From transistors to arithmetic

Let’s build a computer together

Steve Wetzel

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

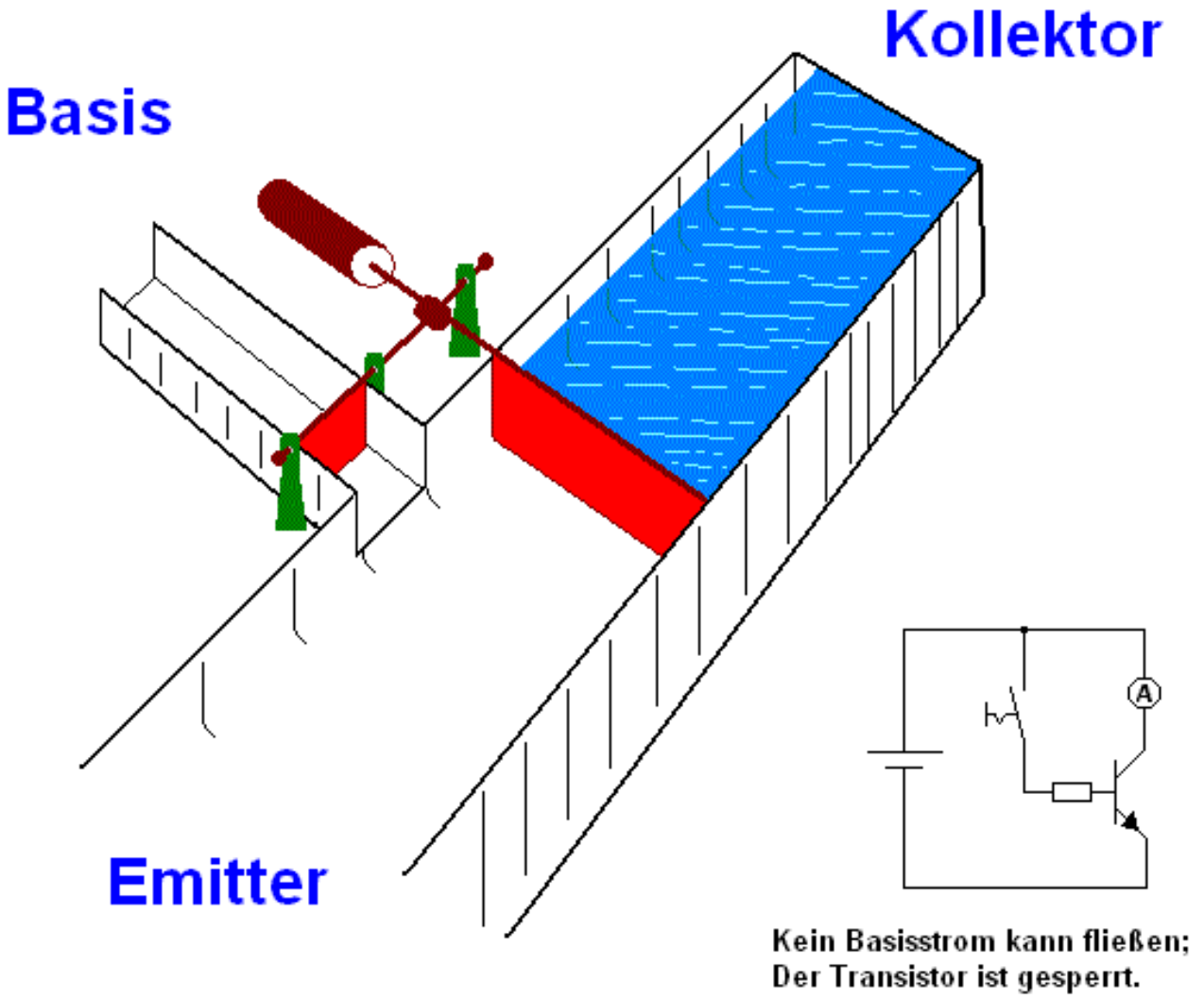
Goals

- 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

Transistors: Water analogy



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


0 0 0 0 0 0

Binary

00	00000000	08	00001000
01	00000001	09	00001001
02	00000010	10	00001010
03	00000011	11	00001011
04	00000100	12	00001100
05	00000101	13	00001101
06	00000110	14	00001110
07	00000111	15	00001111

Adding

```
  1          111
 28     00011100
+14    +00001110
--    ----------
 42     00101010
```

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

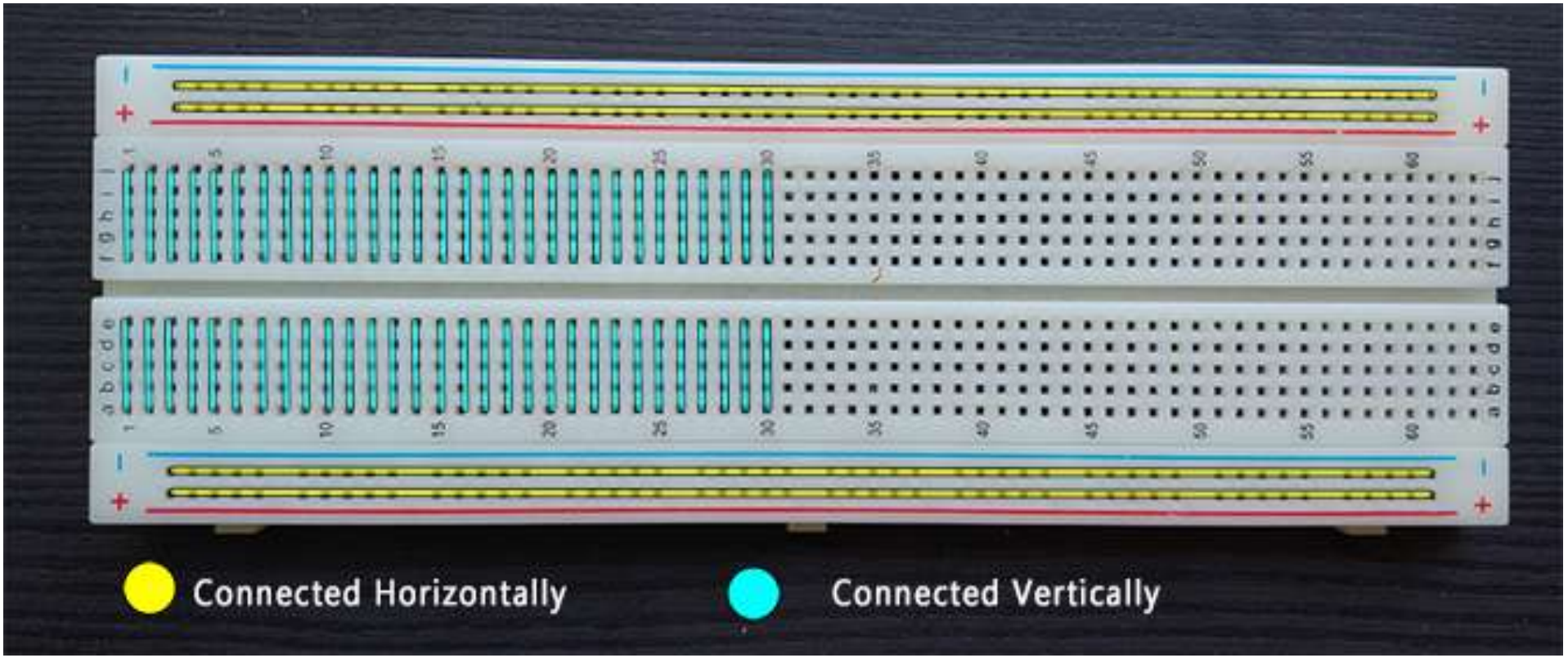
A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

