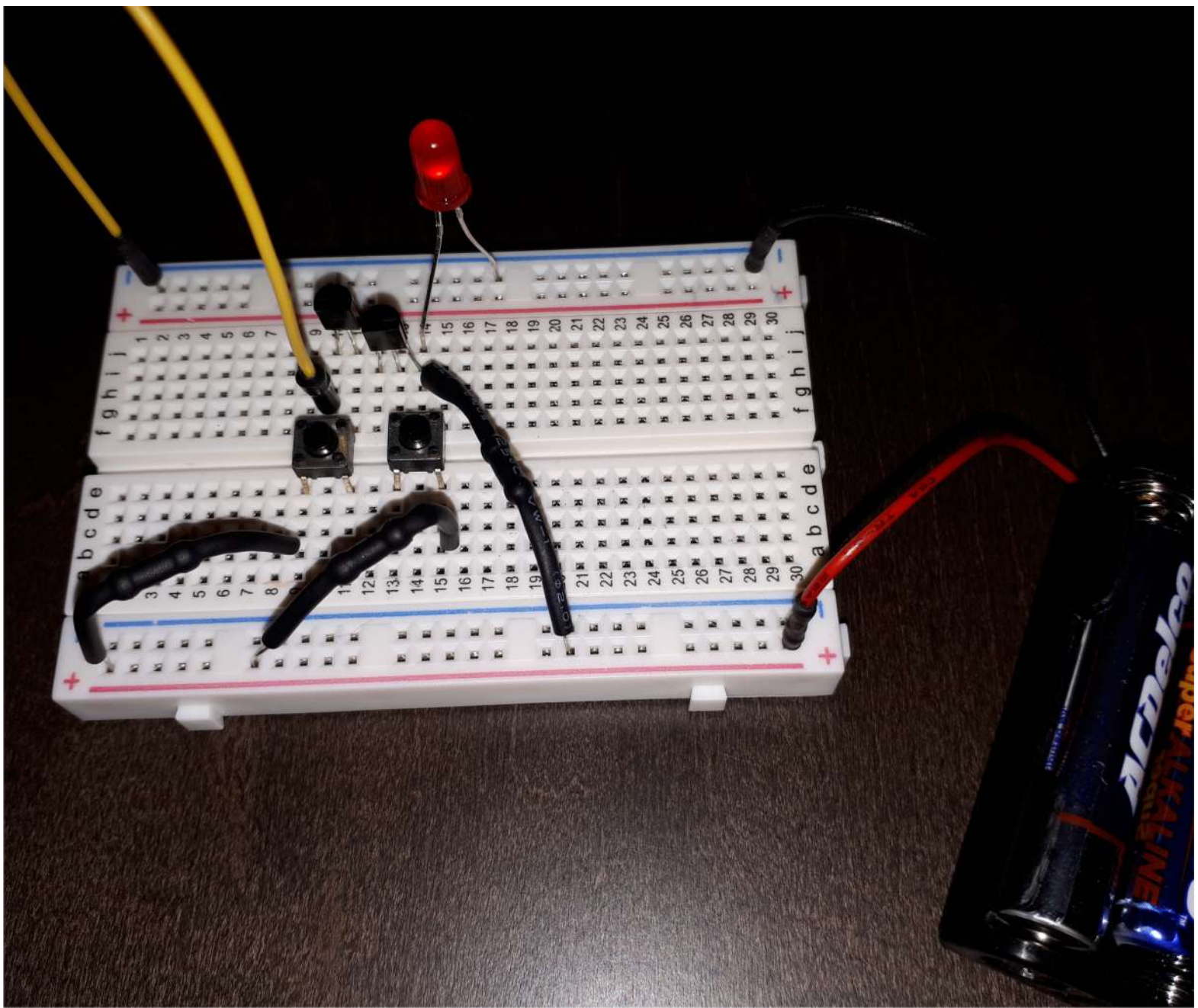
R1: b9  
R2: b15  
R3: h14



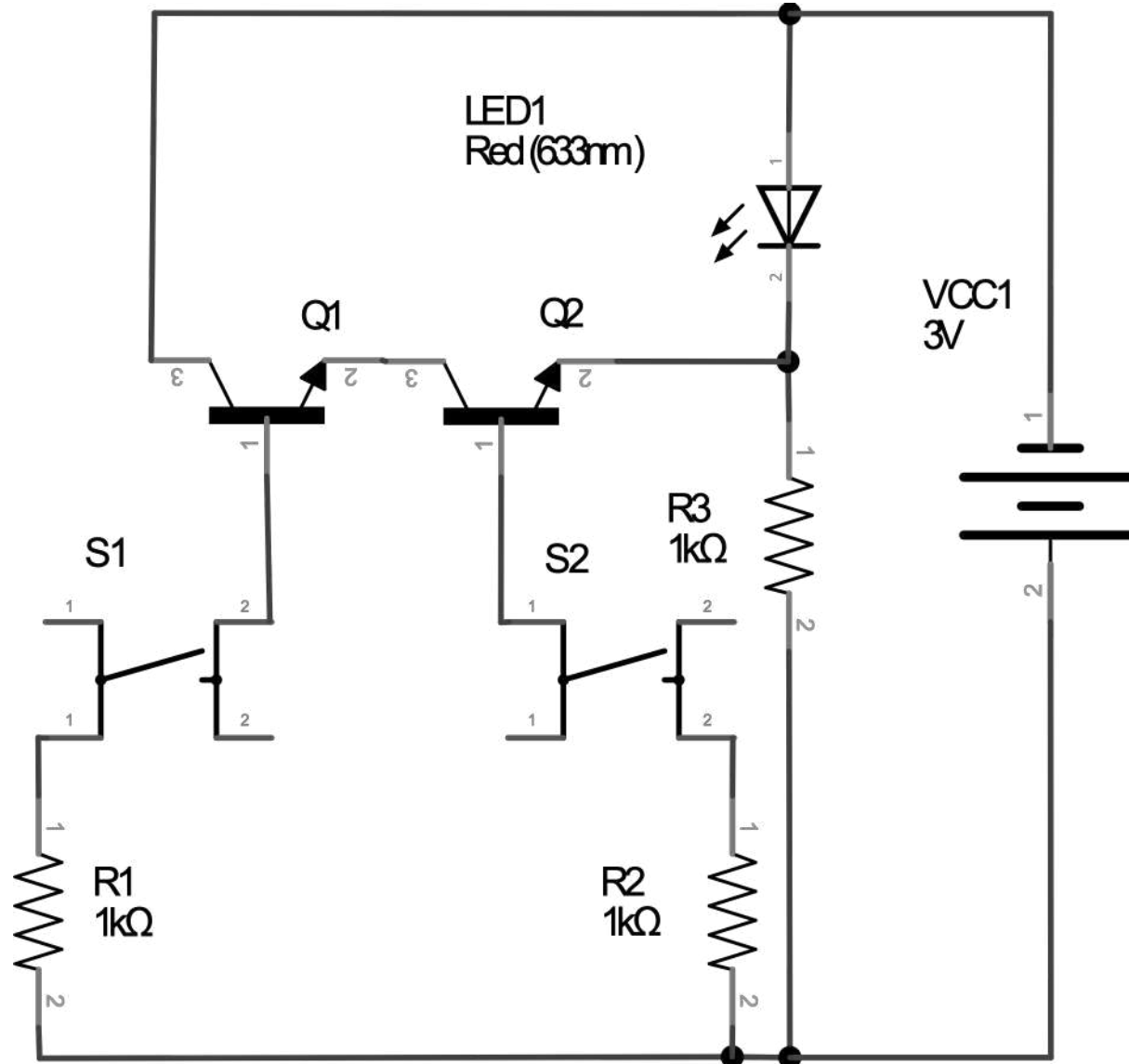


J1: g10





# NAND Circuit



nandgame.com



<https://circuitverse.org/users/10938/projects/31604>

