コードとデザイン

東京藝術大学 芸術情報センター開設科目 金曜4-5限 第5週

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本日のスケジュール

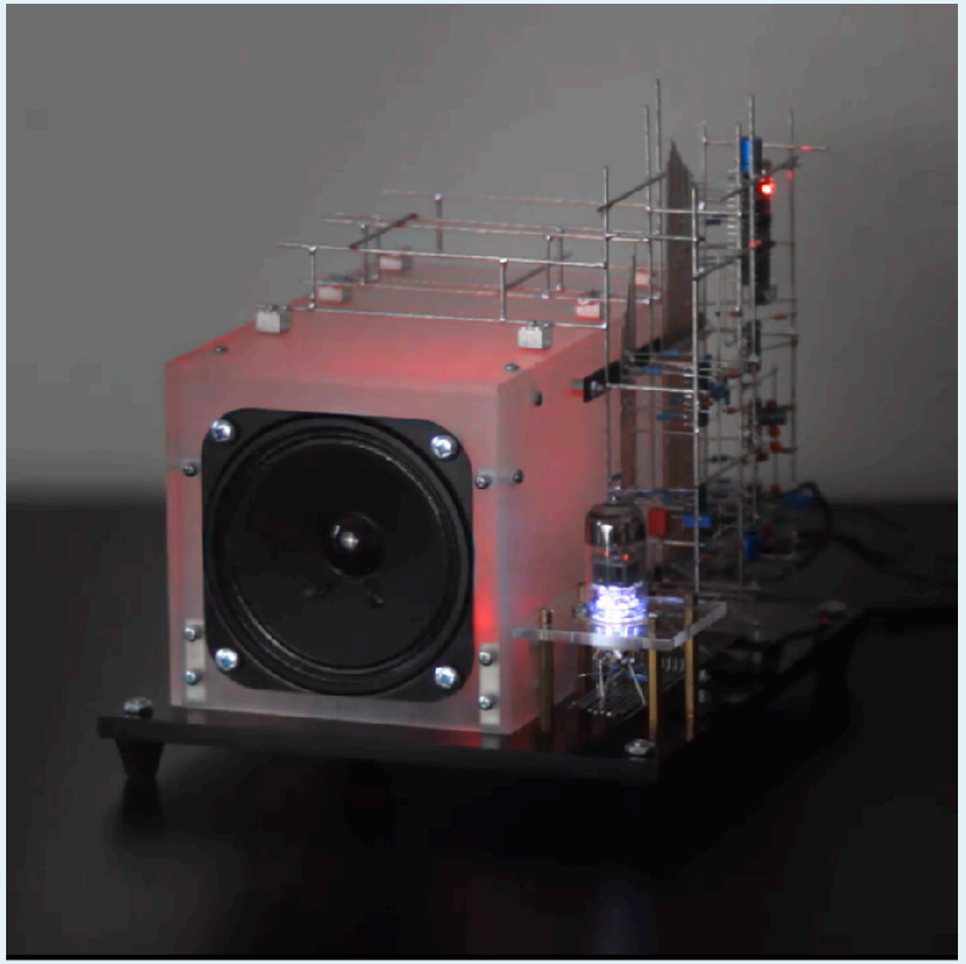
- Unconventional Computingの紹介（15分）
- ロジック回路の組み合わせと加算器の作り方（20分）
- NAND回路を作ってみよう
- NAND回路を組み合わせて全加算器を作ろう

Unconventional Computing

Peter Vogel

https://www.youtube.com/watch?v=NIixUuoDrHw

Eirik Brandal



https://www.instagram.com/p/CYmRmb5hWAX/

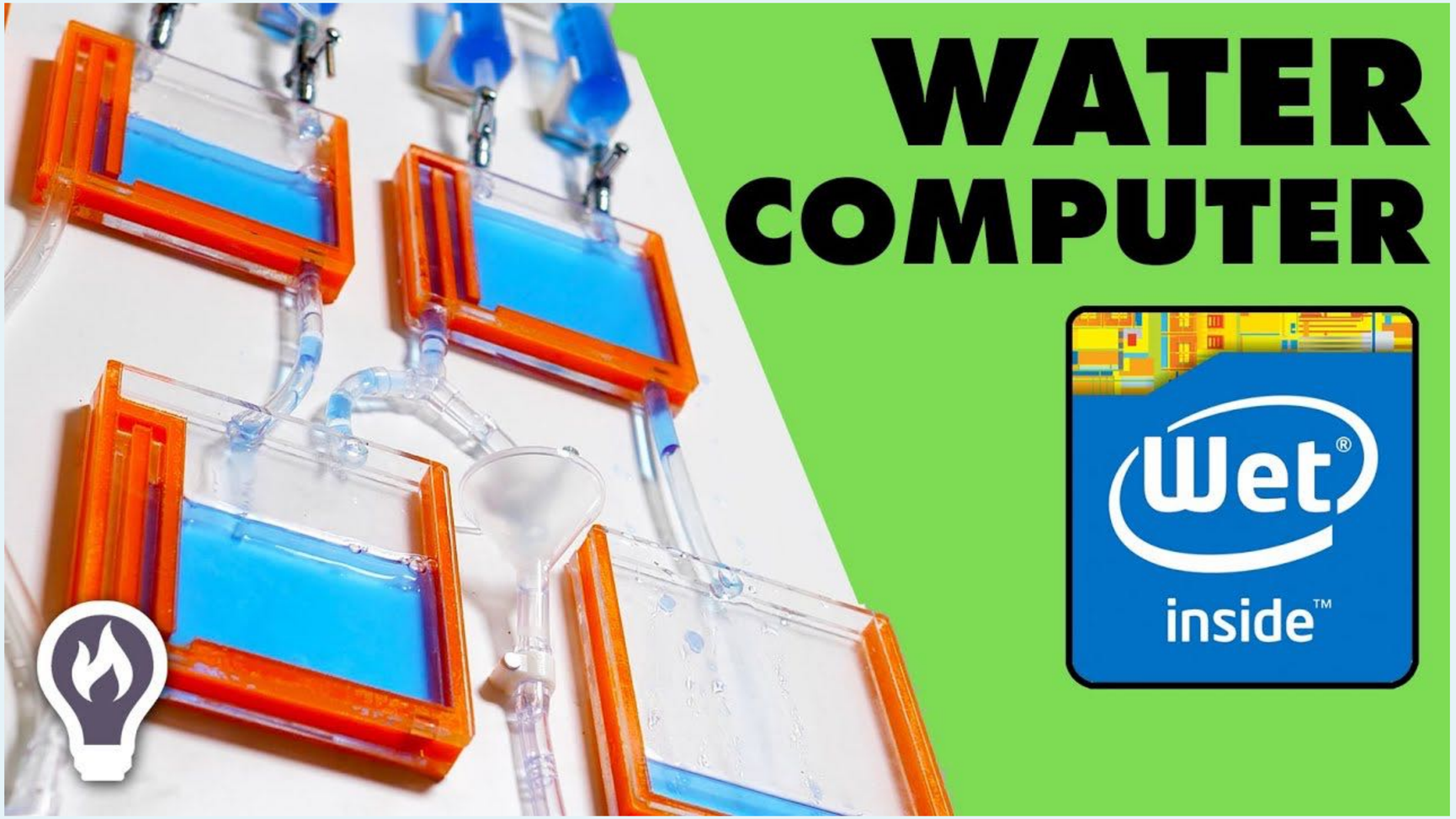
活線プロジェクト（ひつじ）

https://github.com/tenari-jp/electrical-Ikebana

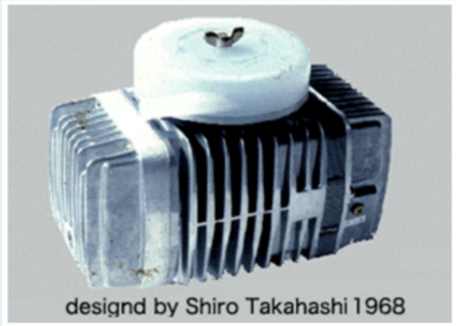
1Bit 1Hz CPU(CW&T)

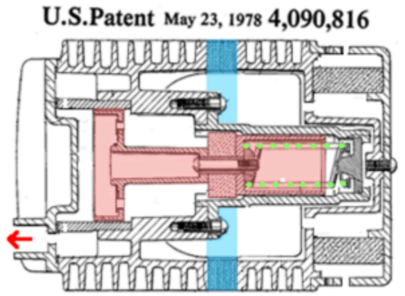
https://vimeo.com/58737613

Domino Addition - Numberphile(2012)
https://www.youtube.com/watch?v=INuPy-r1GuQ

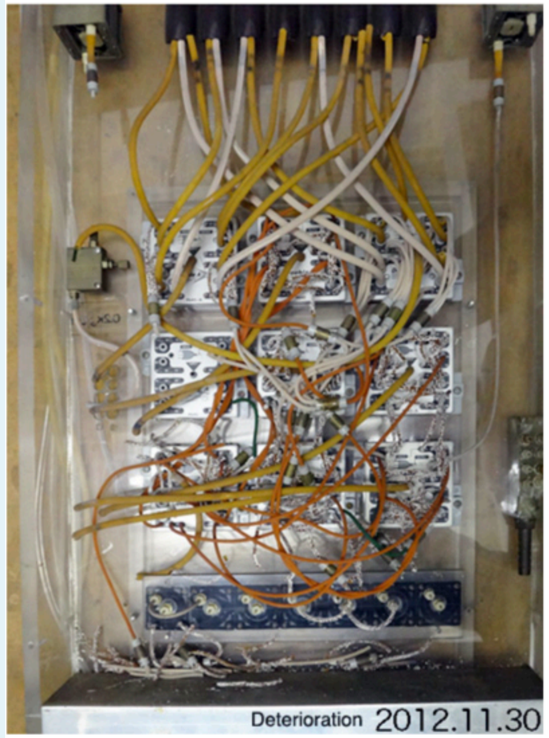


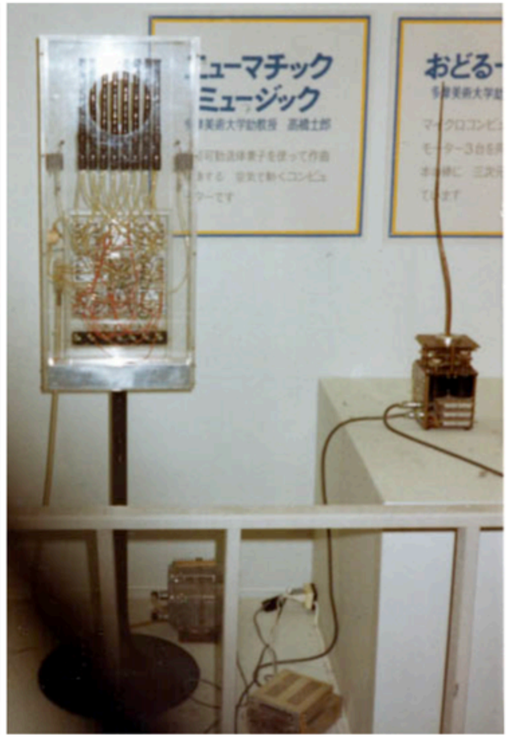
https://youtube.com/watch?v=IxXaizglscw





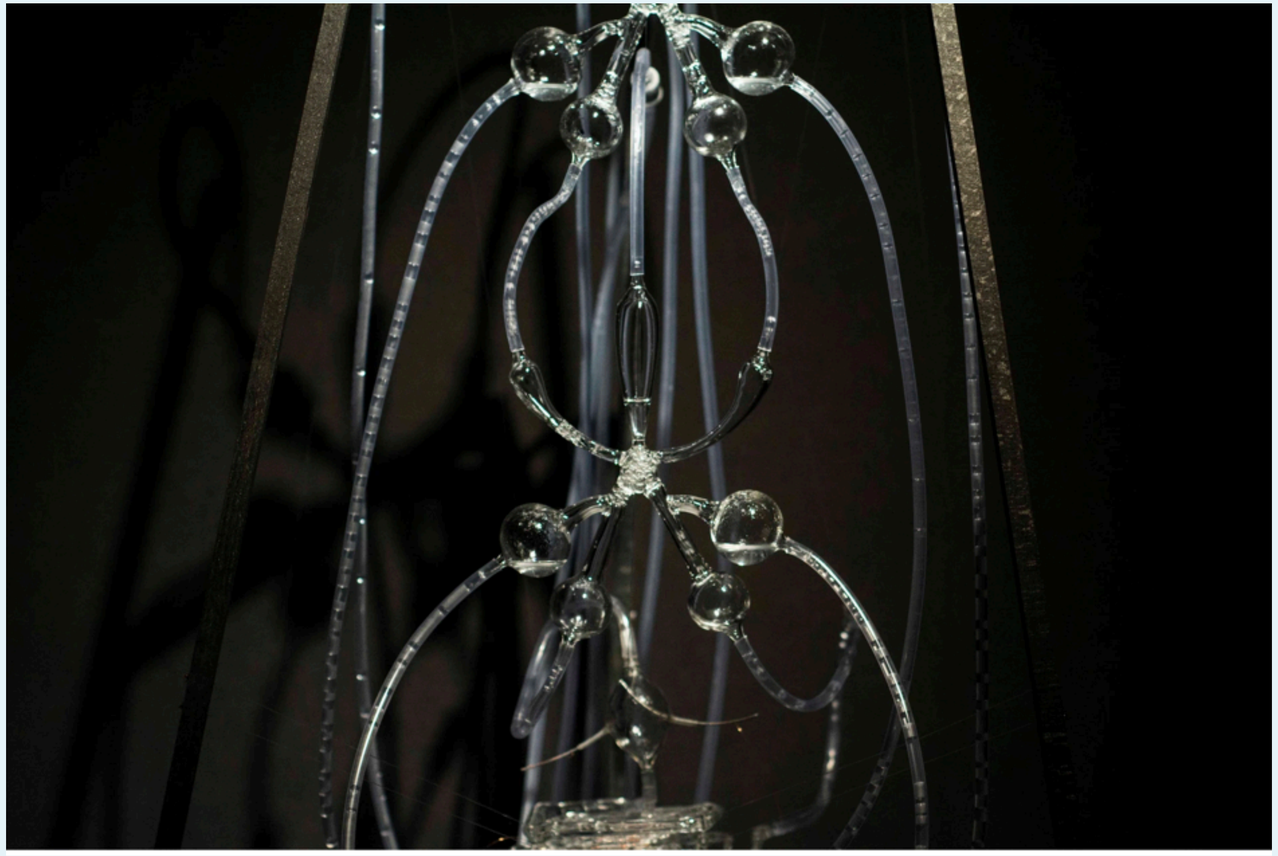
Air compressor
[Pat.4090816]





“ニューマチック　コンピューター” 高橋士郎　（1970）

http://www.shiro1000.jp/mpu/compo.htm
https://mediaarts-db.bunka.go.jp/id/M781436



"Fluid Memory” Ioana Vreme Moser (2019-2020)

https://www.ioanavrememoser.com/fluidmemory

“PISS (ON) LOGIC”, MARTIN HOWSE & JONATHAN KEMP(2015)

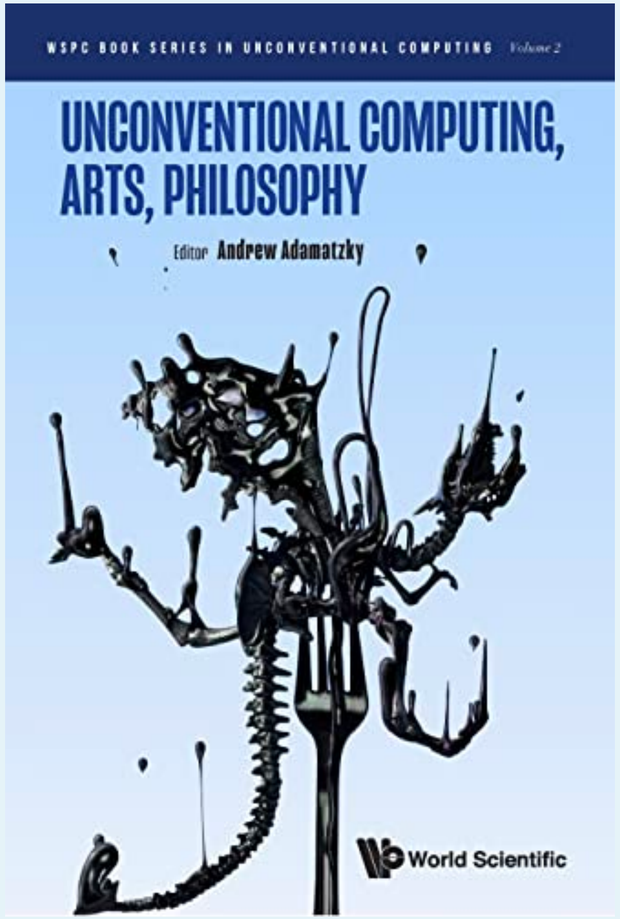
https://vimeo.com/172568522

https://projects.stwst.at/stwst48/pissonlogic-by-martin-howse-and-jonathan-kemp/index.html

https://ja.wikipedia.org/wiki/酒船石遺跡

酒船石が流体素子であった可能性に関する考察(2017),村上優依・窪田佳寛・望月修

https://www.nagare.or.jp/download/noauth.html?d=36-6_tokushu13.pdf&dir=63



Unconventional Computing, Arts, Philosophy (Unconventional Computing, 2), Edited by Andrew Adamatzky, 2022, World Scientific Pub Co Inc