XOR

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

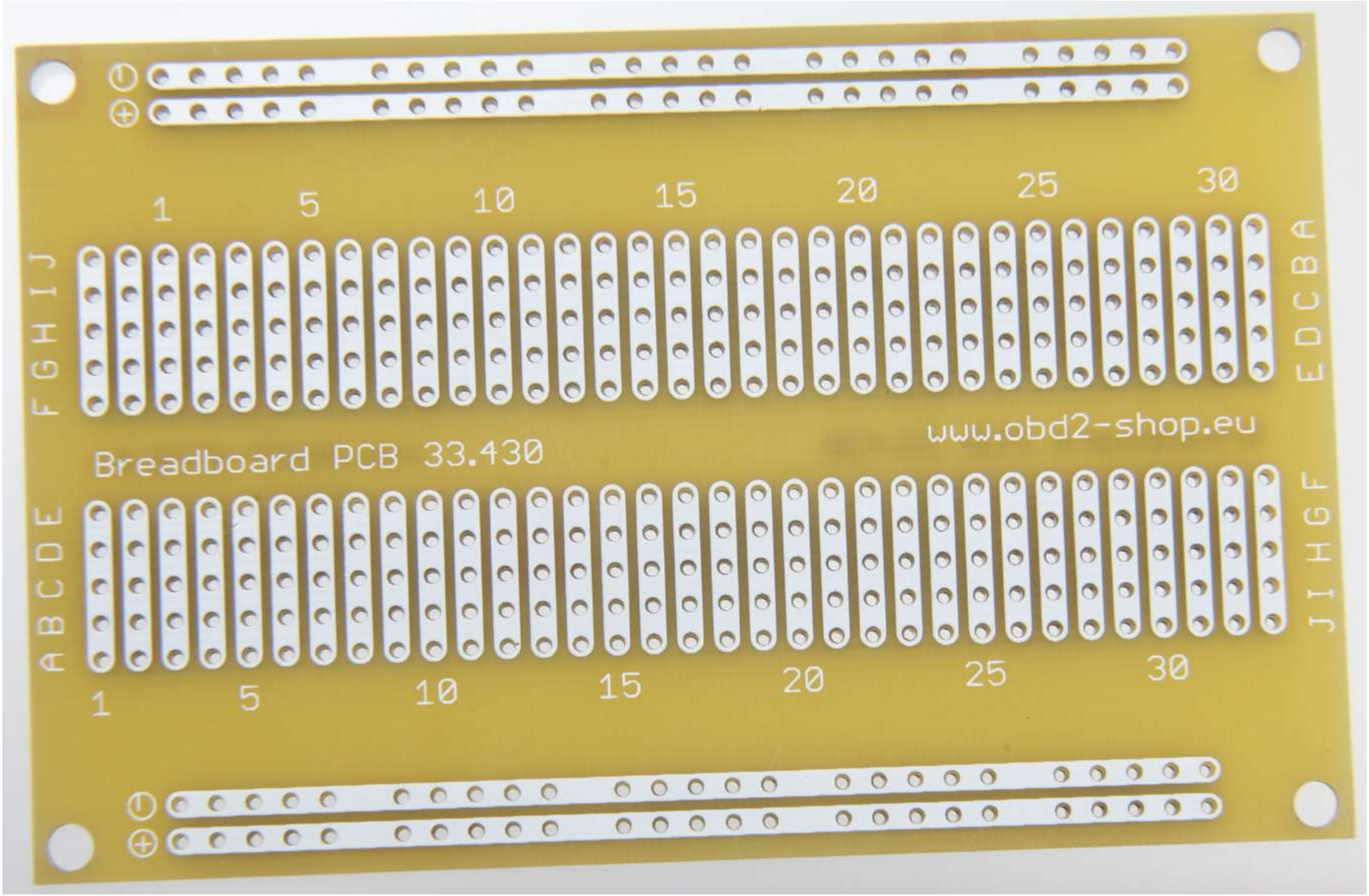
Components

Breadboard

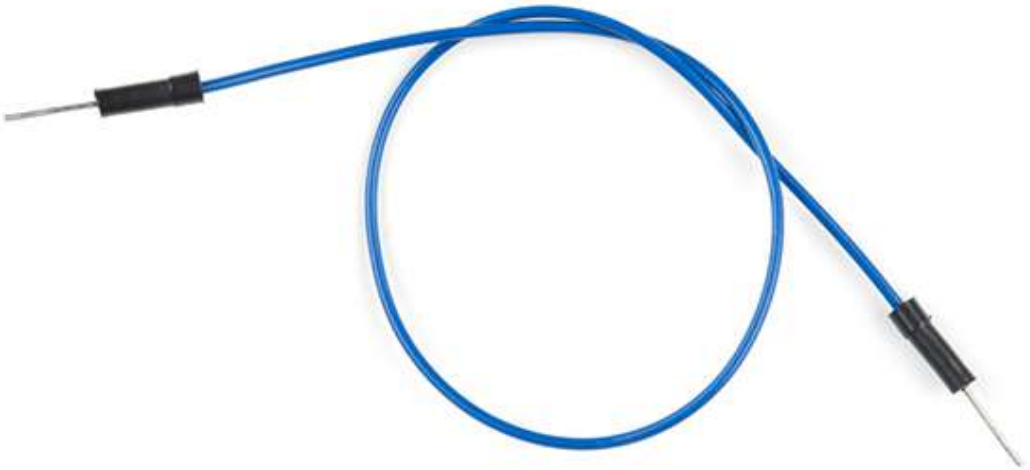


Breadboard

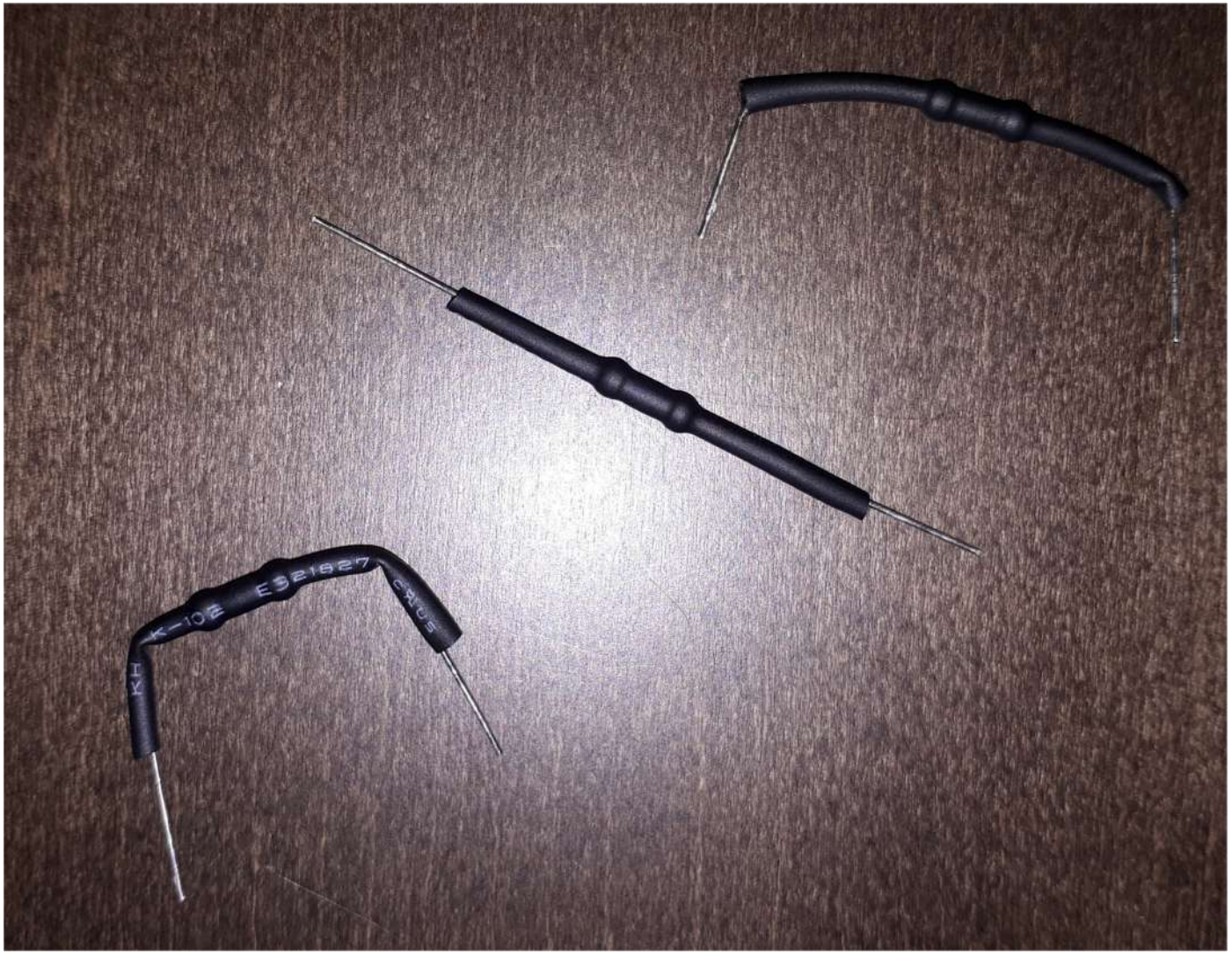
Breadboard


1
5
10
15
20
25
30
A B C D E
F G H I J
Breadboard PCB 33.430
www.obd2-shop.eu
J I H G F
E D C B A
1
5
10
15
20
25
30

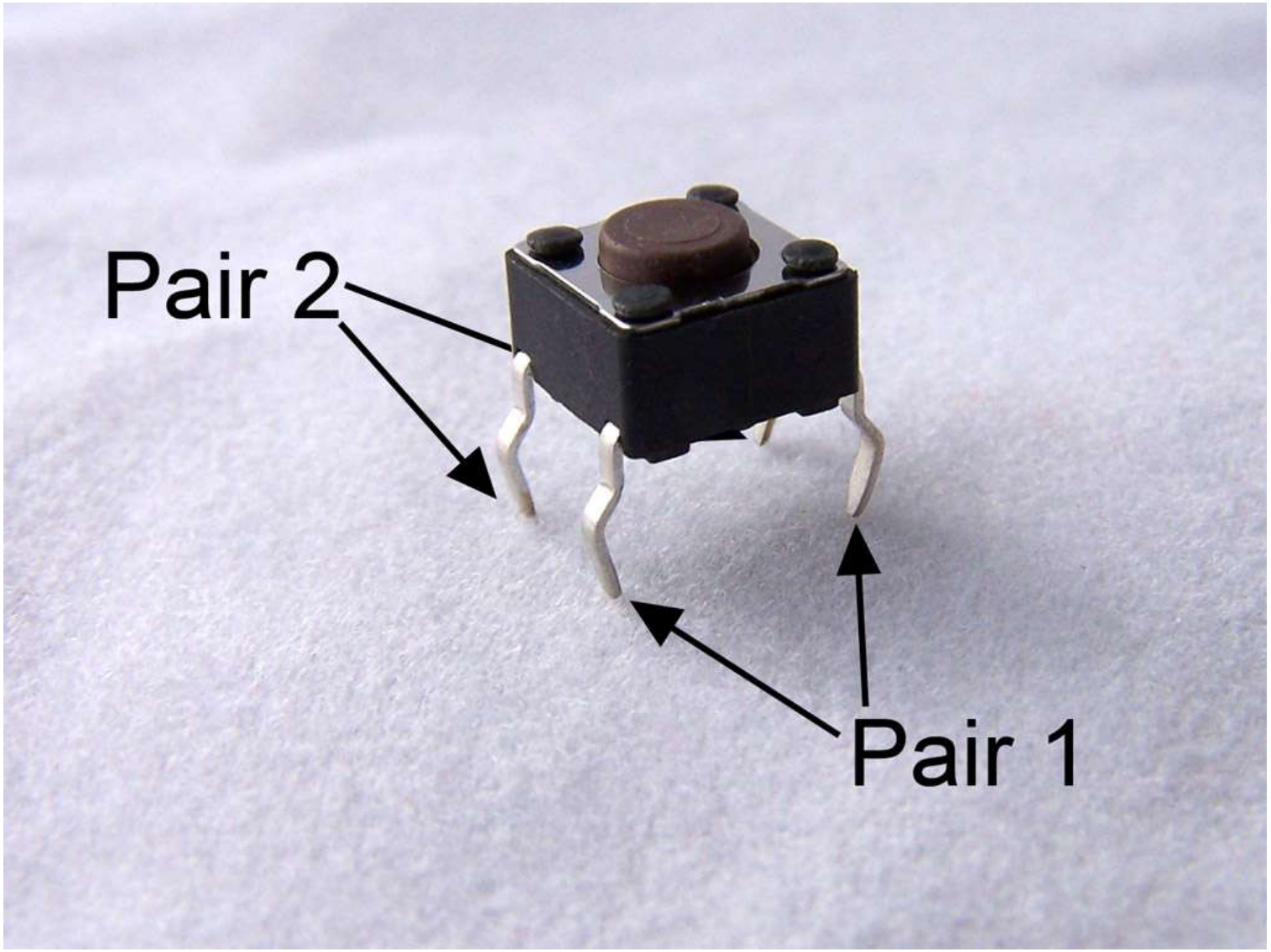
Jumper Wire



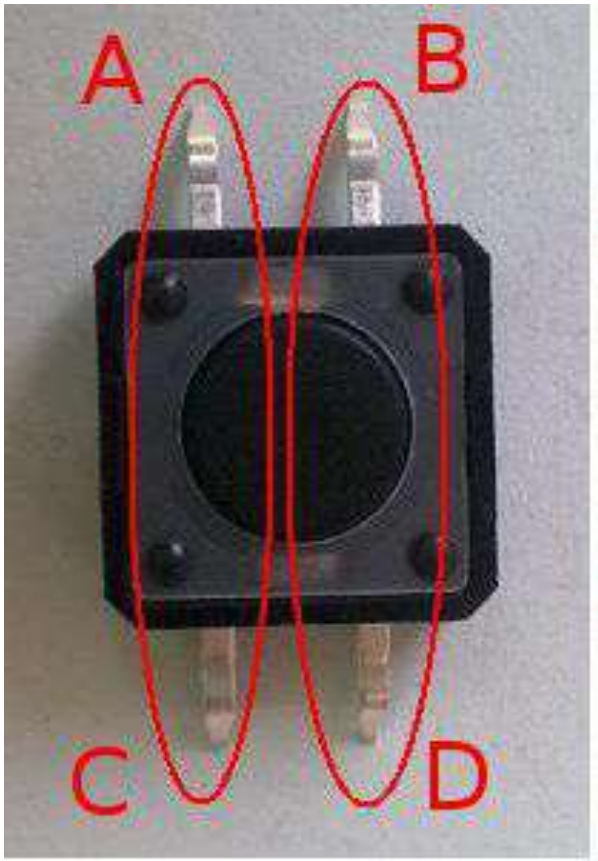
Resistors

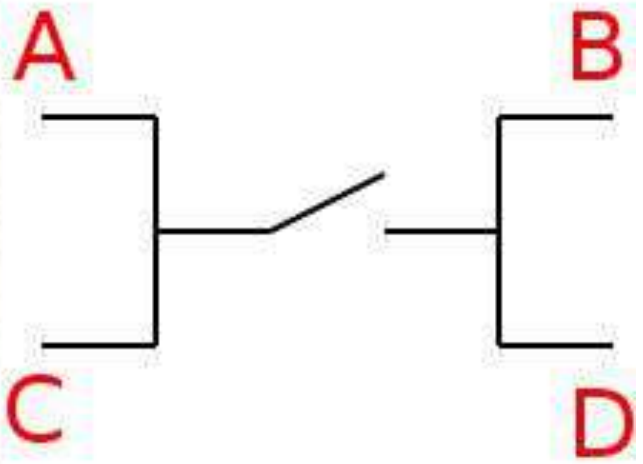


Momentary Push Button Switch

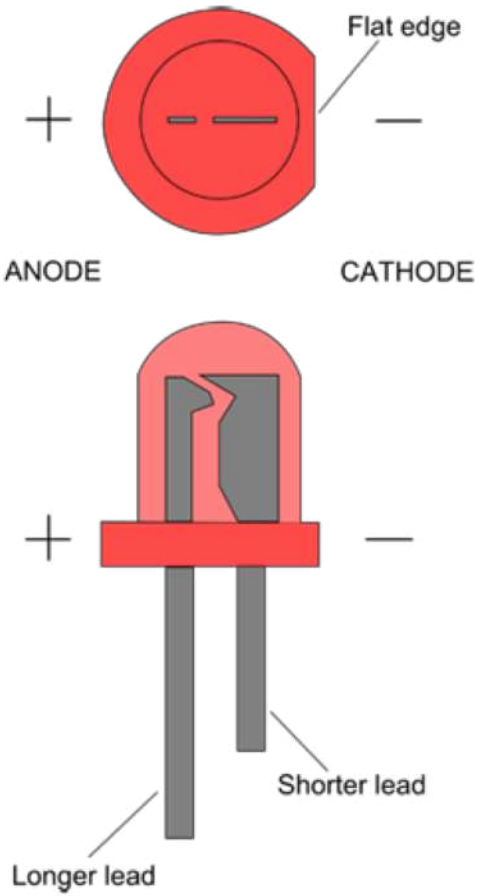


Momentary Push Button Switch

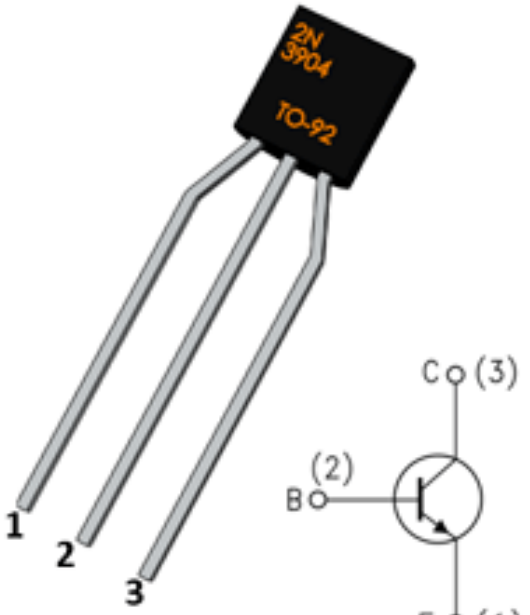




Light Emitting Diode



Transistors