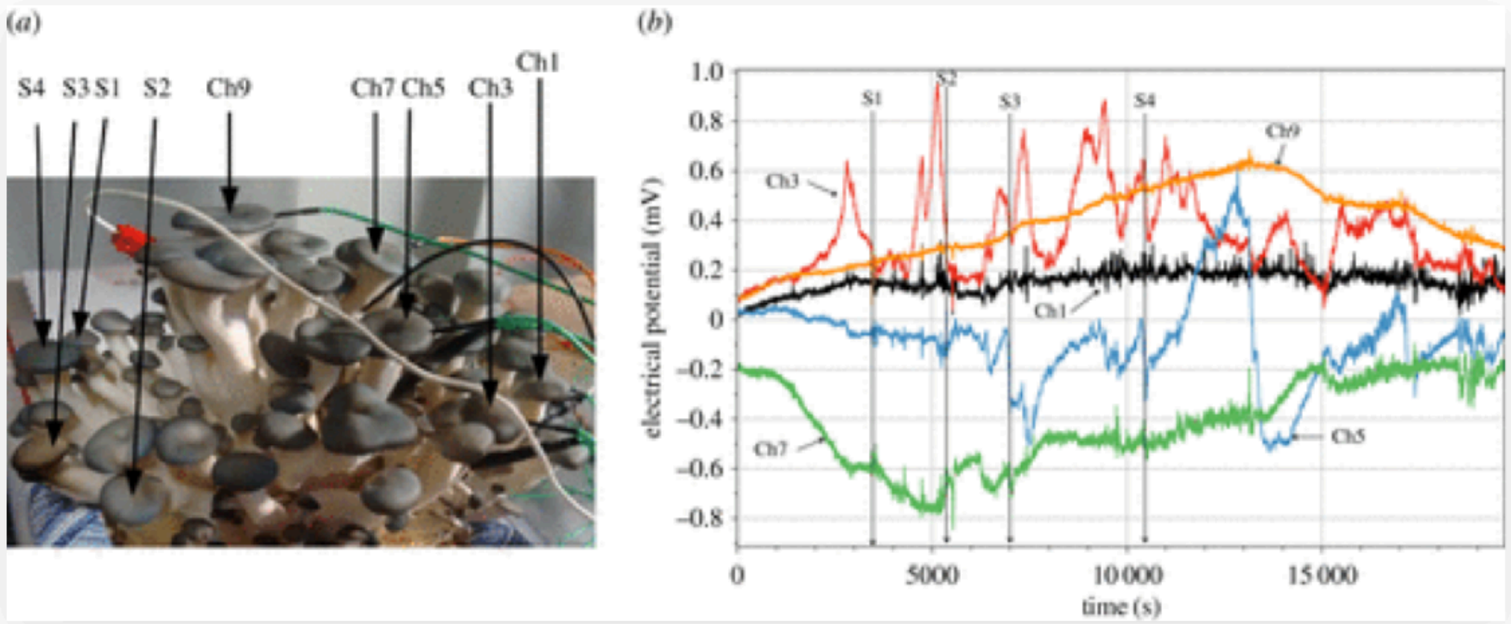


Figure 4. Stimulation of fruits. (*a*) Set-up of recording, sites of stimulation and location of electrode pairs corresponding to channels Ch1–Ch9. (*b*) Electrical potential recording on five mushrooms. Channel Ch1 is shown by black, Ch3 red, Ch5 blue, Ch7 green and Ch9 orange. The following stimuli have been applied to fruiting bodies. (S1) 3450 s: start open flame stimulation for 20 s. (S2) 5310 s: start open flame stimulation for 60 s. (S3) 7000 s: ethanol drop is placed on a cap of the fruit. (S4) 10440 s: 15 mg of table salt is placed on a cap of one of fruiting bodies.

"Towards fungal computer", Adamatzky Andrew, (2018),*Interface Focus.***8,**20180029 http://doi.org/10.1098/rsfs.2018.0029

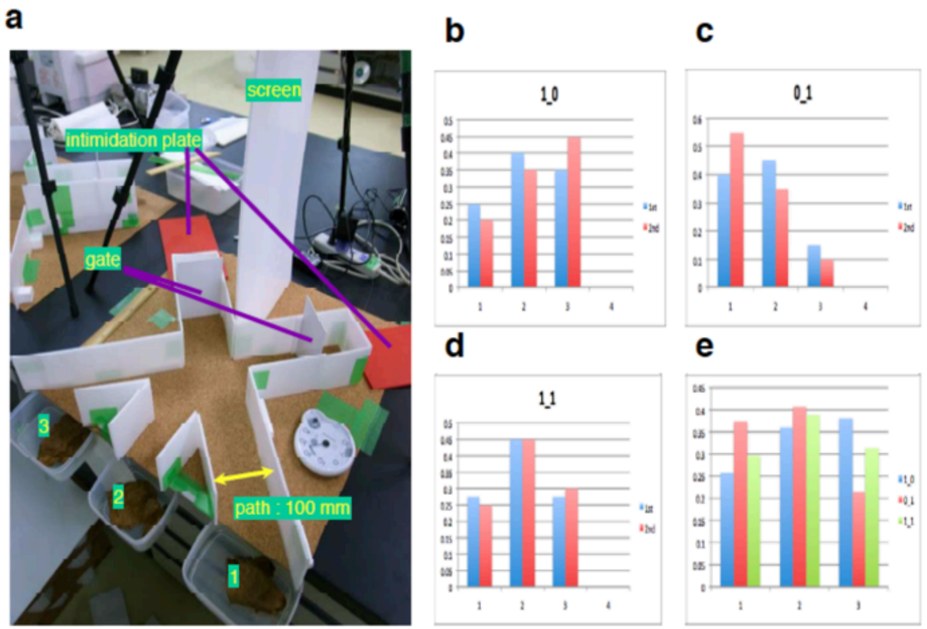


FIGURE 5. a. Implementation of AND gate by real soldier crabs. A or B represents input space for input x or y, respectively. The symbol 1, 2 and 3 represent output for NOT(x) AND y, x AND y, and x AND NOT(y), respectively. The experimental results of AND gate implemented by real soldier crabs. b. Frequency distribution of output 1, 2 and 3 for input, (1, 0). Output 4 represents the rate of individuals not reaching the output in a limited time. c. Frequency distribution for input, (0, 1). d. Frequency distribution for input, (1, 1). e. Frequency distribution of output 1, 2 and 3 over 21 trials.

"Robust Soldier Crab Ball Gate" Yukio-Pegio Gunji, Yuta Nishiyama, Andrew Adamatzky(2012)
https://arxiv.org/abs/1204.1749

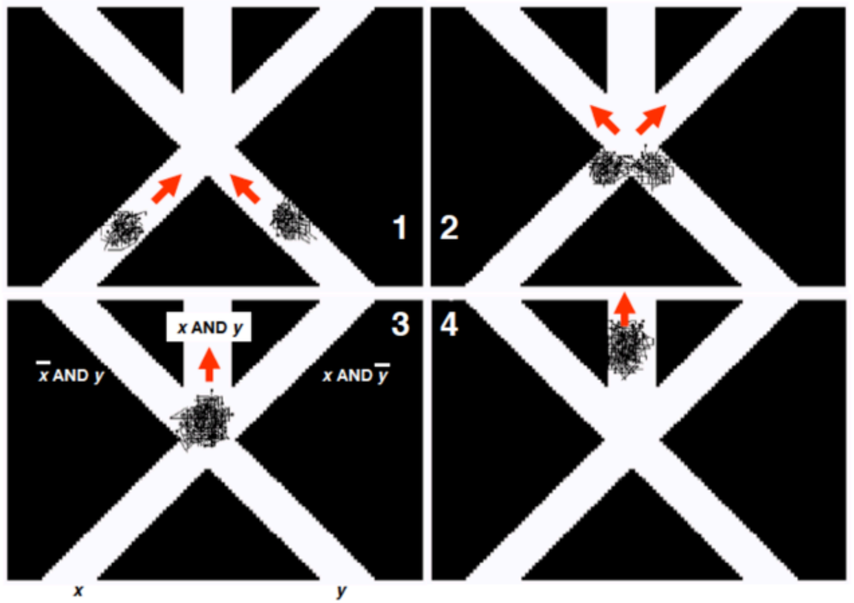
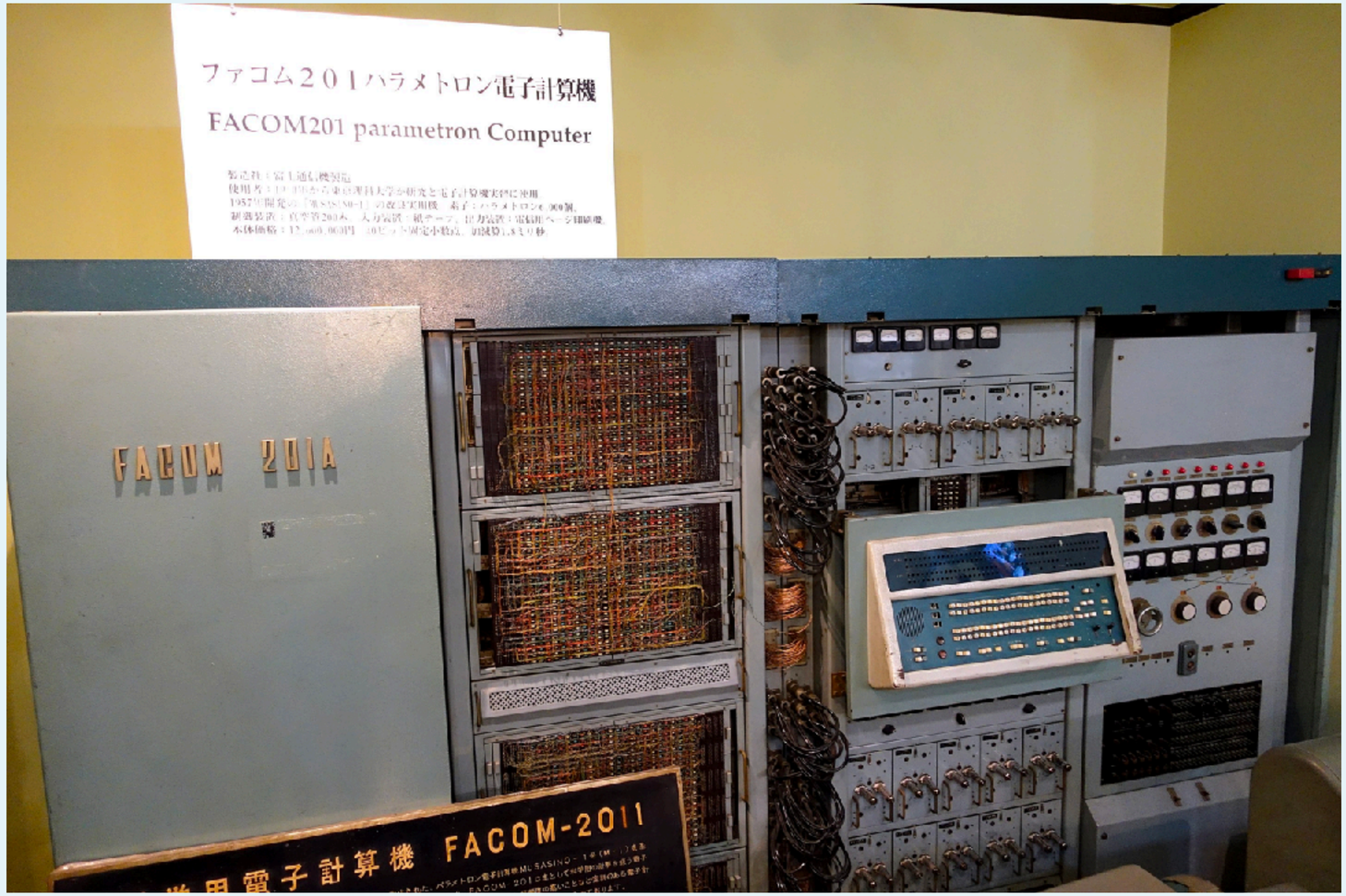


FIGURE 3. A series of snap shots (1, 2, 3 and 4) in AND gate of swarm balls. A swarm ball locate at x- and y-position consists of 40 agents, respectively. Each agent is represented by a square with its 5-steps-trajectories. Red arrows represent the direction of motion of a swarm ball.

“Dr.Stone(24)” 原作：稲垣理一郎、作画：Boichi、2022、21p

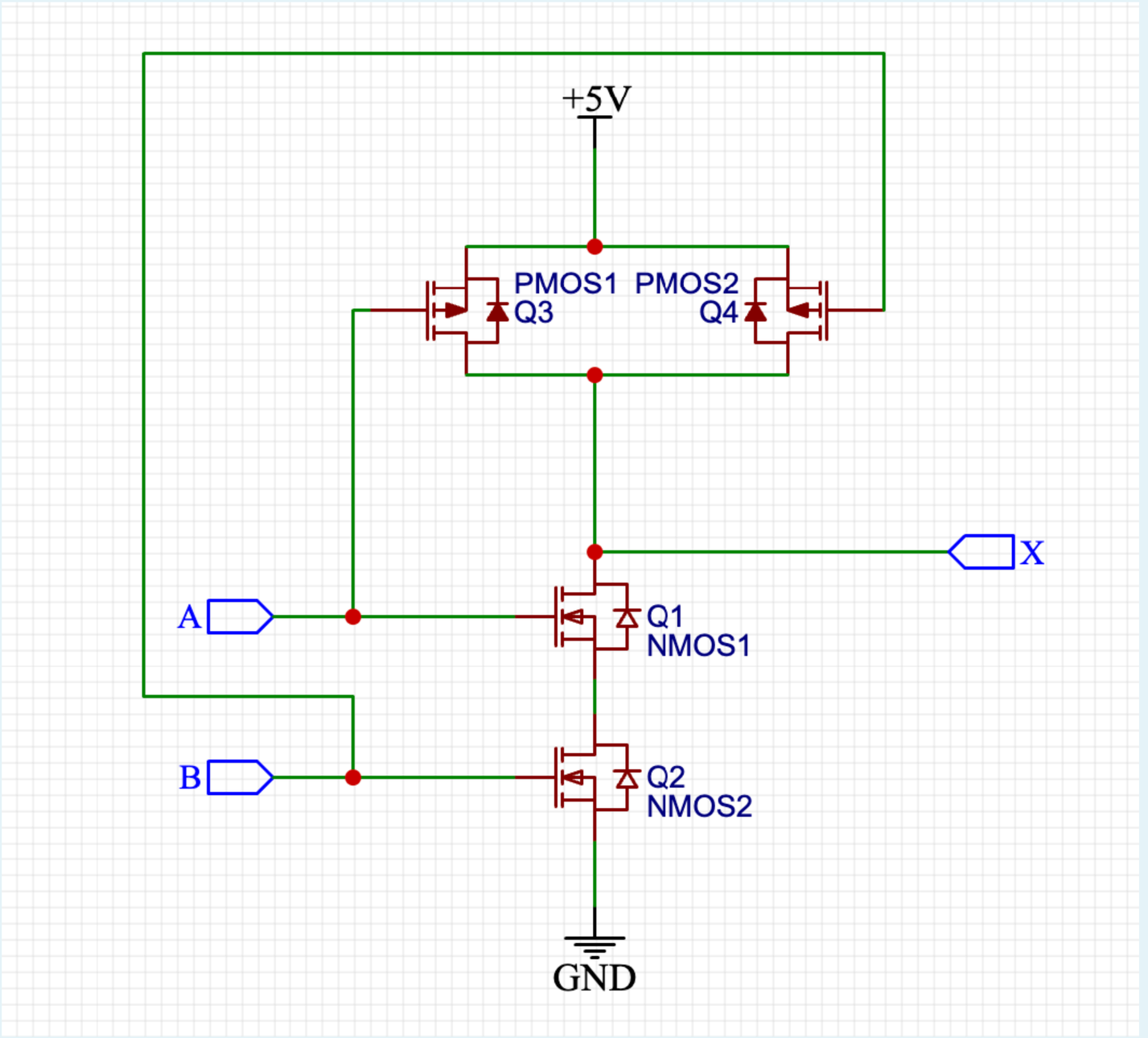


https://ja.wikipedia.org/wiki/%E3%83%91%E3%83%A9%E3%83%A1%E3%83%88%E3%83%AD%E3%83%B3

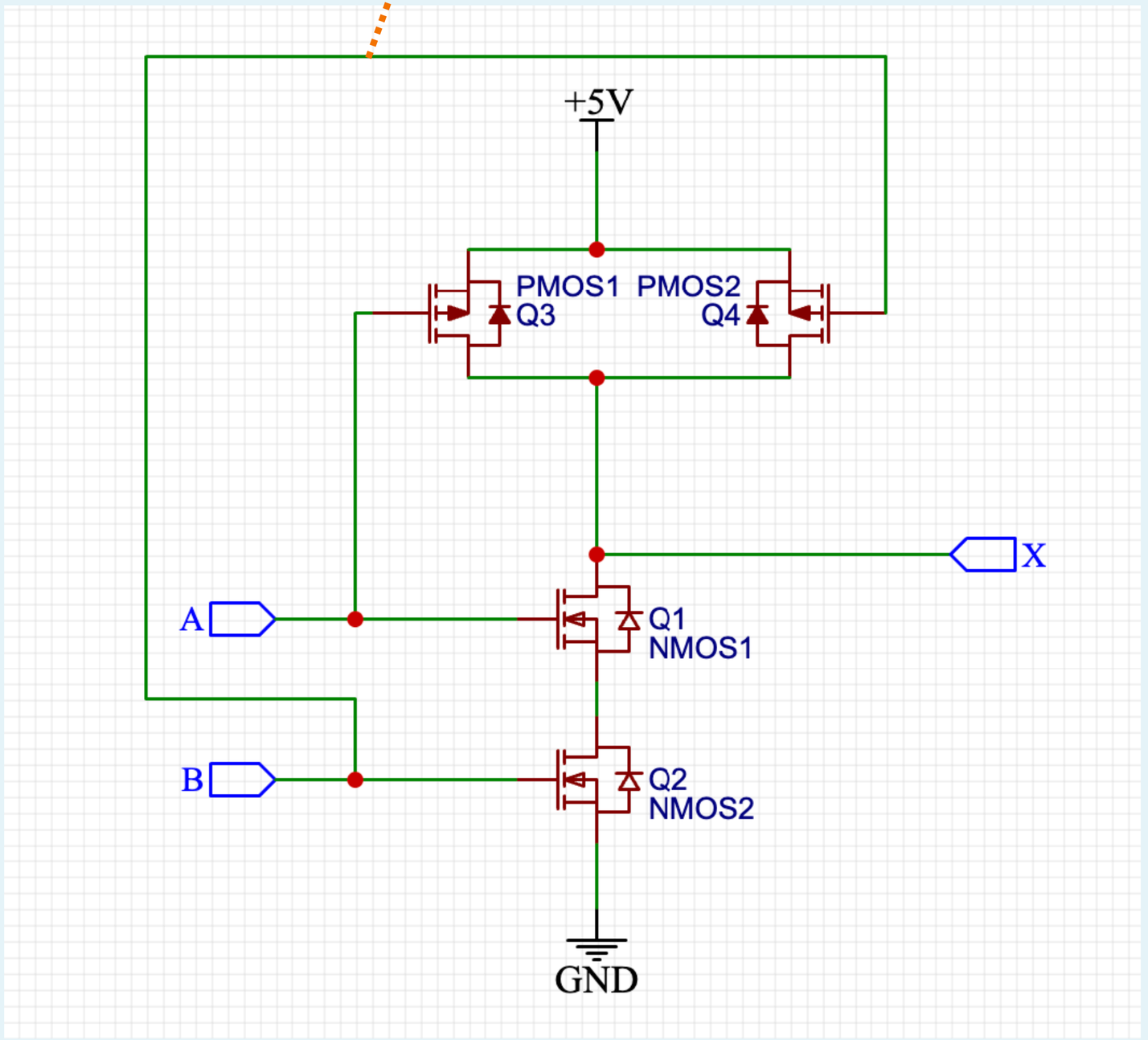
NANDゲートを作ろう

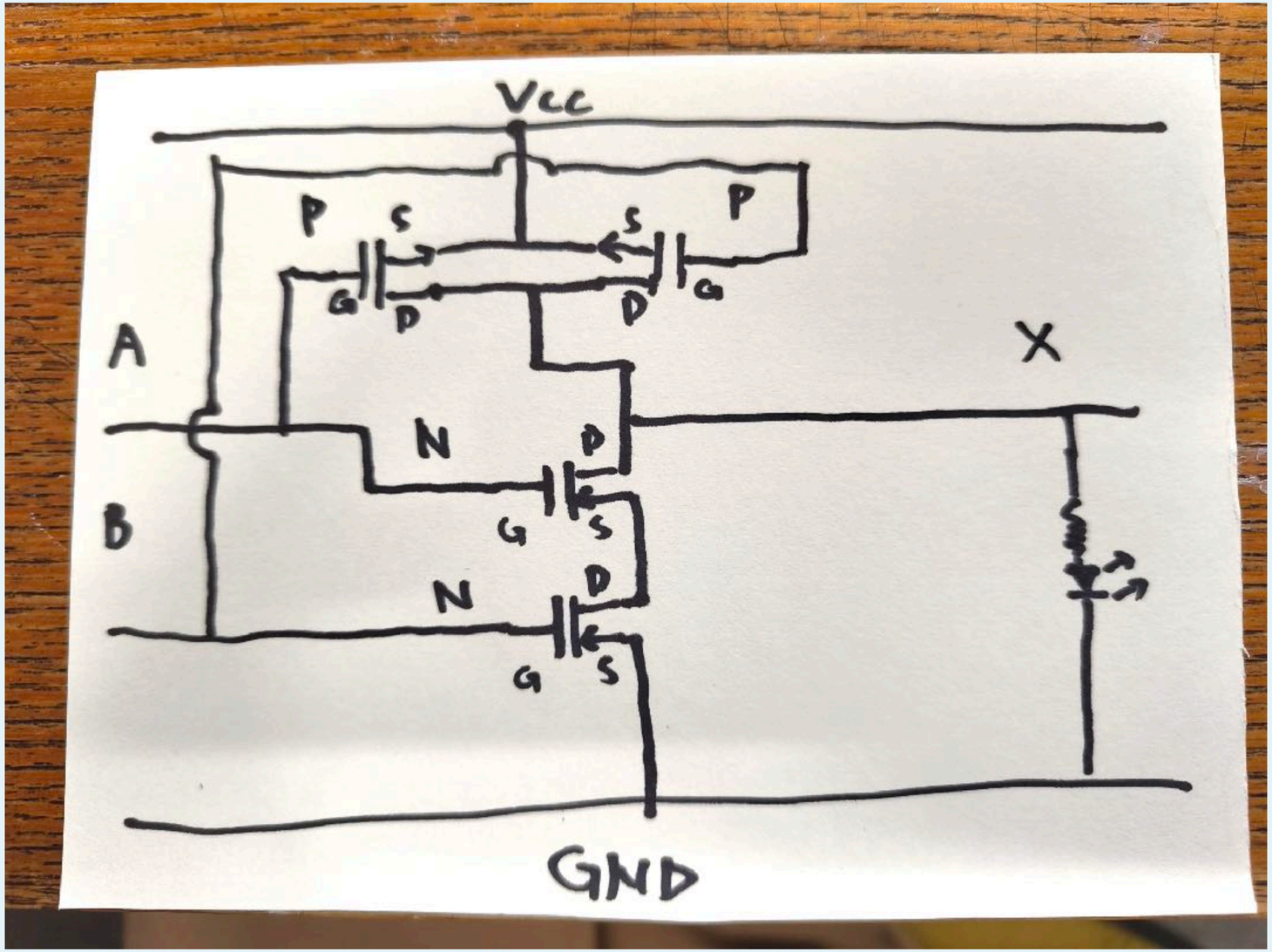
必要パーツ

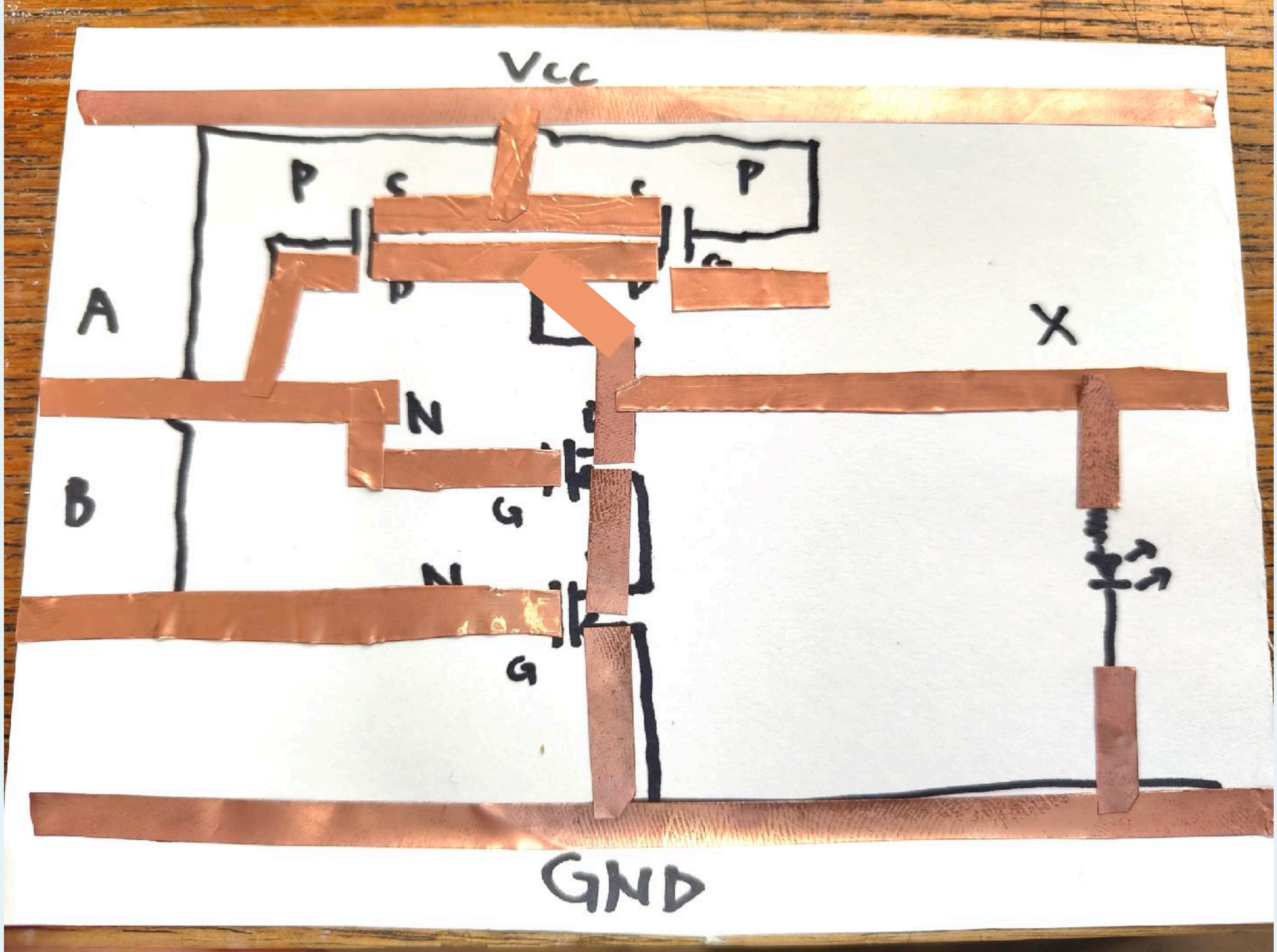
- ボタン電池(3V) or 9V電池x1
- 銅箔テープ
- N型MOSFET(2SK4017) x2
- P型MOSFET（MTP4835）x2
- 抵抗入りLEDx1