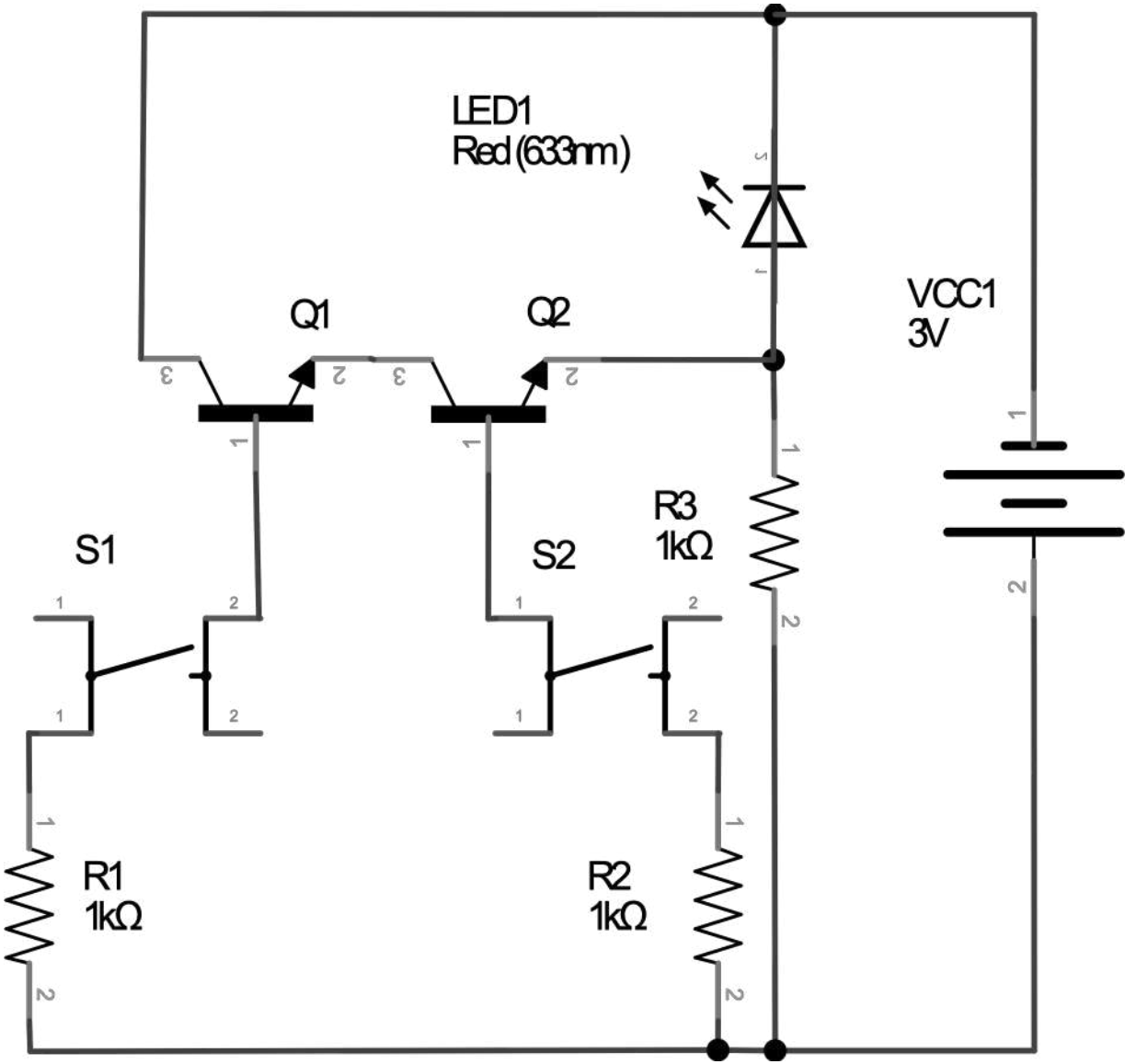
2N3904	
1	Emitter
2	Base
3	Collector

Assembly

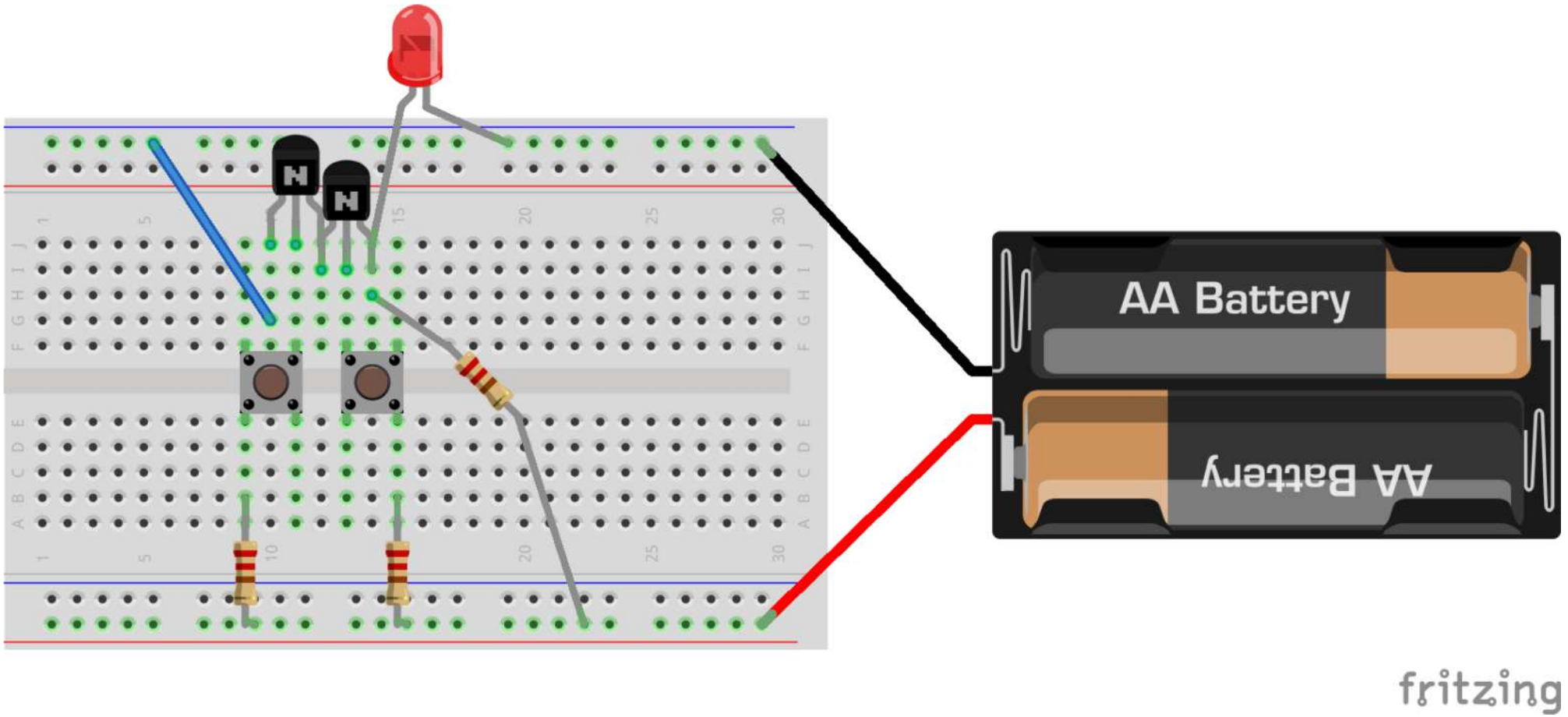
Pro Tips

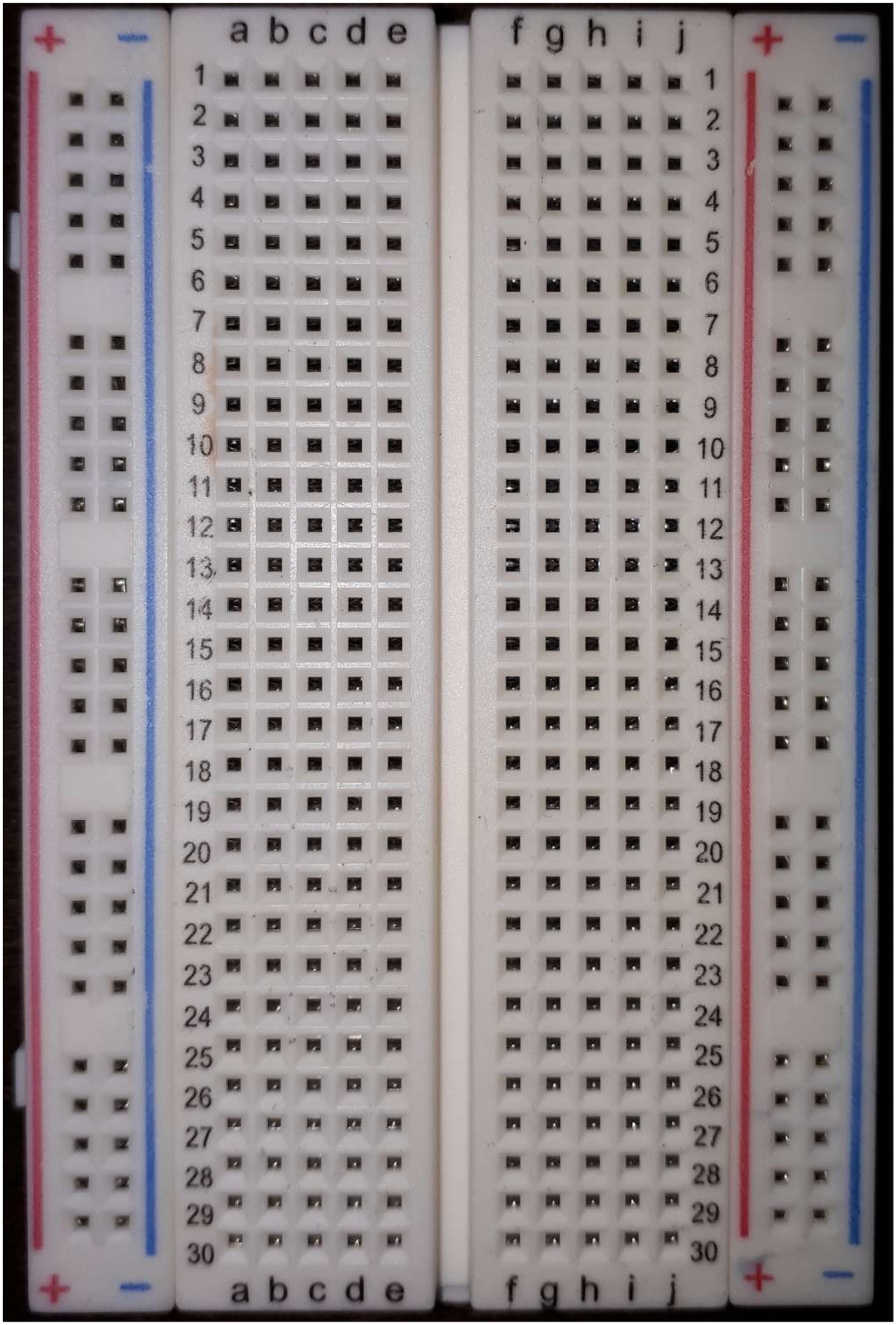
- Don’t put batteries in until end
- Push the components in firmly
- You can bend the pins a bit to make things fit
- Other spots in same row will work
    - But it’s easier to follow number