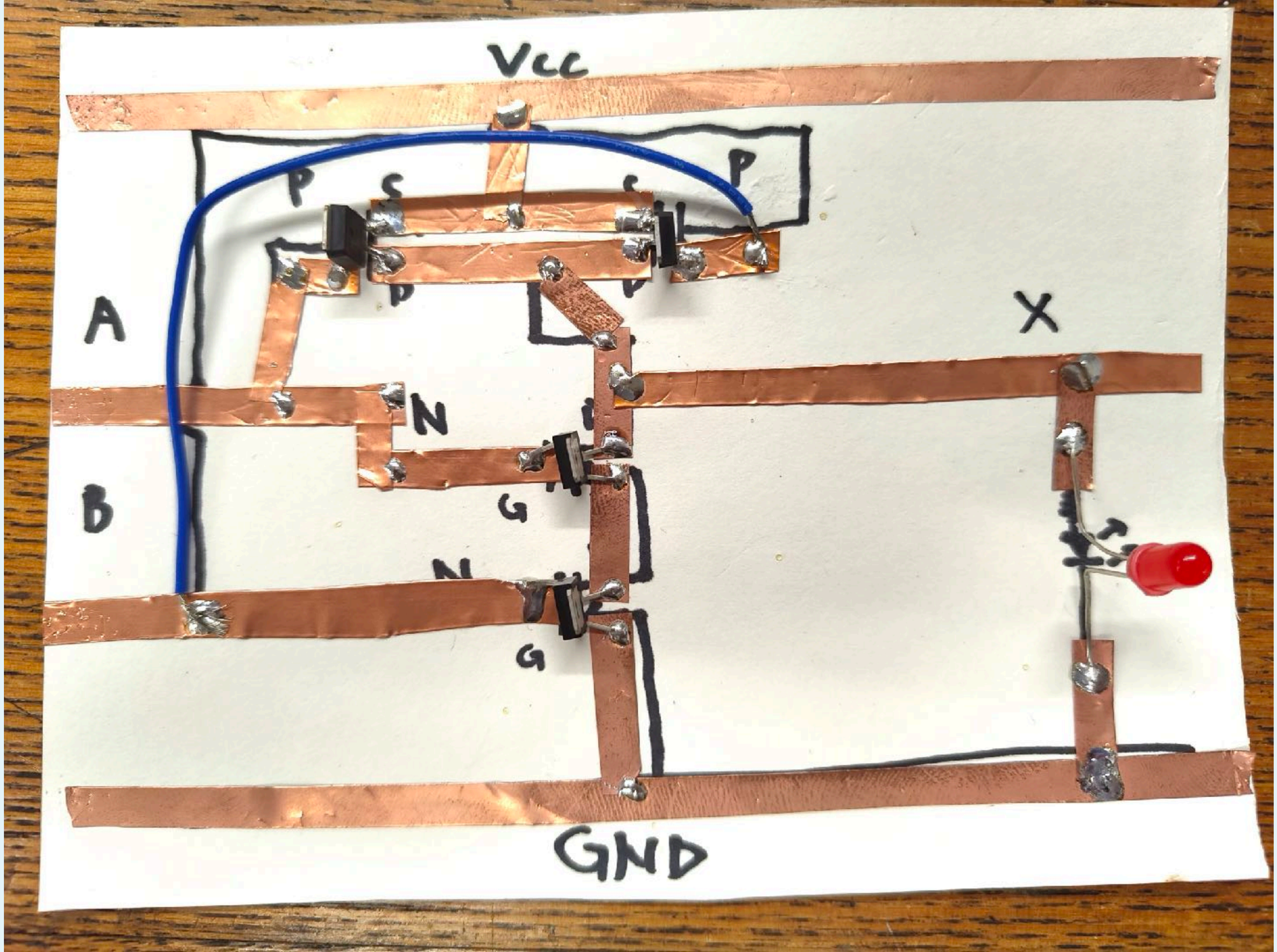

+5V
PMOS1
Q3
PMOS2
Q4
X
A
Q1
NMOS1
B
Q2
NMOS2
GND

この部分がどうやっても他の線を跨ぐので工夫しよう



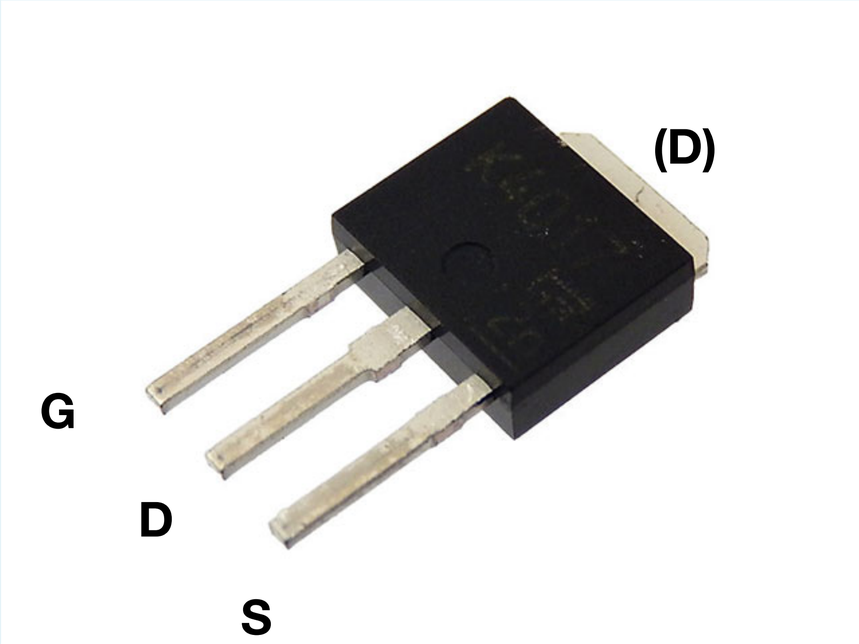

Vcc
P
S
S
P
G
D
D
G
A
X
N
D
B
G
S
D
N
G
S
GND


Vcc
P
P
A
X
N
B
G
N
G
GND


Vcc
P
S
S
P
A
X
N
B
G
N
G
GND

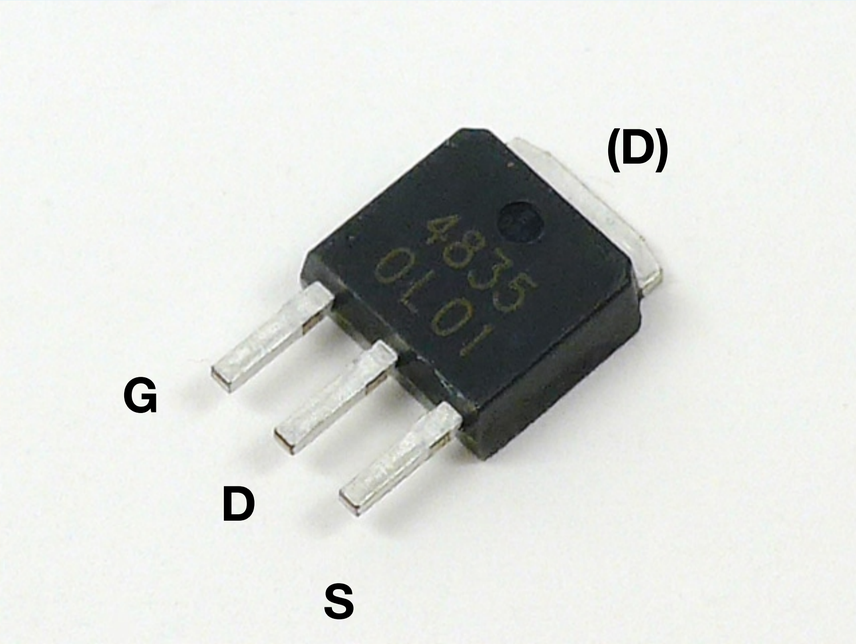
N型

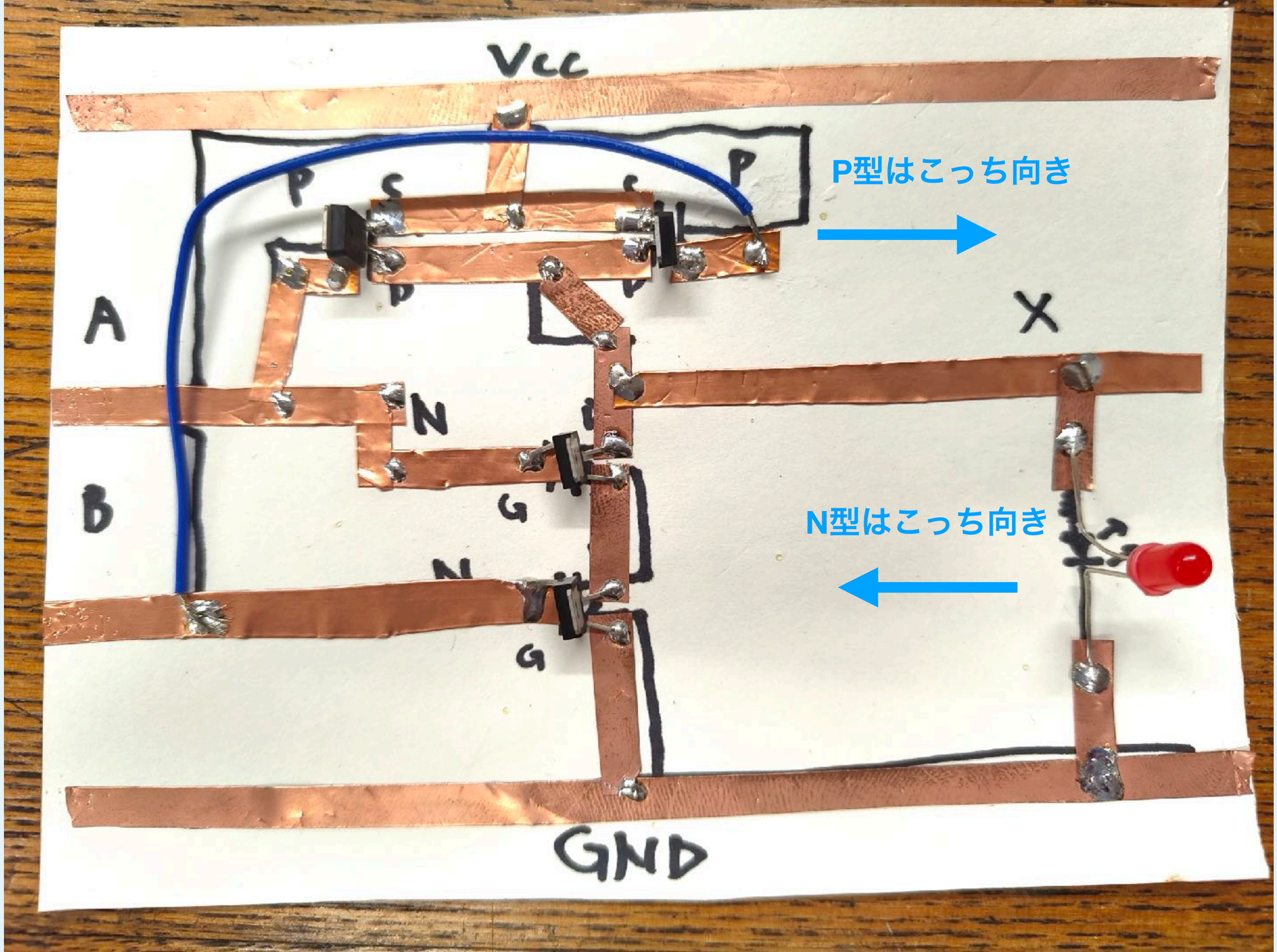
2SK4017

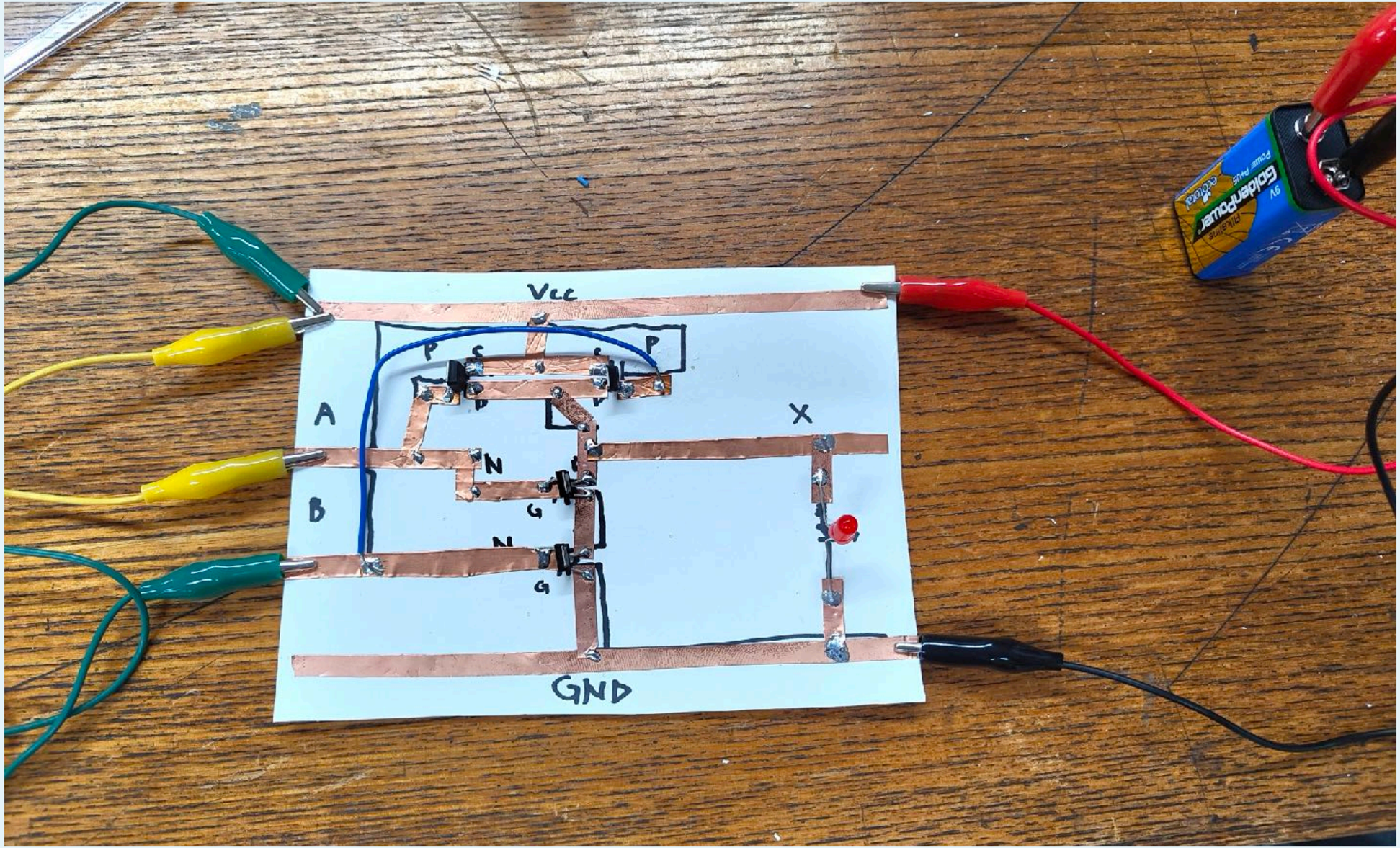


P型

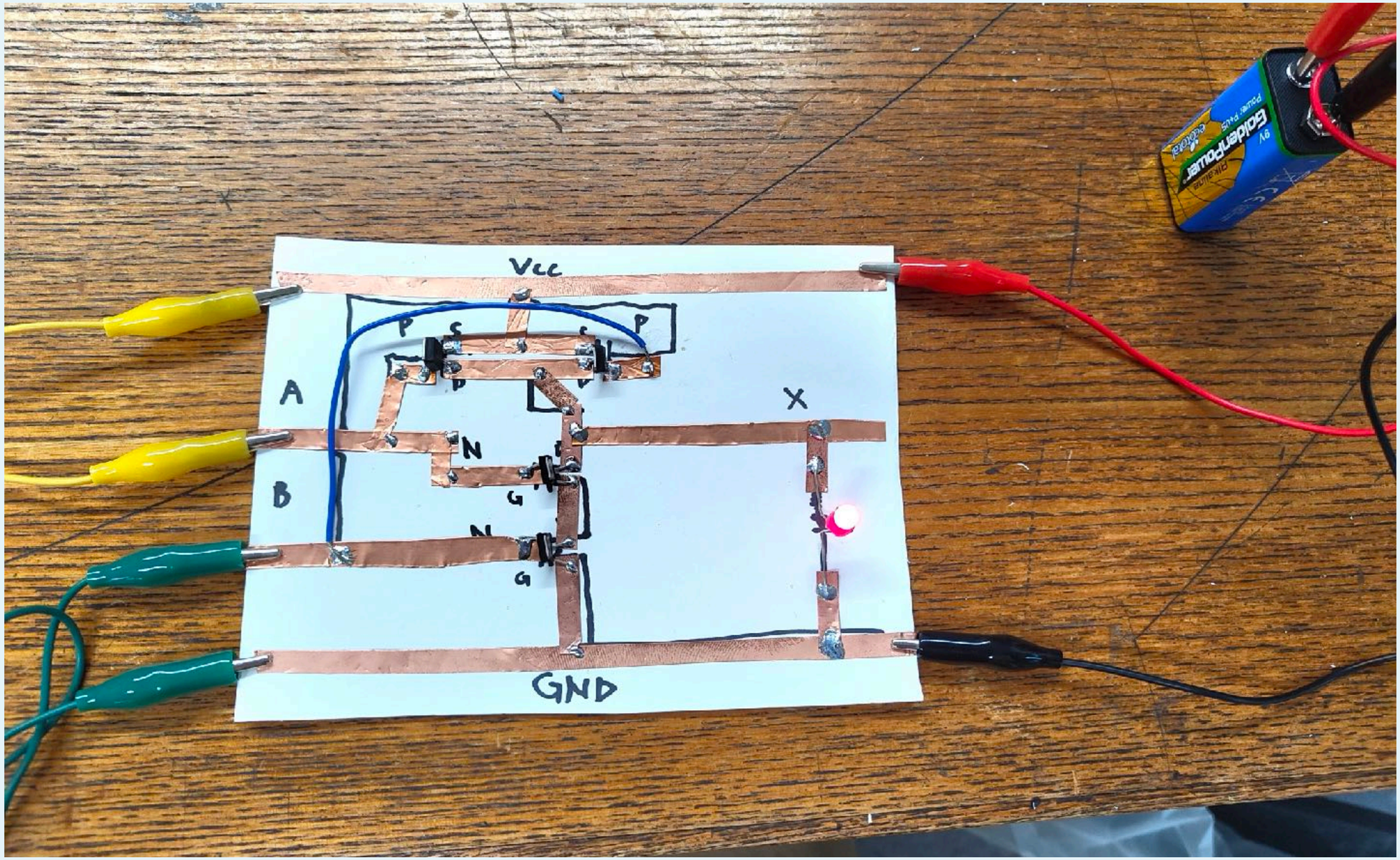
MTP4835
(足が短い)