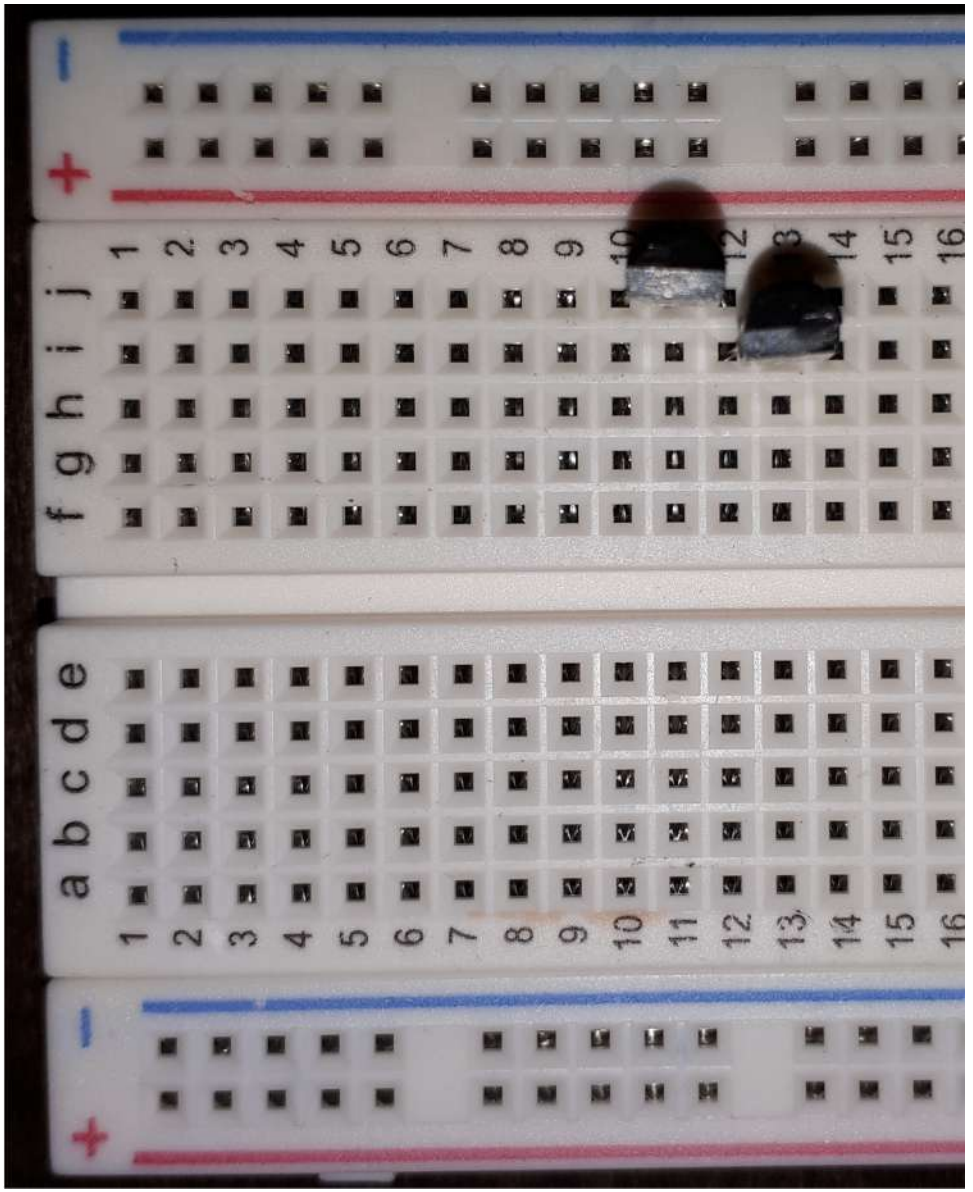
NAND Circuit

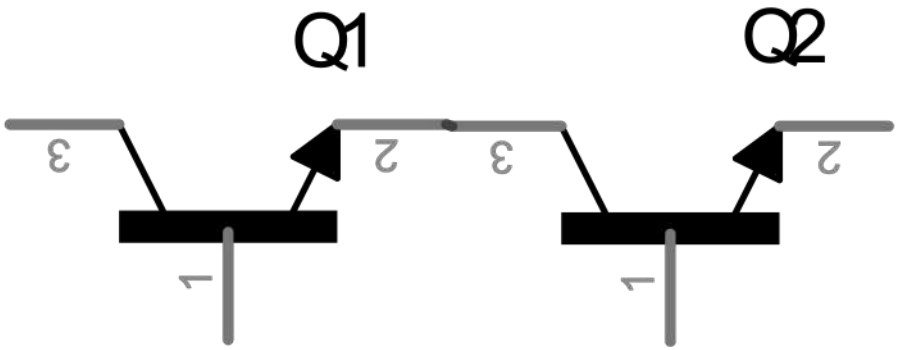


NAND Circuit



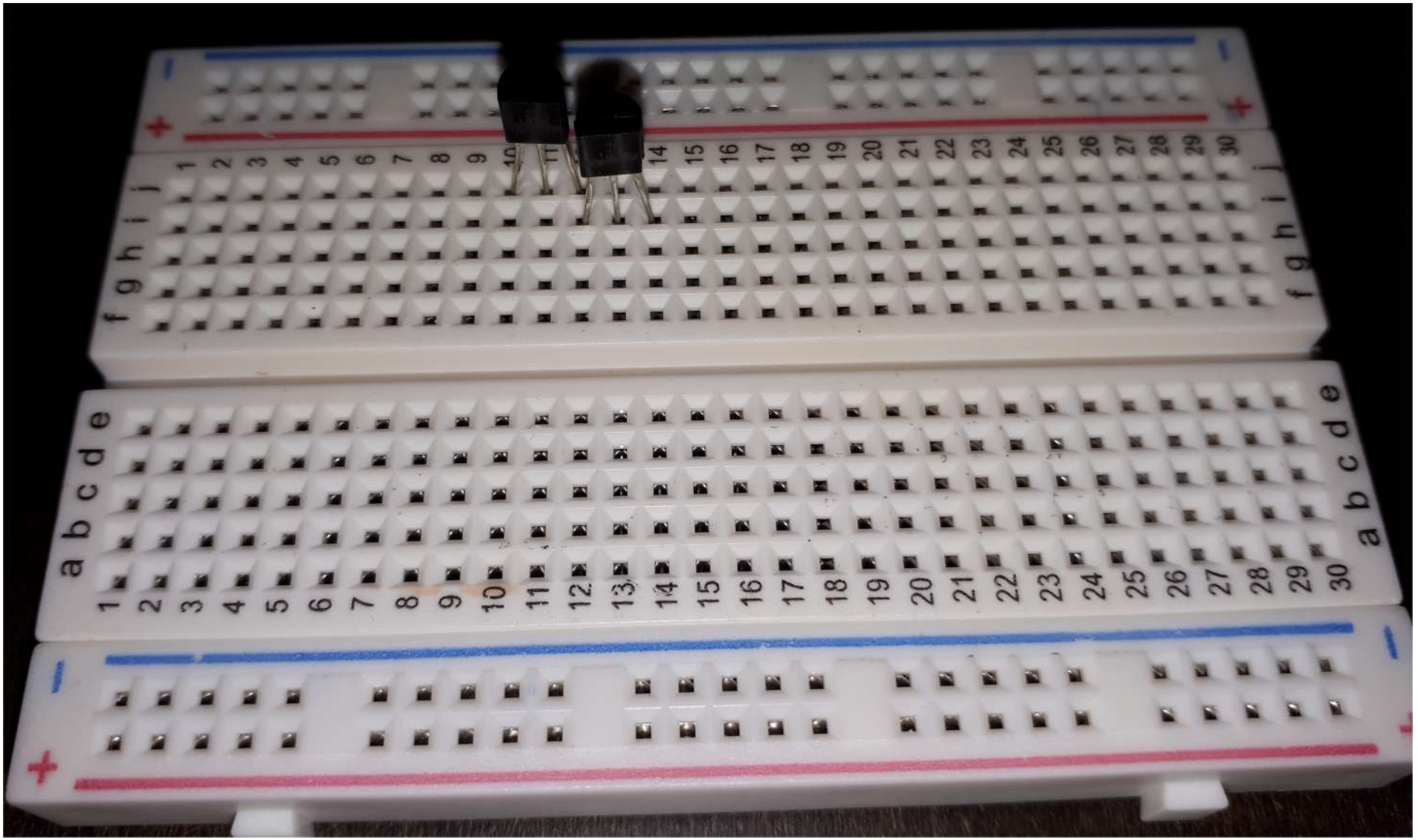

a b c d e
f g h i j
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30



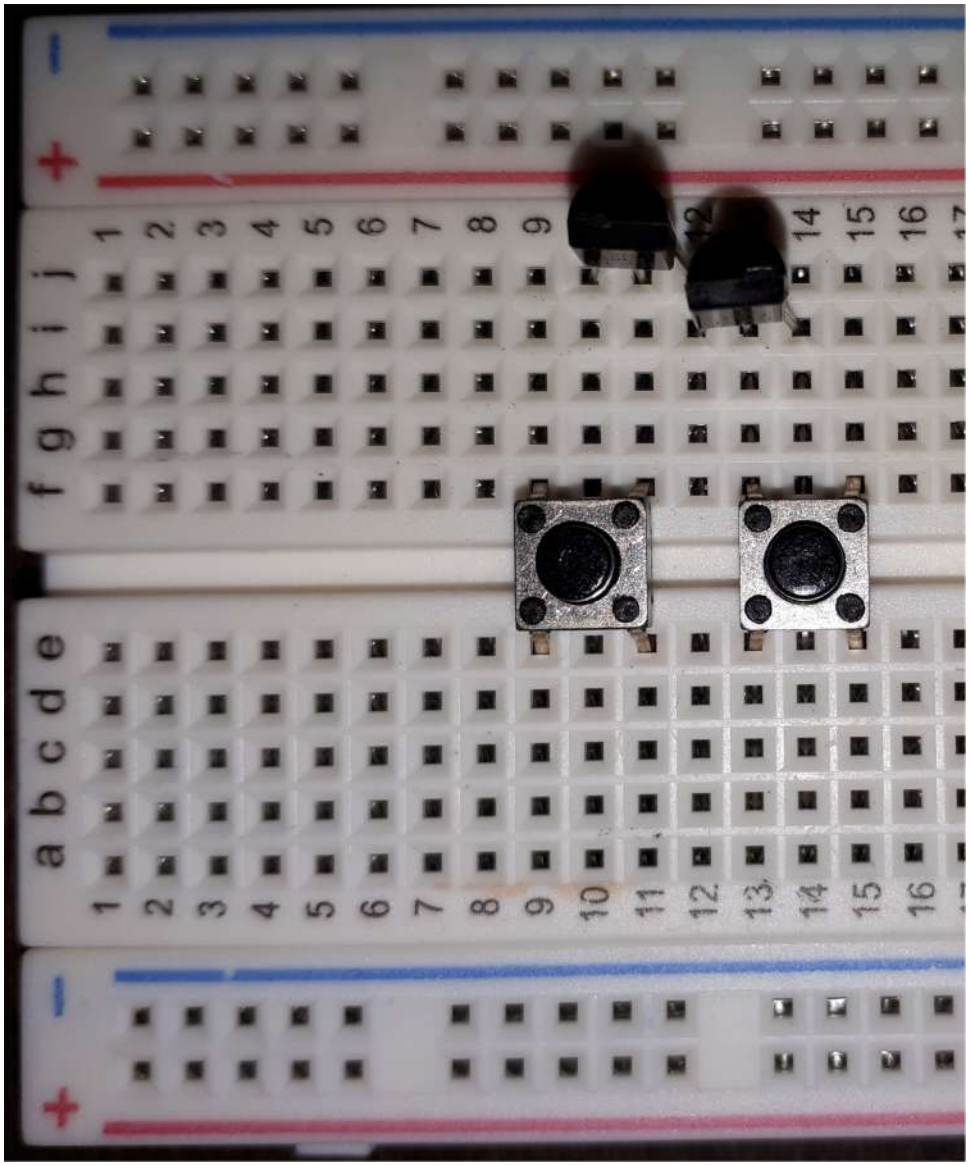