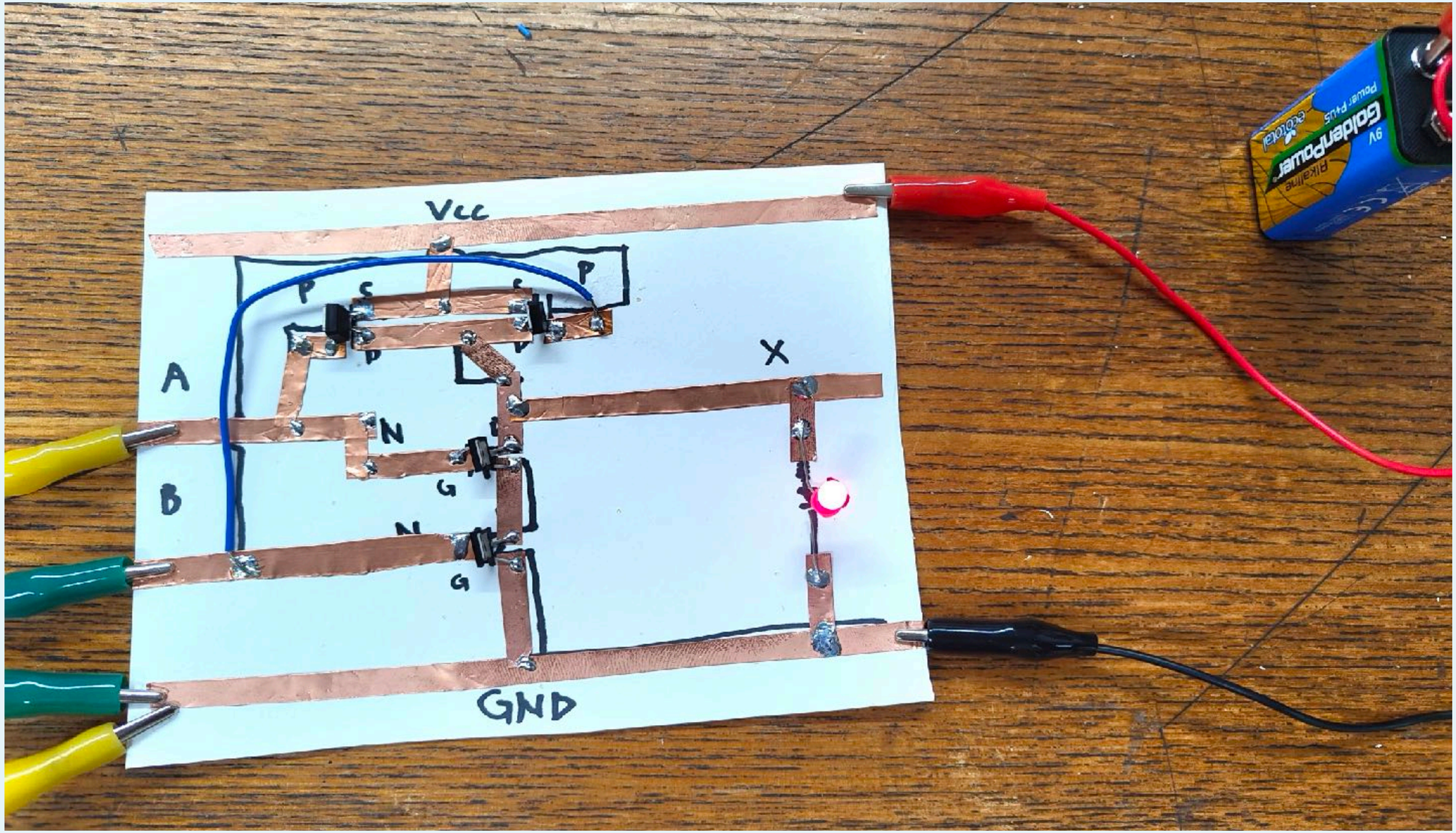

Vcc
P
S
S
P
P型はこっち向き
A
X
N
B
G
N型はこっち向き
N
G
GND



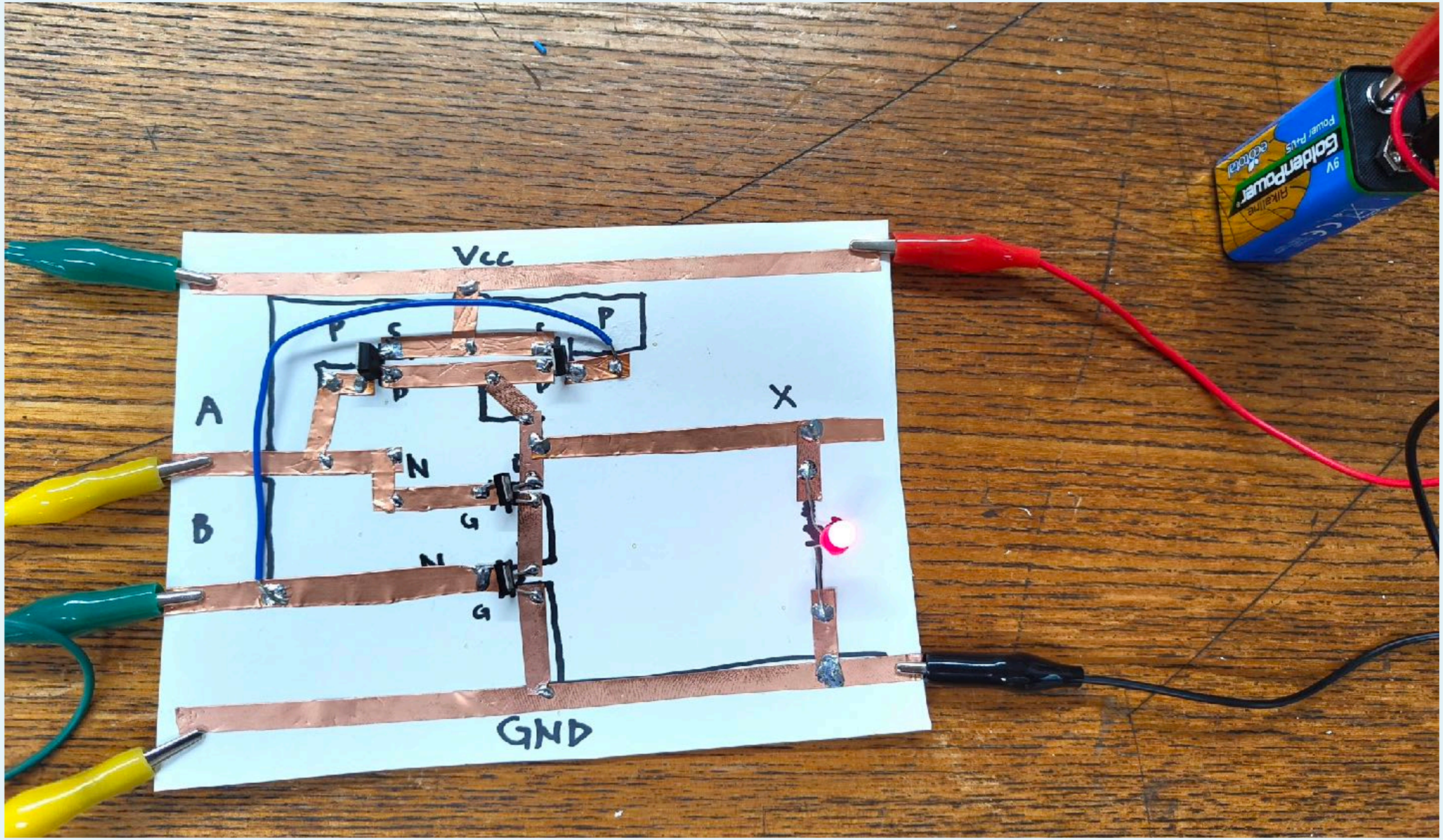
両方入力HIGH：出力LOW



ほかはすべて出力HIGH

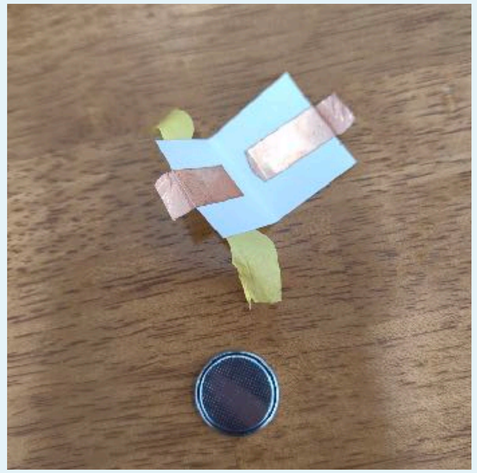


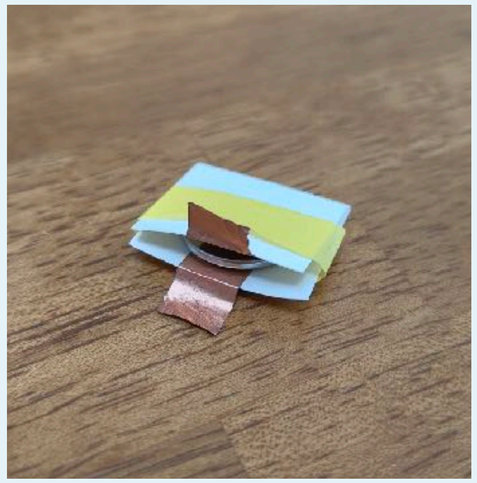
ほかはすべて出力HIGH

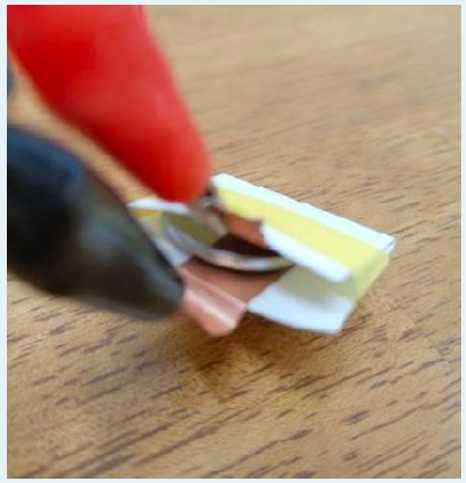


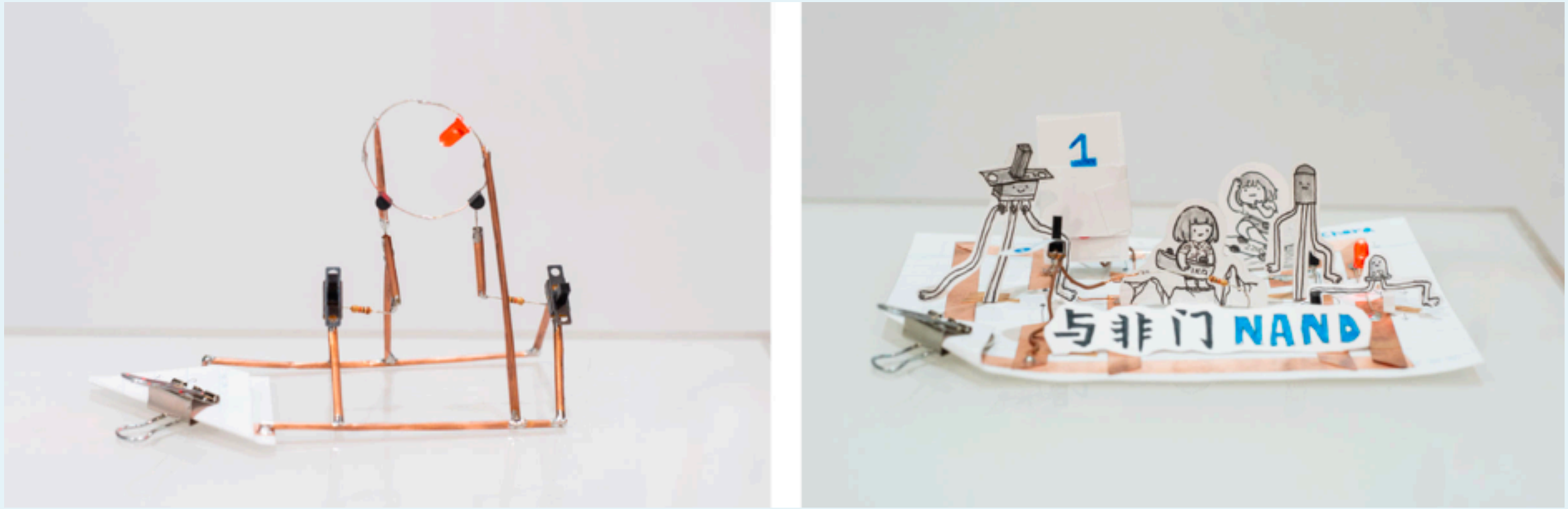
ほかはすべて出力HIGH

- 9V電池でやる場合、FETの向きを間違えるとFETを通してショートして、過熱する可能性があるので、注意
- NAND単体のテストはボタン電池を推奨





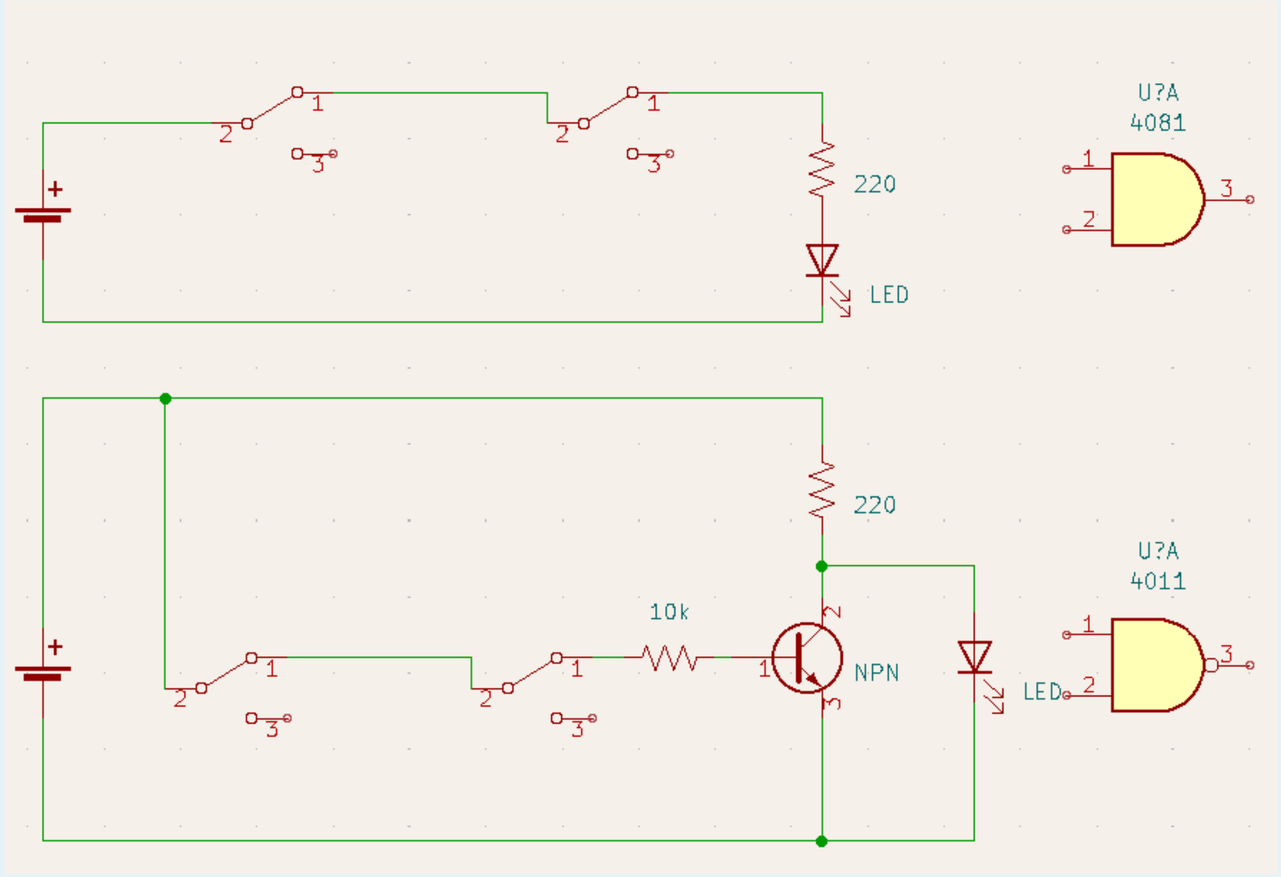


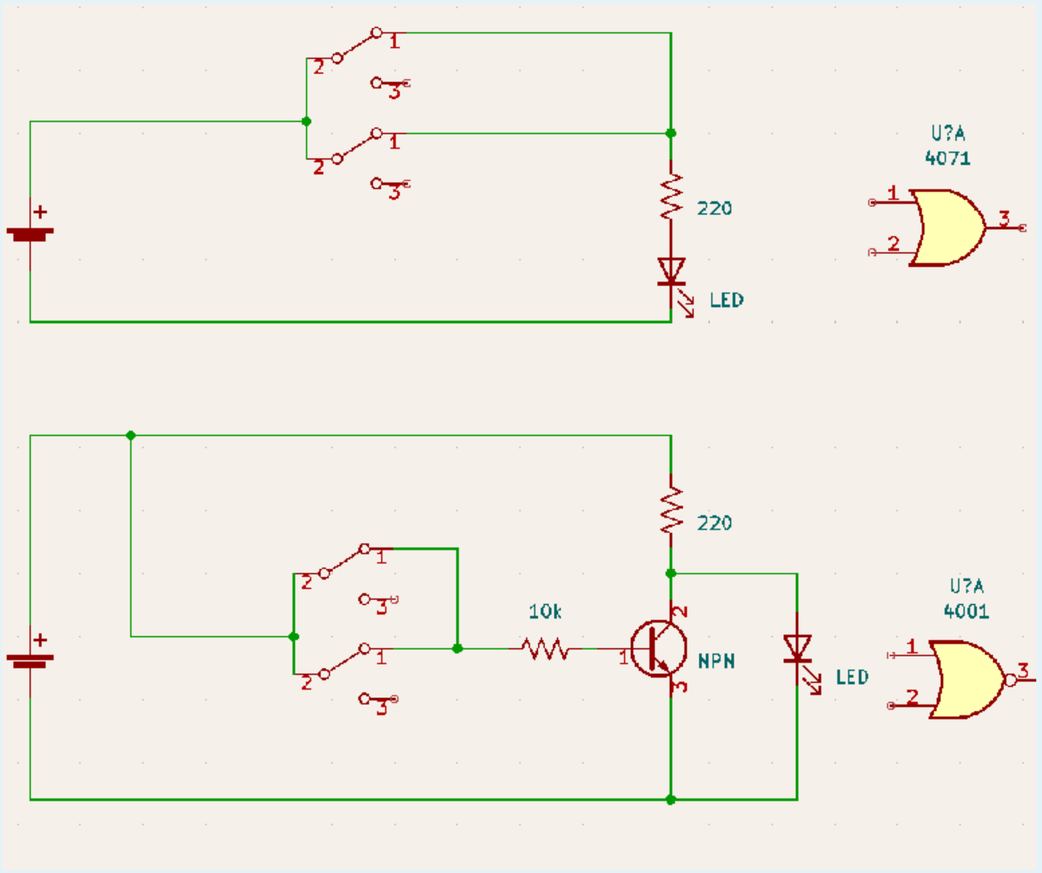


SFPC Summer in Yamaguchi 2019 での製作例(左：大網拓真、右：Chara Wang)