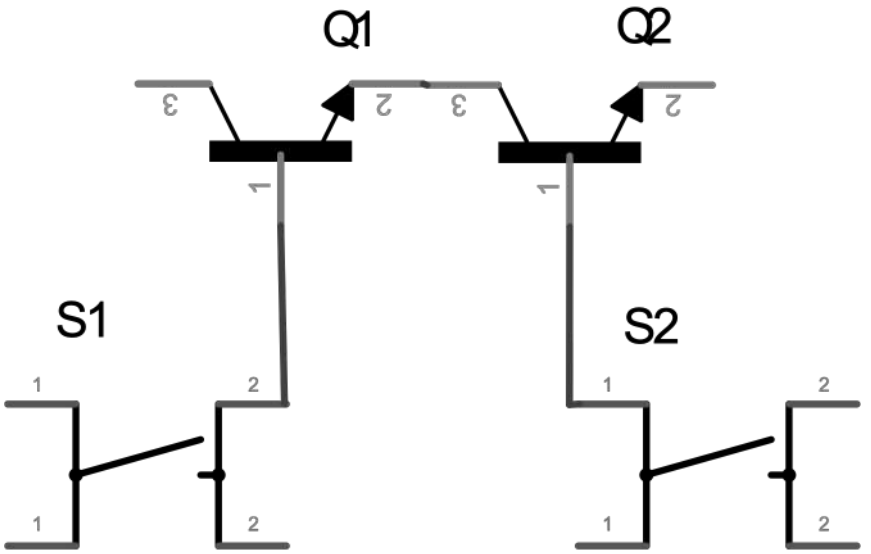
T1: j10, j11, j12

T2: i12, i13, i14



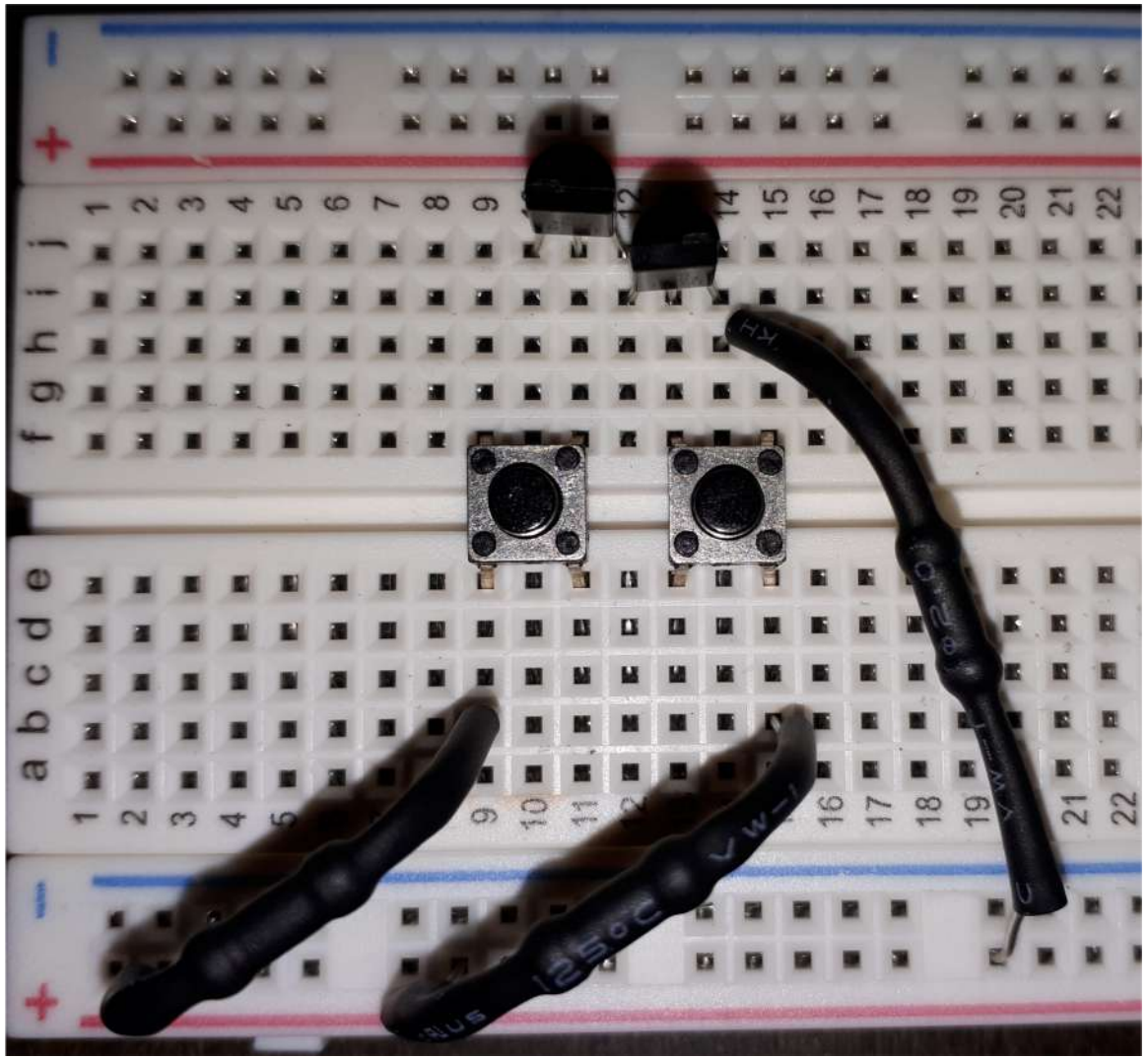
T1: j10, j11, j12
T2: i12, i13, i14

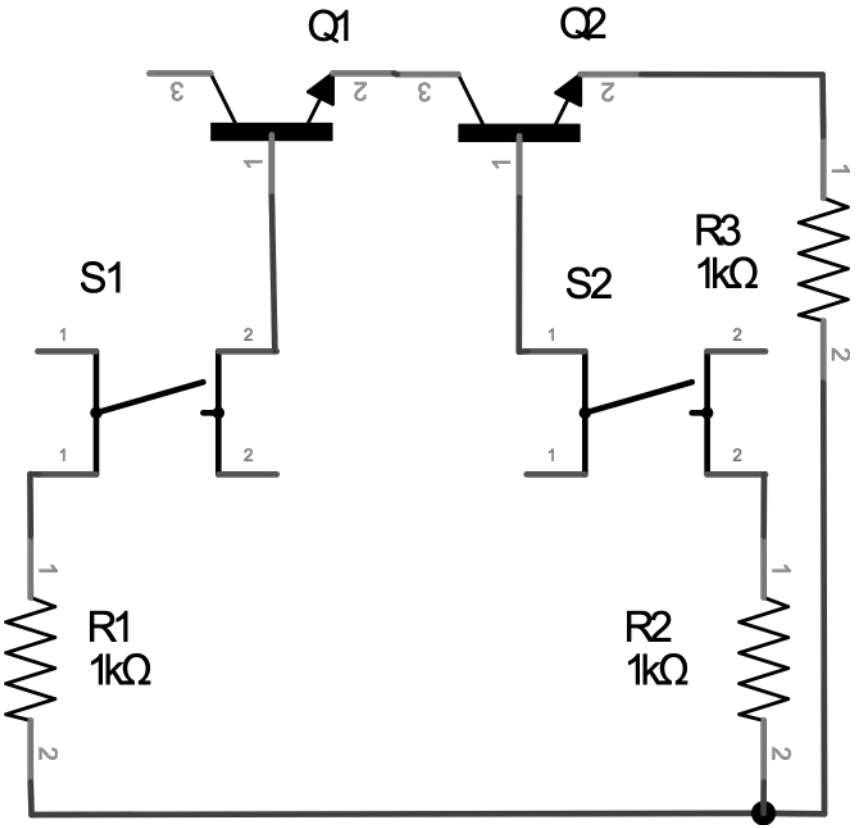




B1: e9, f9, e11, f11

B2: e13, f13, e15, f15