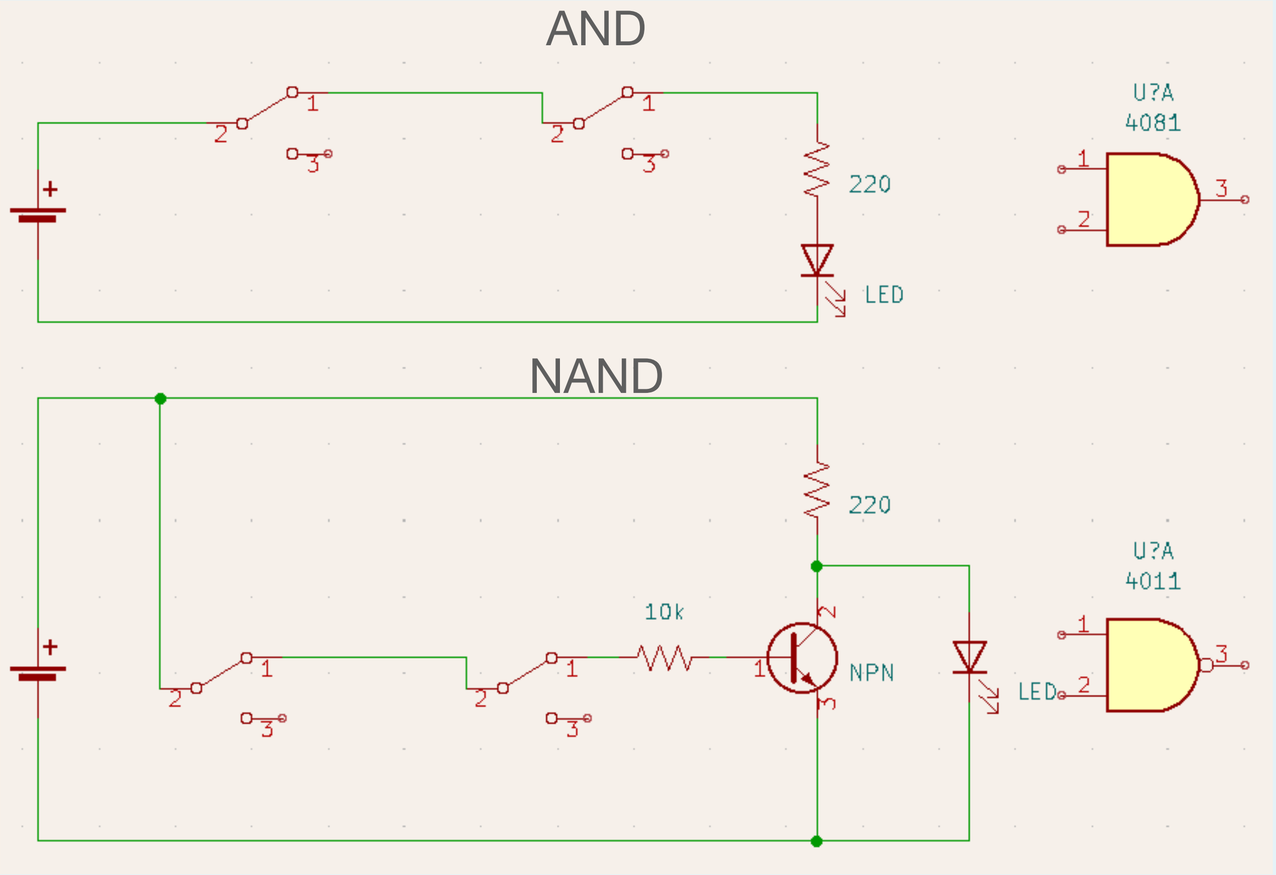
https://makezine.jp/blog/2019/11/sfpc_report_01.html

NANDゲートから加算器を作ろう


U?A
4081
220
LED
10k
NPN
U?A
4011
LED

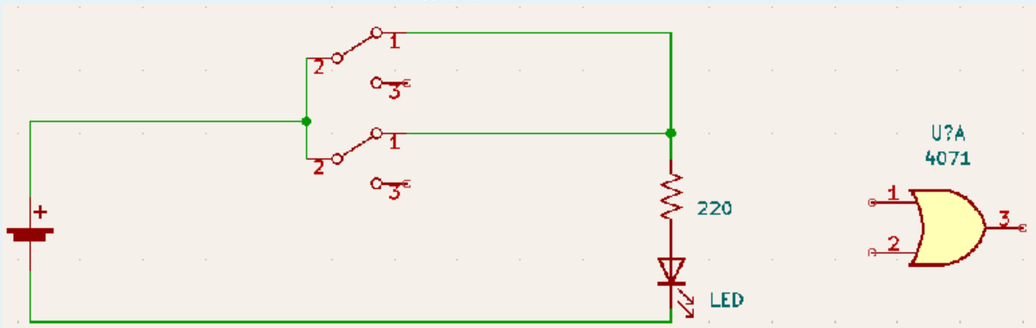

U?A
4071
220
LED
10k
NPN
U?A
4001
LED

AND

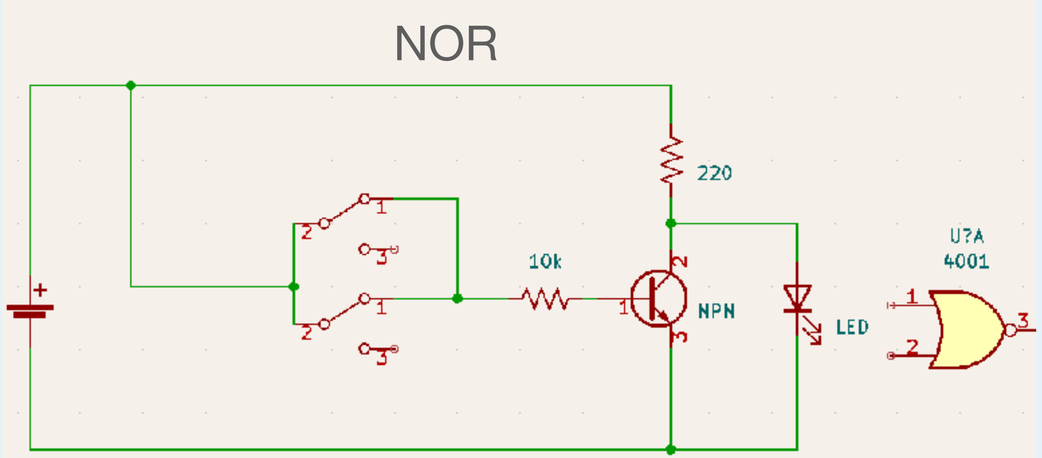


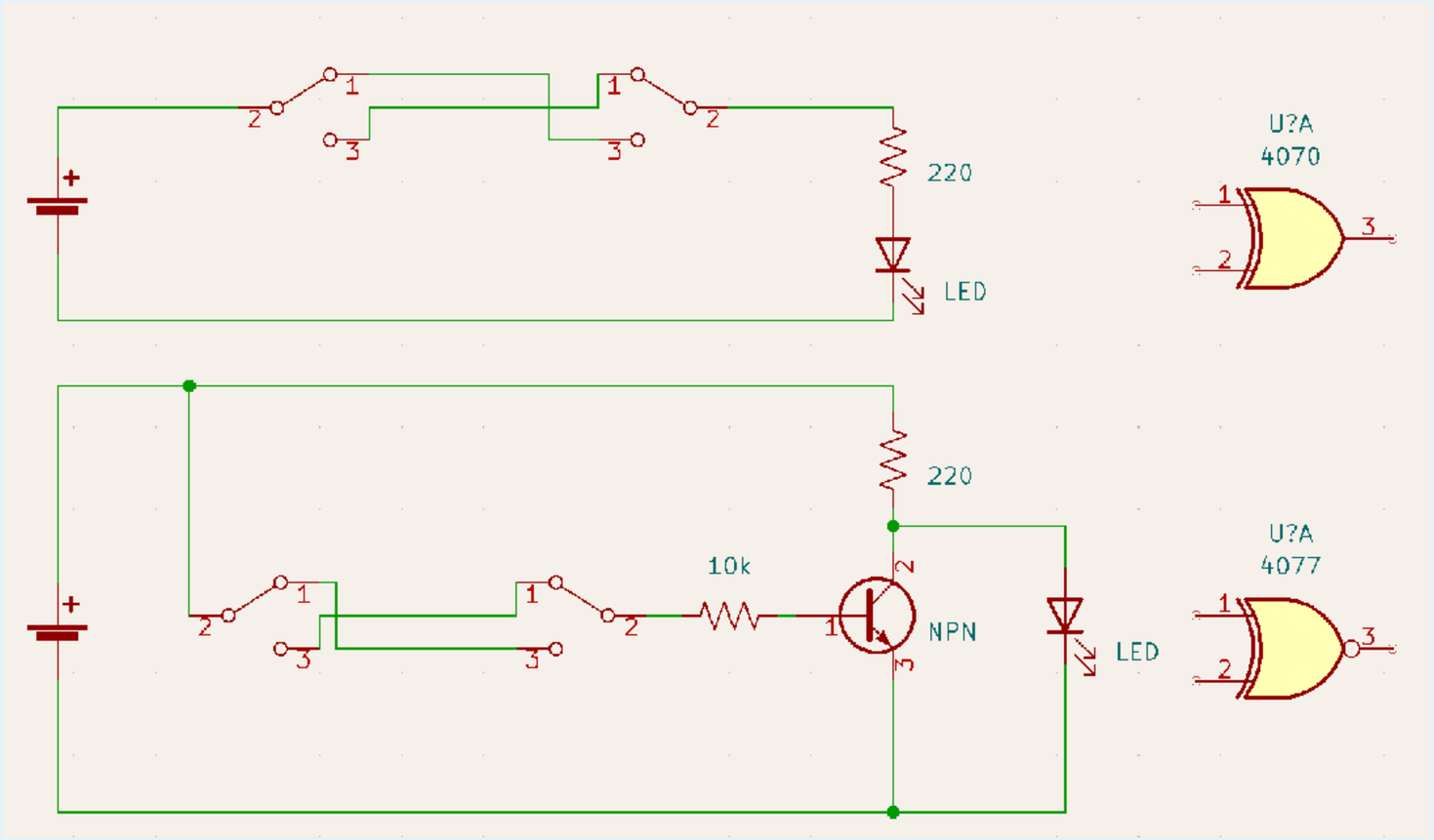
NAND

OR



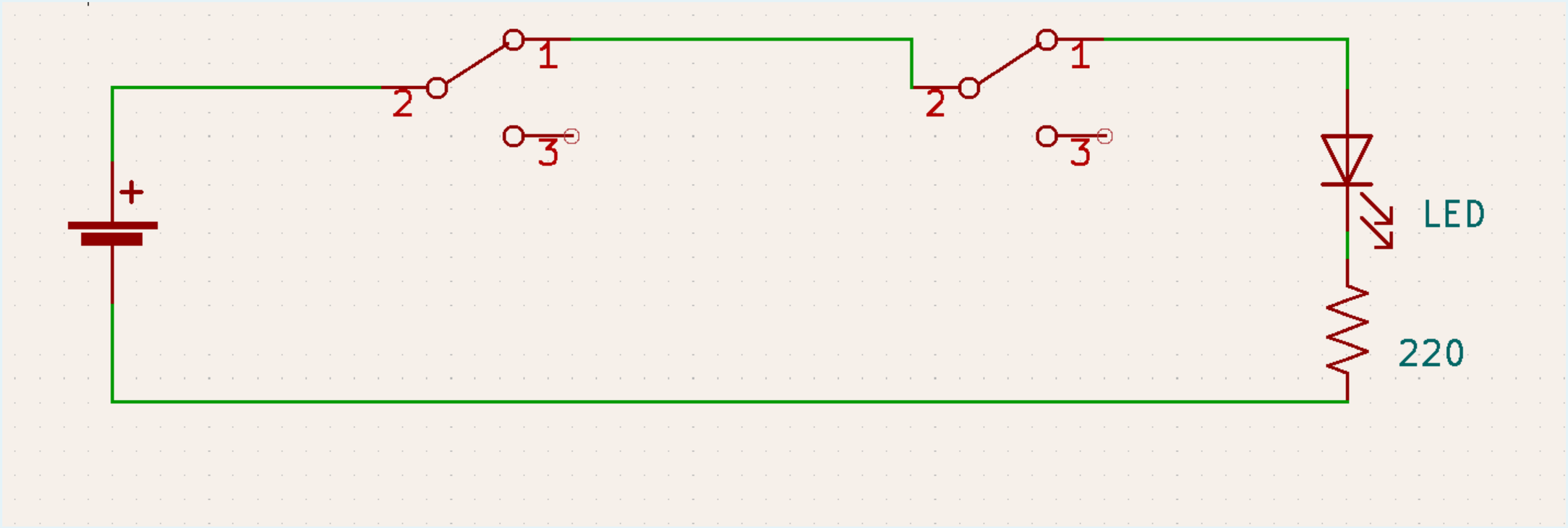
NOR

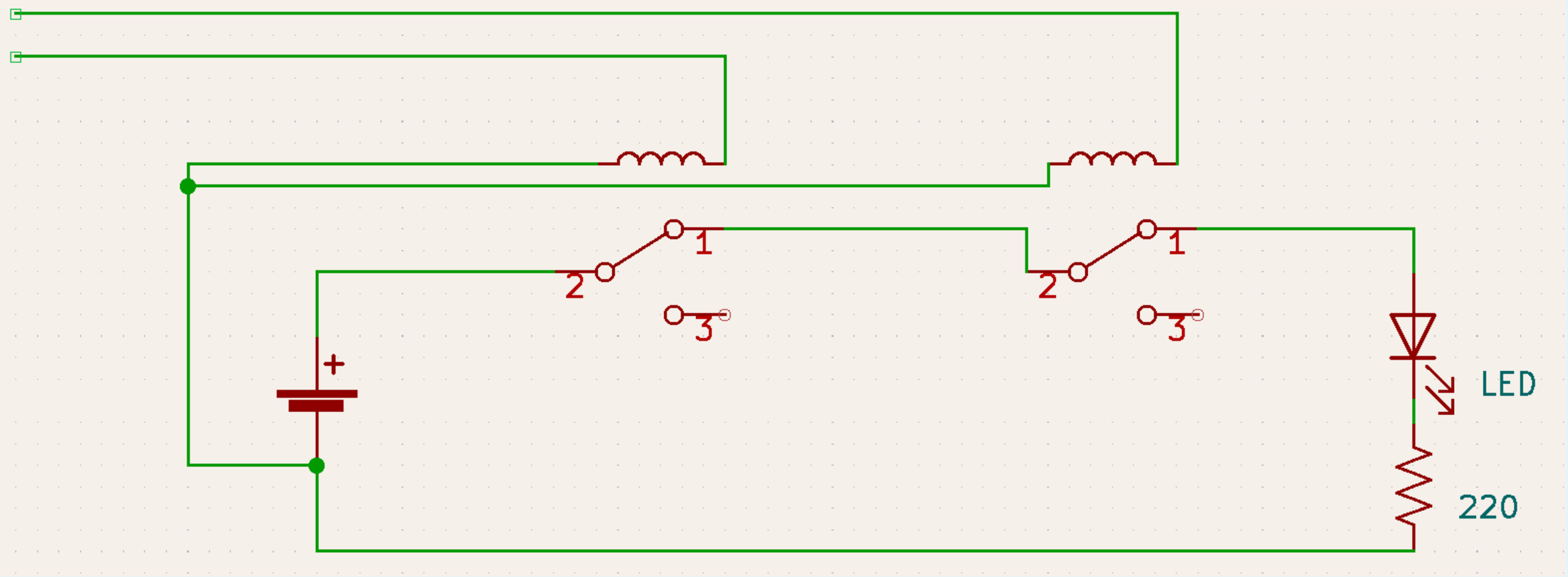




XOR

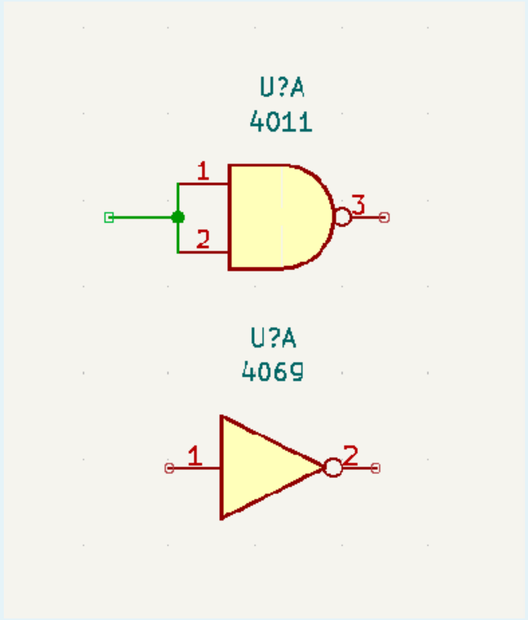
XNOR


1
2
3
1
2
3
+
LED
220



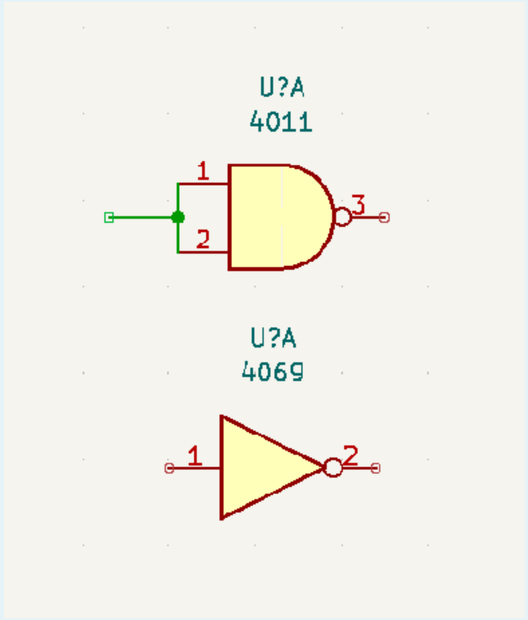
スイッチのオンオフも、電気的にコントロールしたい

NANDからNOT



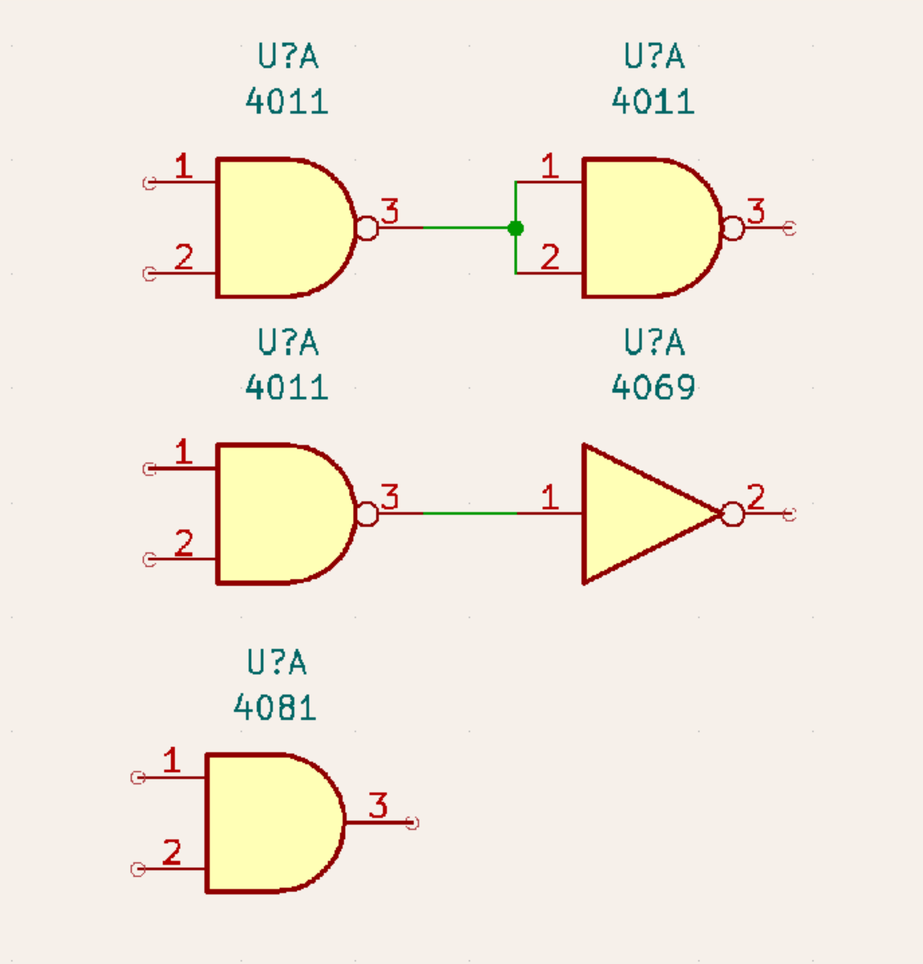
A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

NANDからNOT



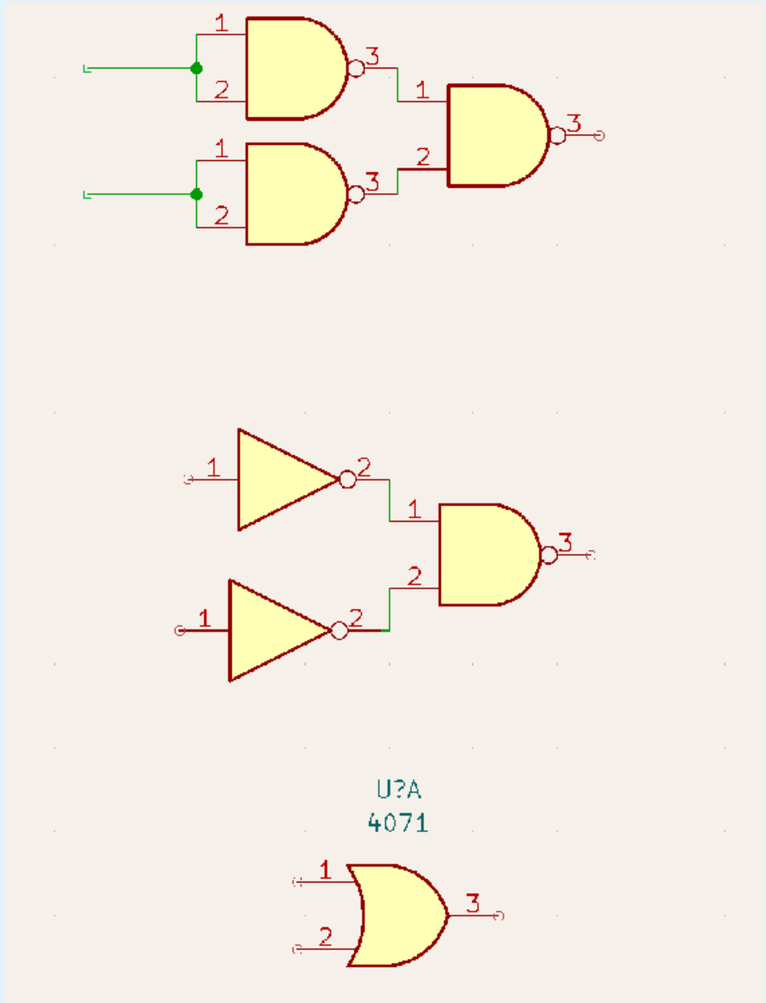
A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

NANDからAND



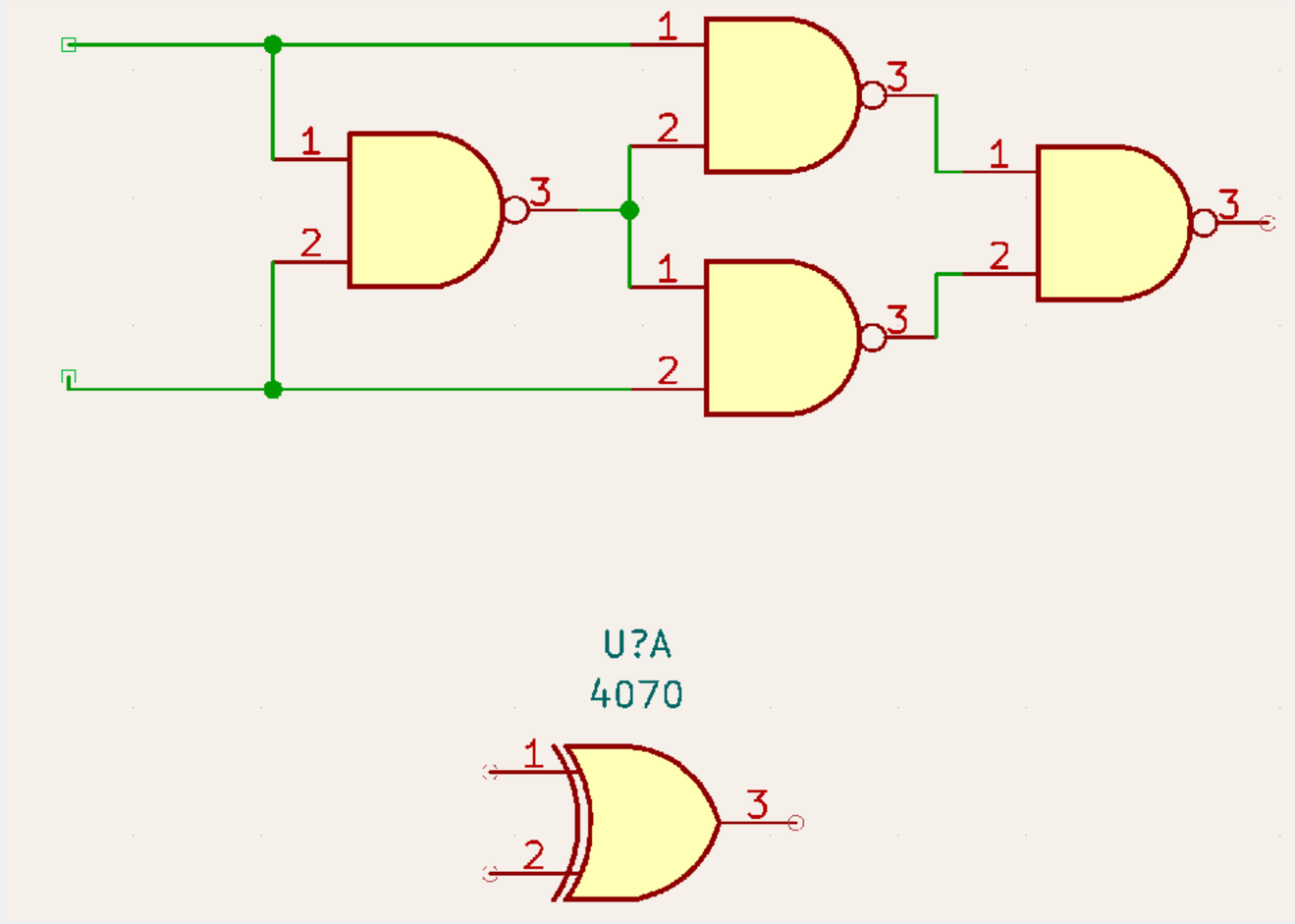
A	B	X	NOT(X)
0	0	1	0
0	1	1	0
1	0	1	0
1	1	0	1