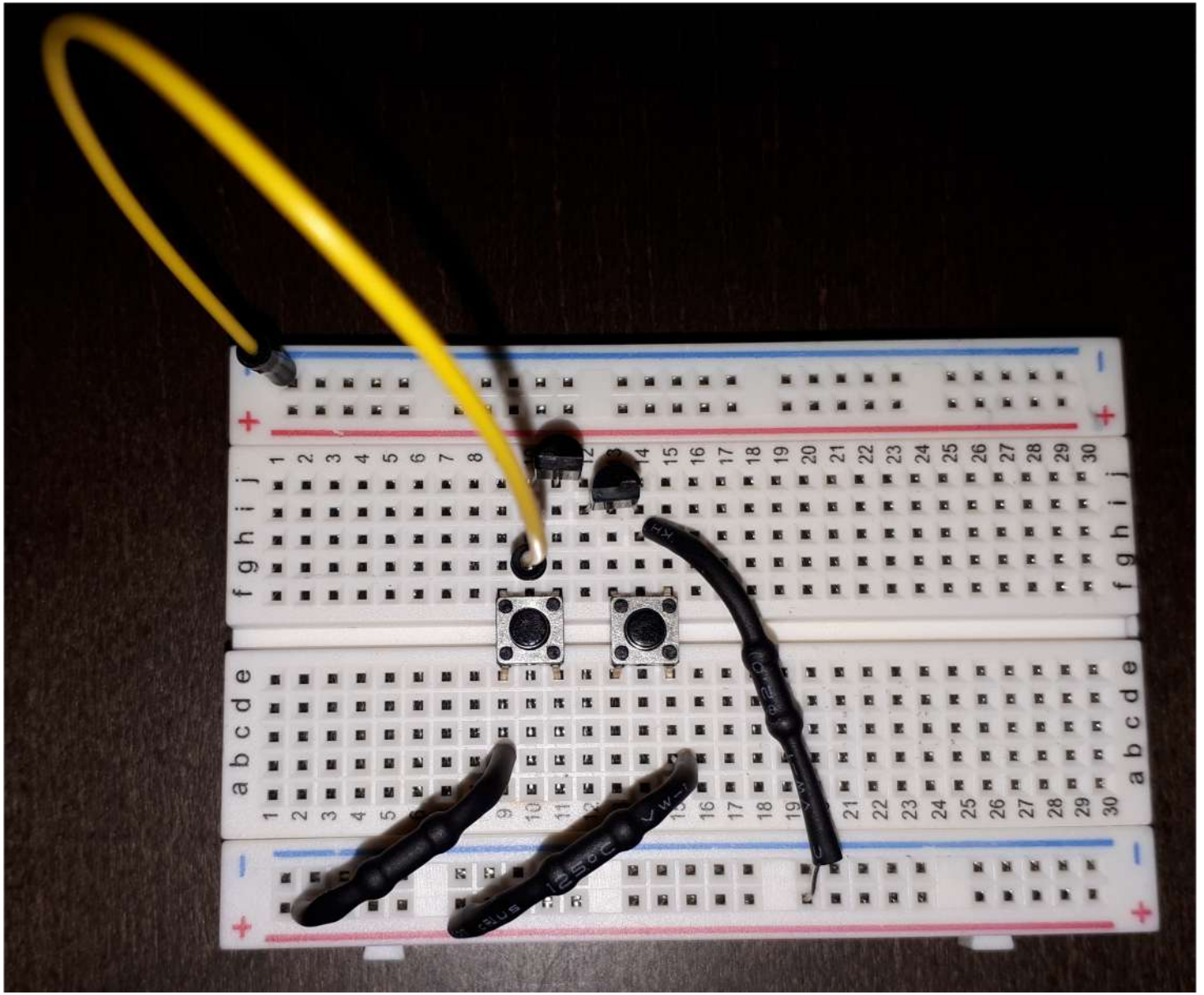




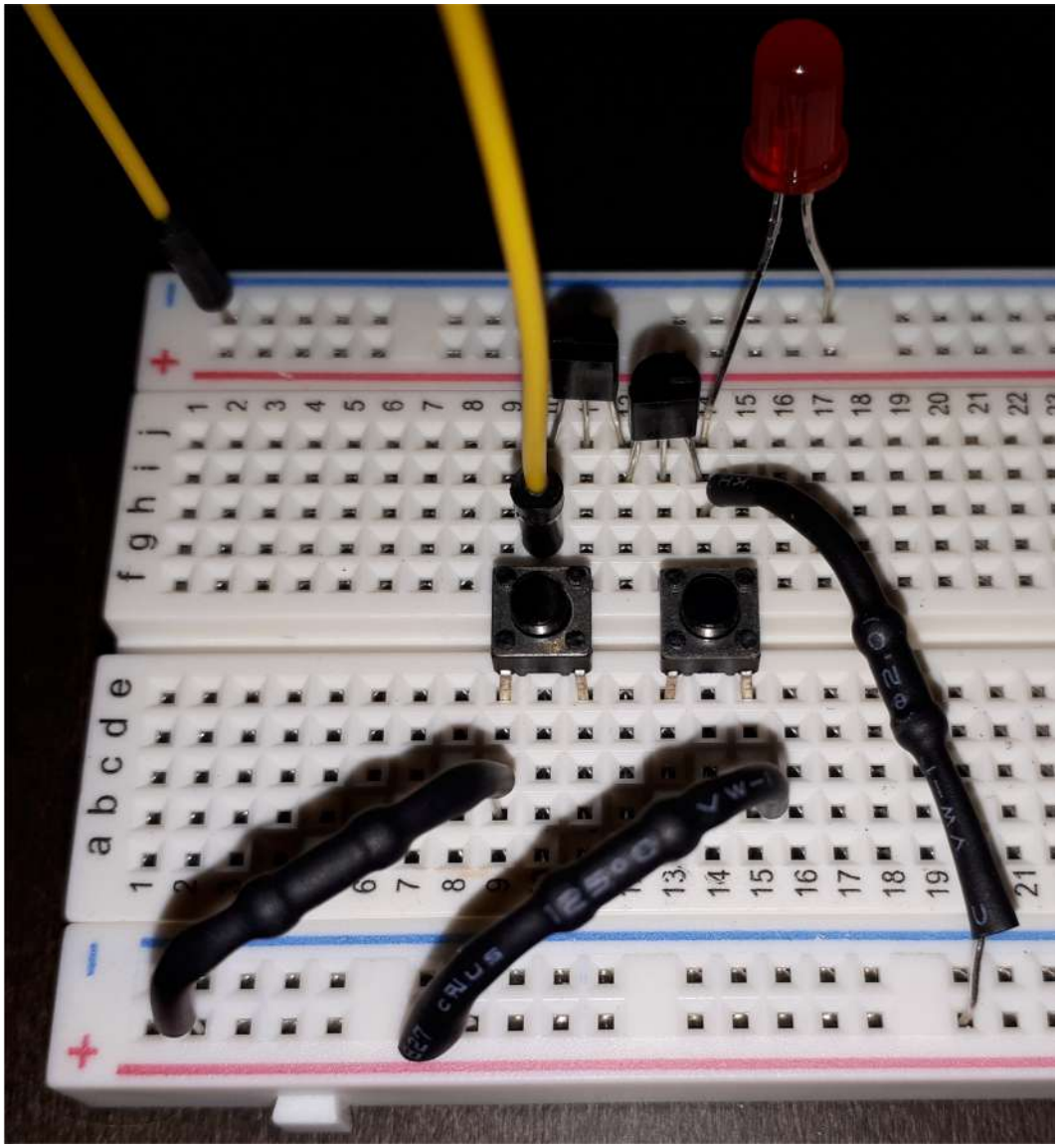
R1: b9

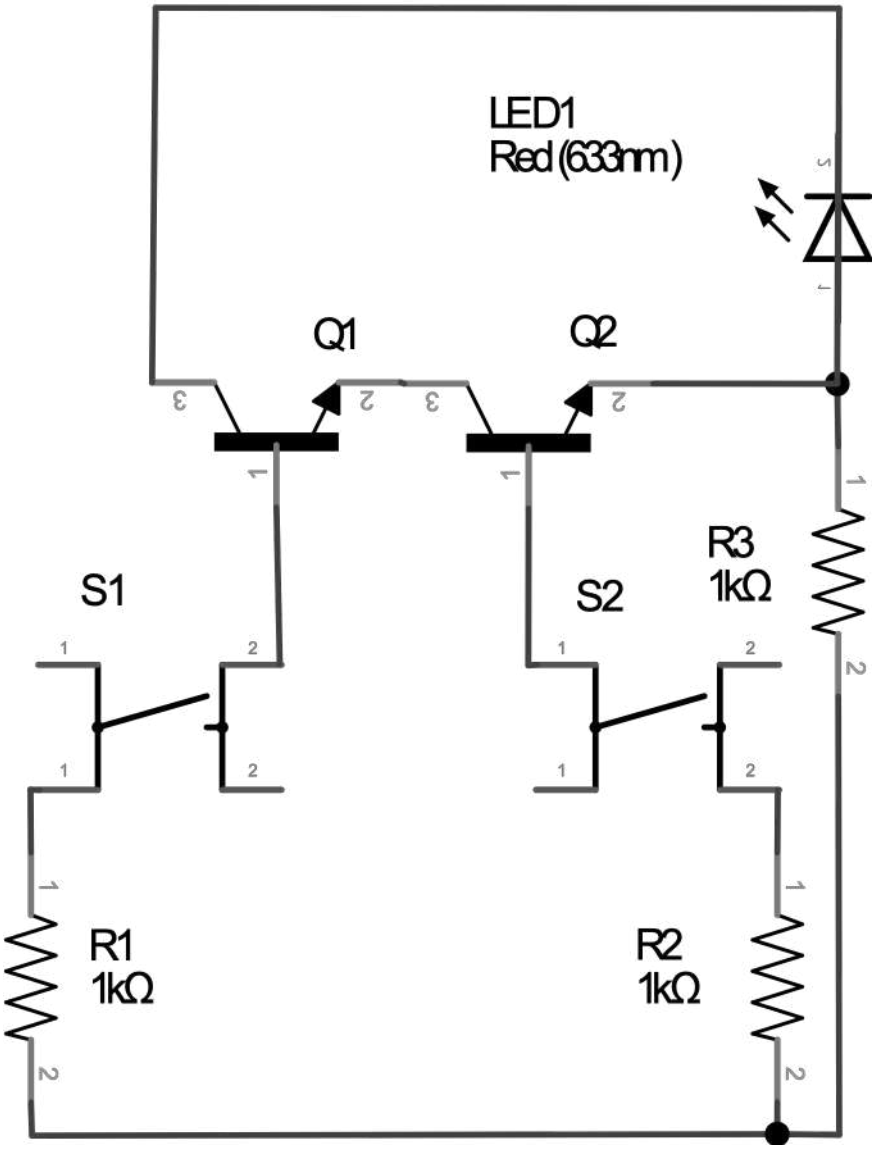
R2: b15

R3: h14

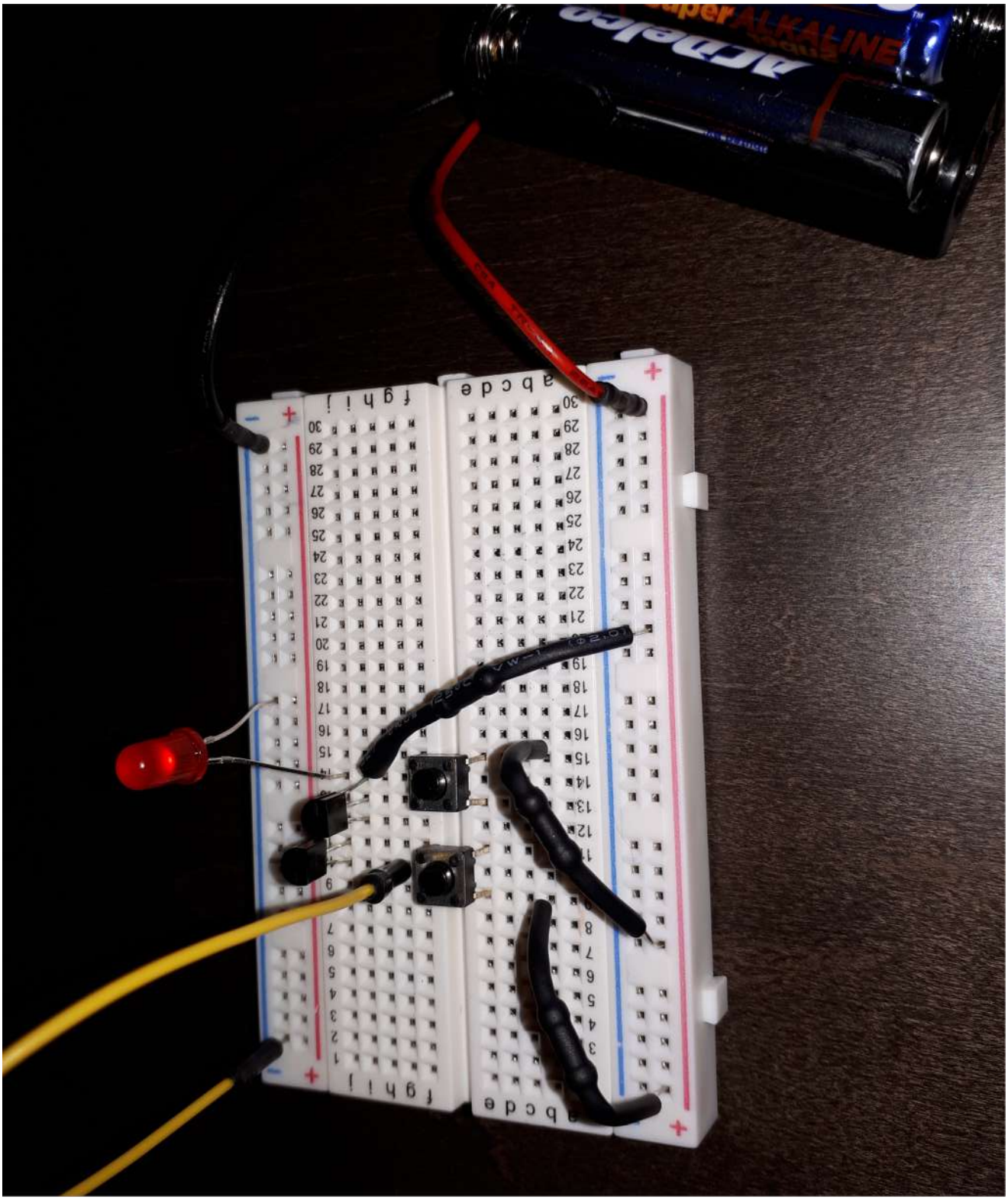


J1: g10

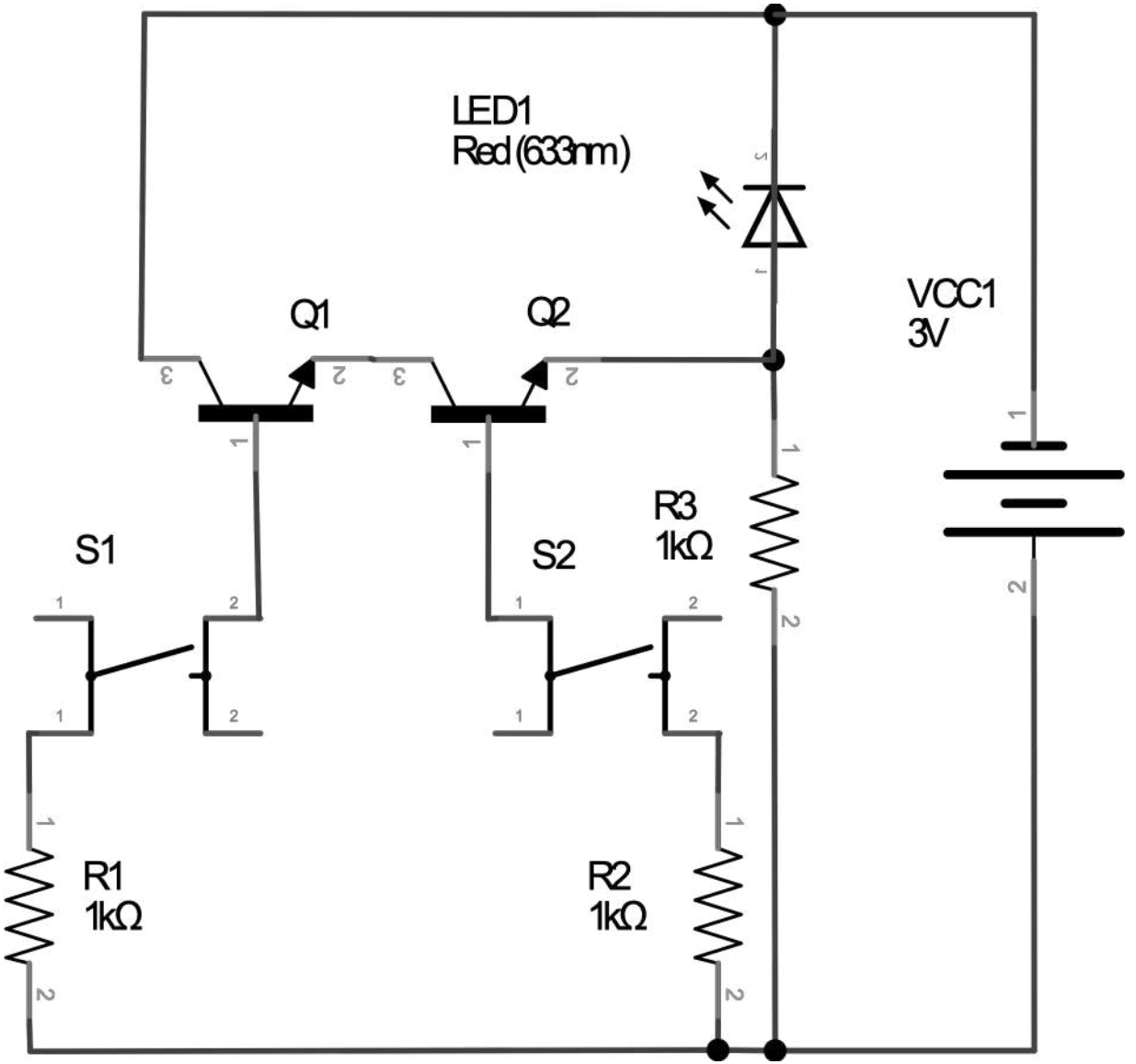




L1: j14 (longer round pin)

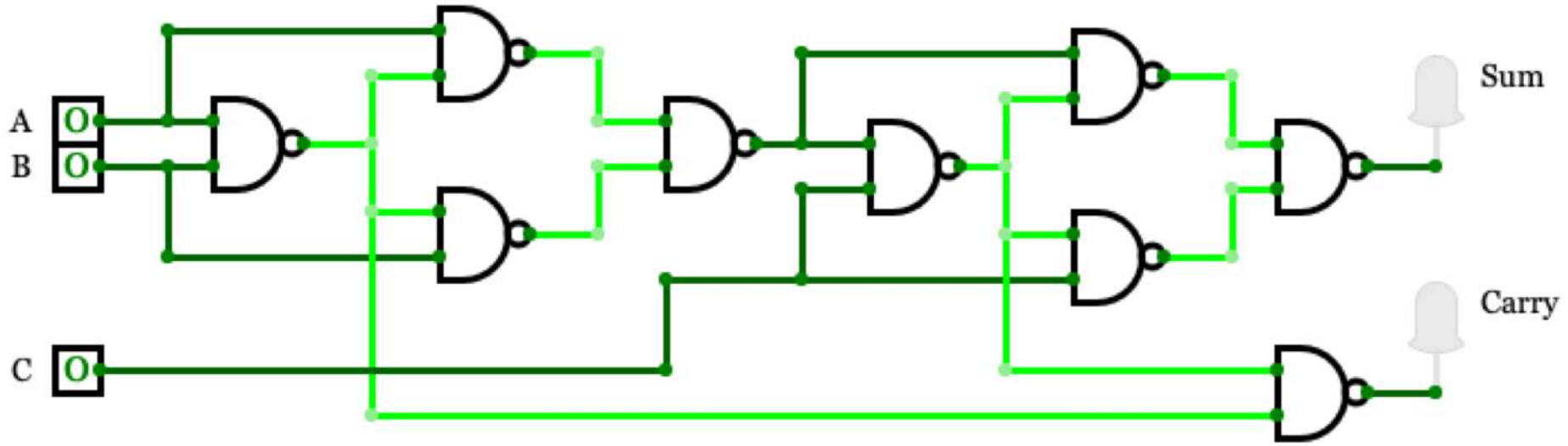

AlkalinePower
ALKALINE

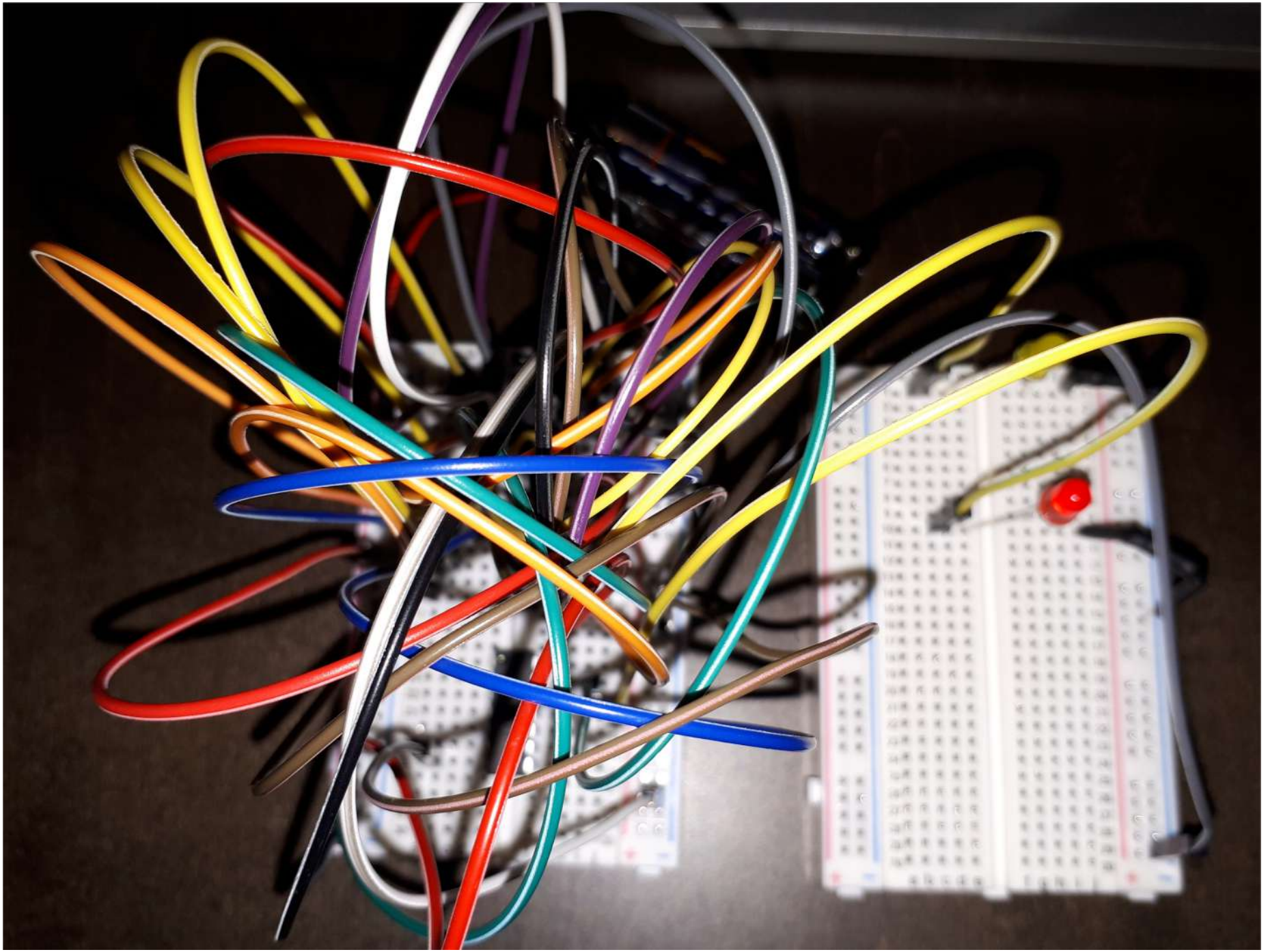
NAND Circuit

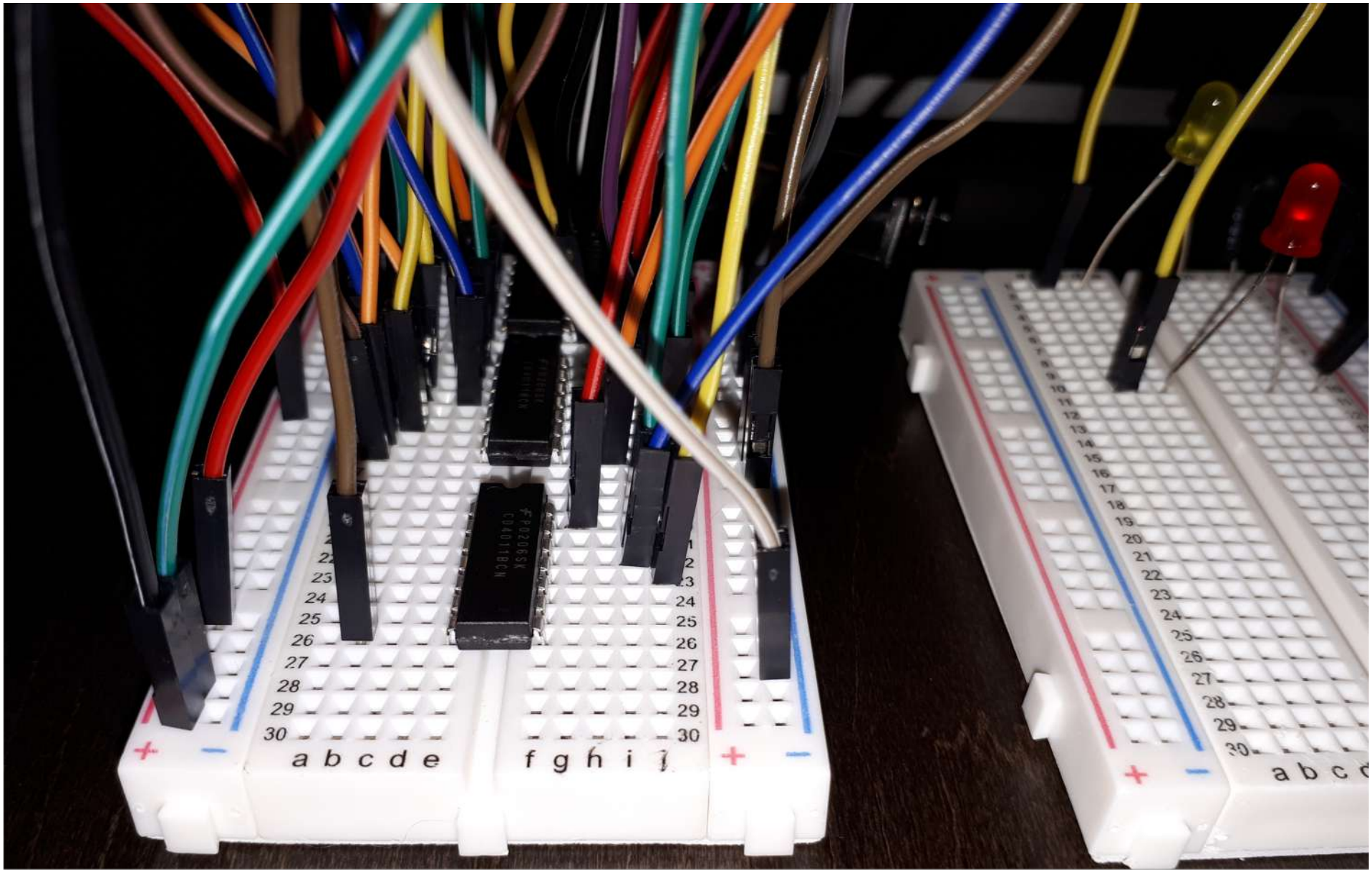


nandgame.com

https://circuitverse.org/users/10938/projects/31649






CD4011BCN
a b c d e
f g h i j
+
−