NANDからOR

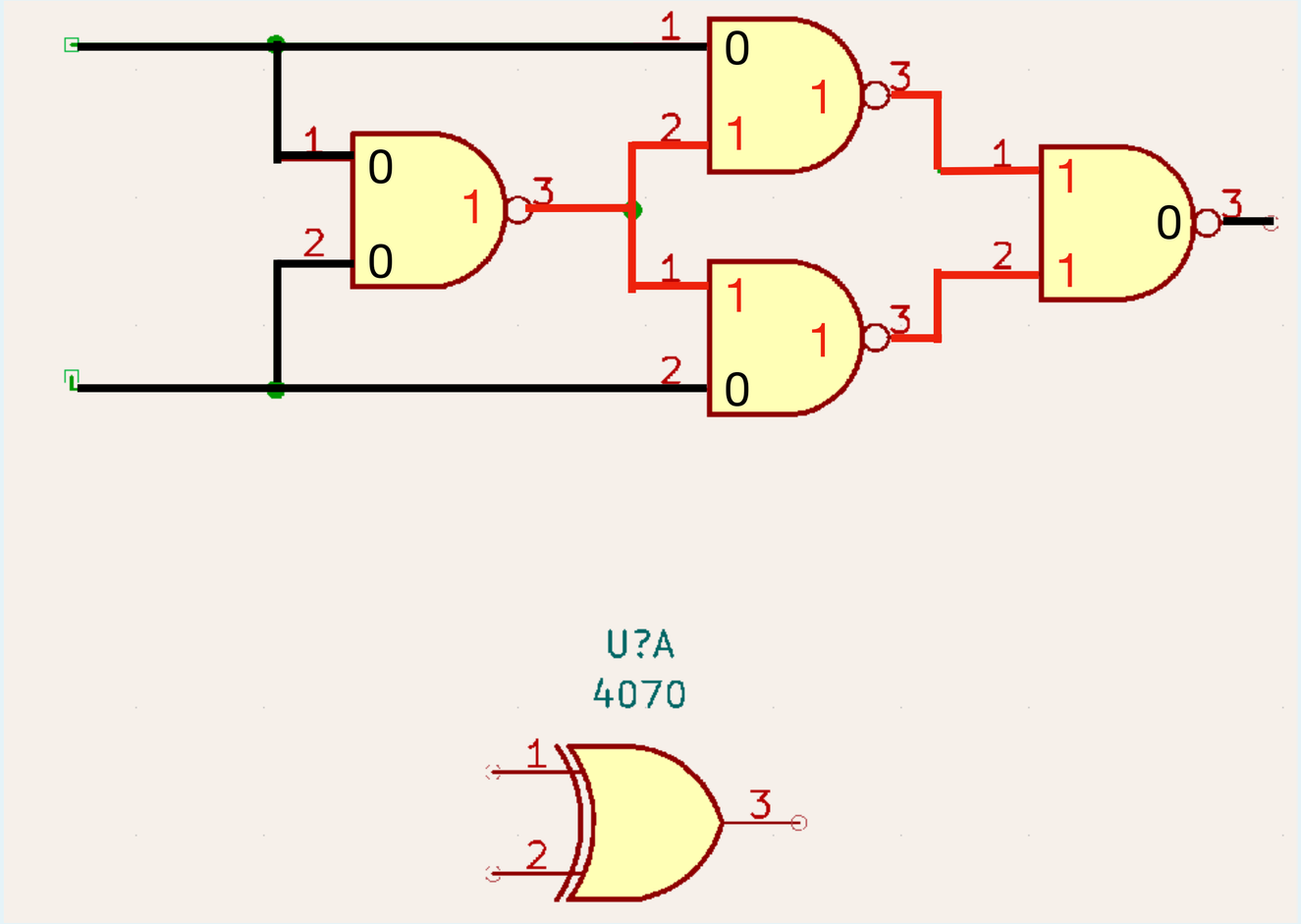


A	NOT(A)	B	NOT(B)	OR(A,B)
0	1	0	1	0
0	1	1	0	1
1	0	0	1	1
1	0	1	0	1

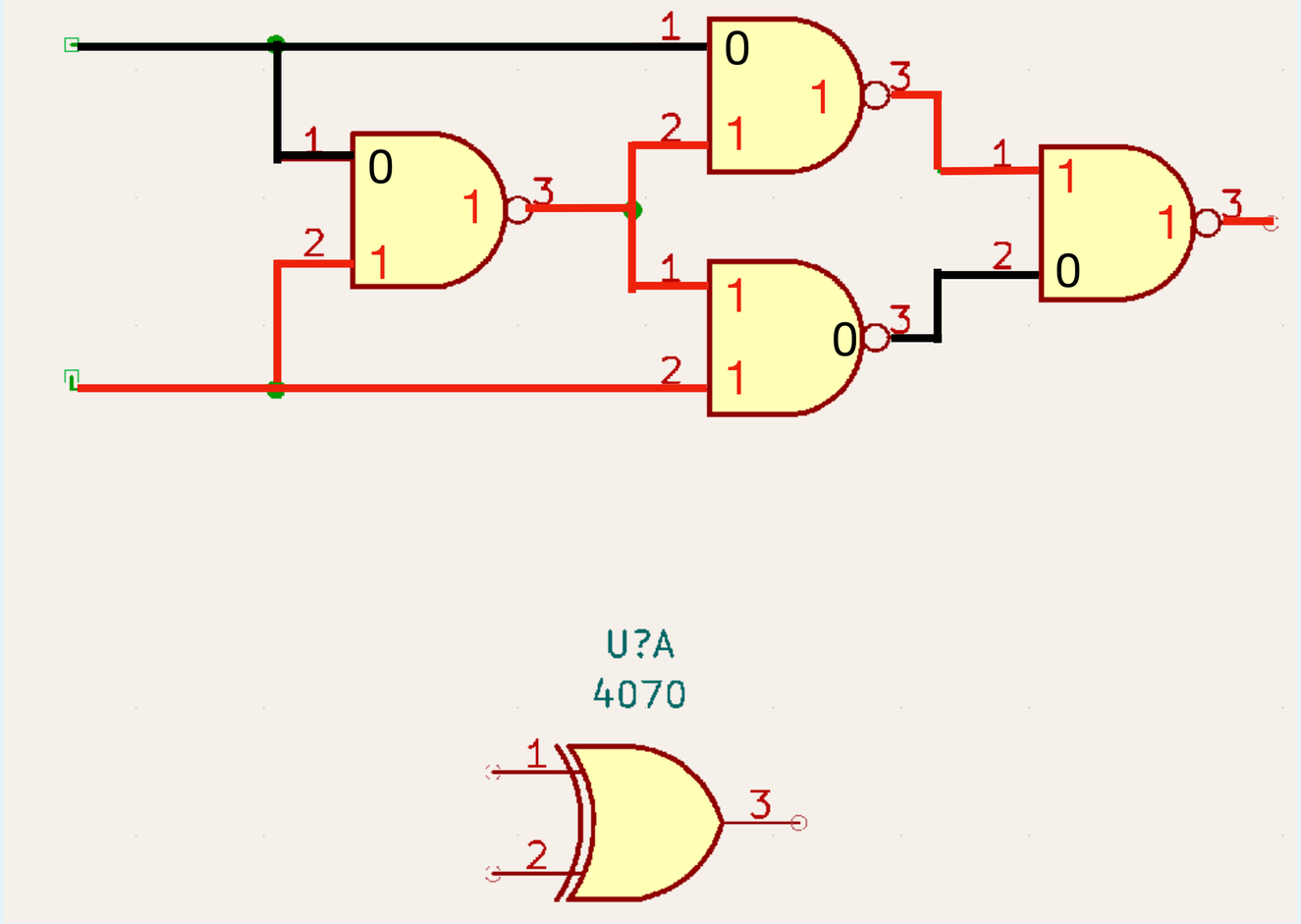
NANDからXOR



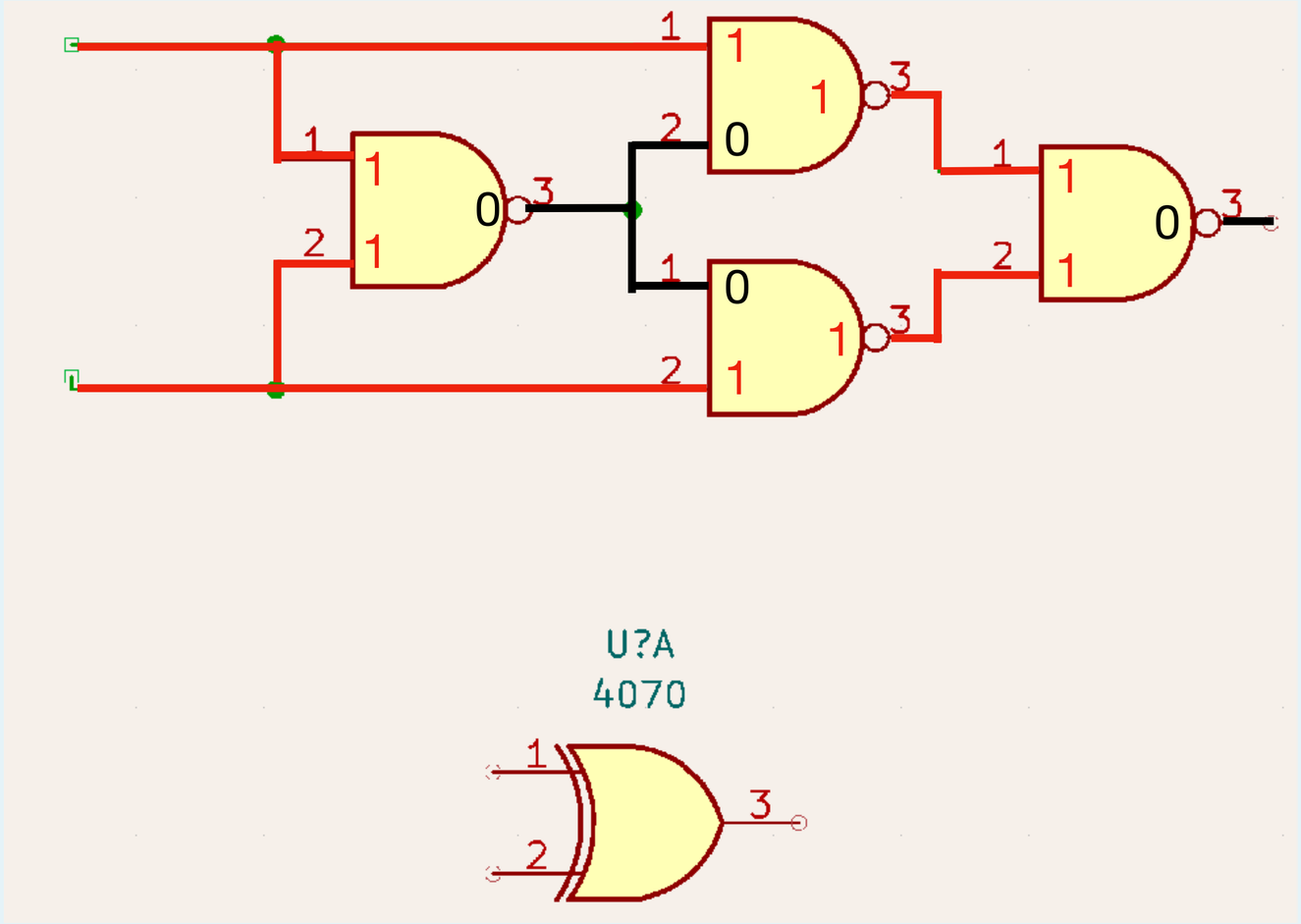
NANDからXOR



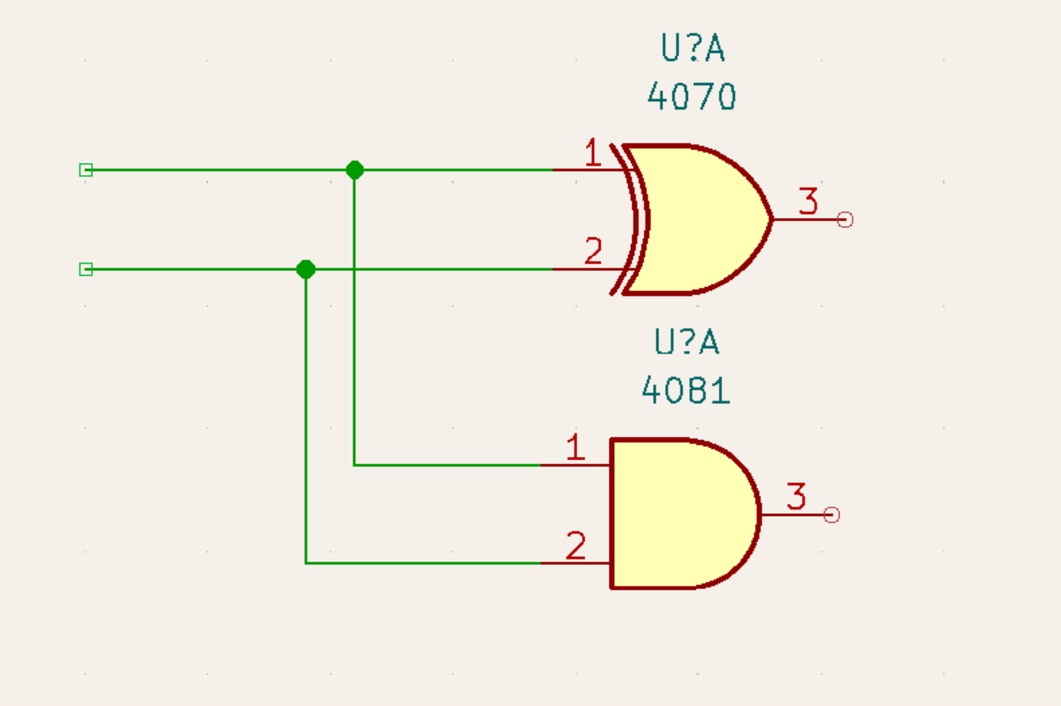
NANDからXOR



NANDからXOR

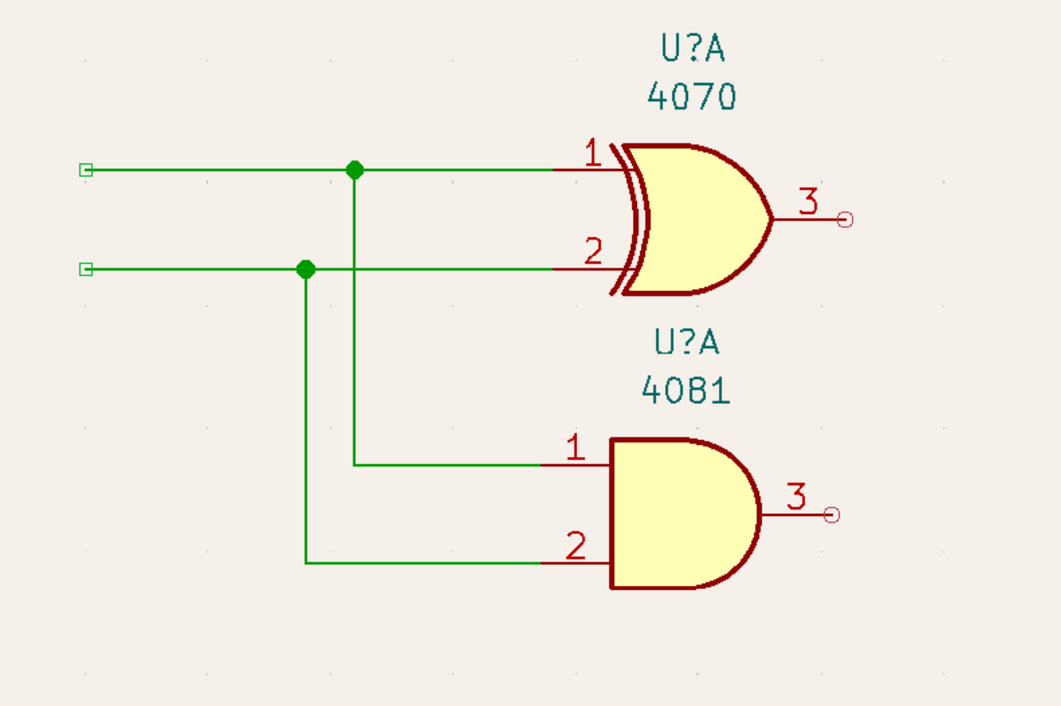


半加算器(一桁入力の足し算)



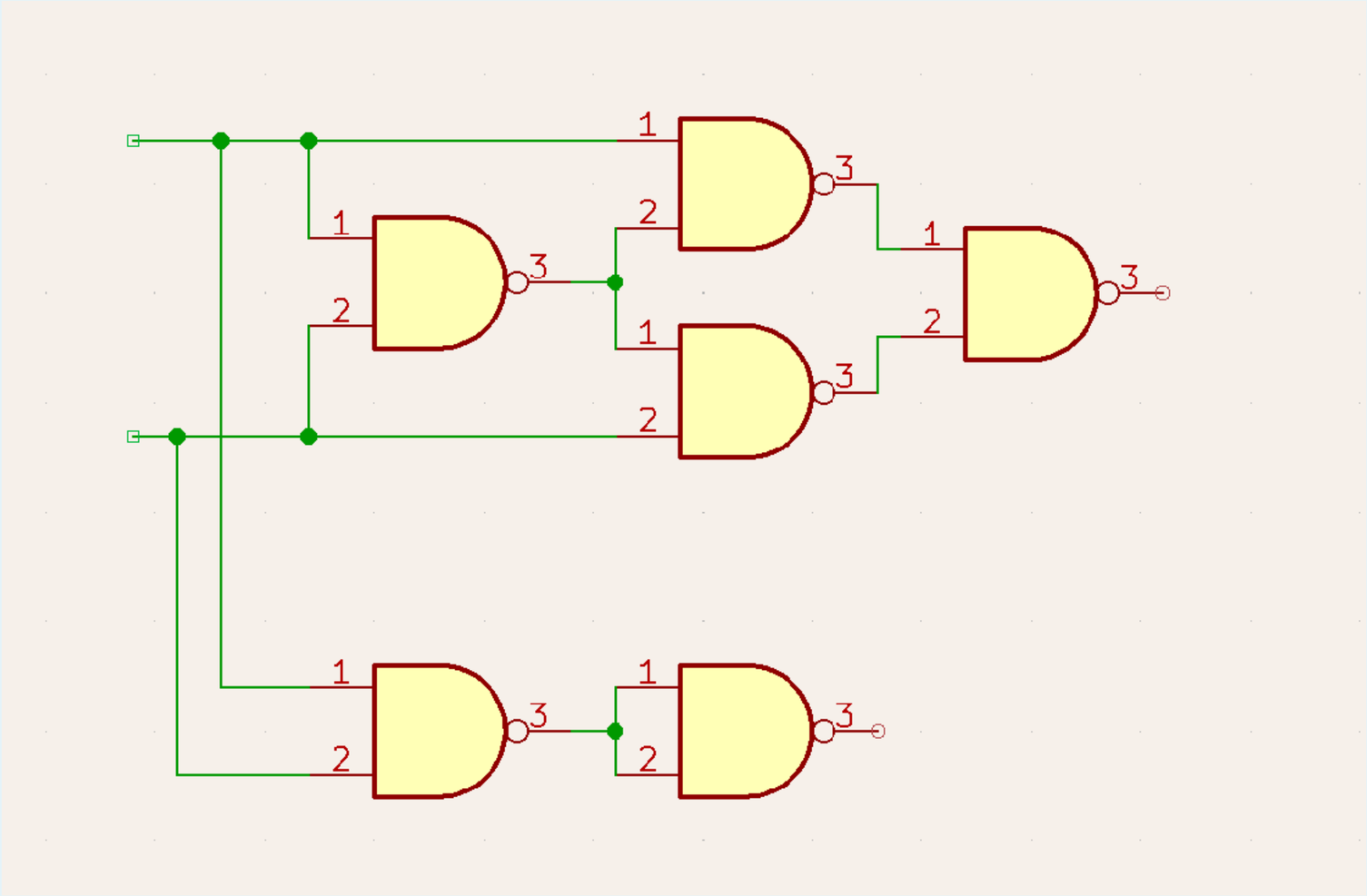
A	B	A+B(上位)	A+B（下位）
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

半加算器(一桁入力の足し算)

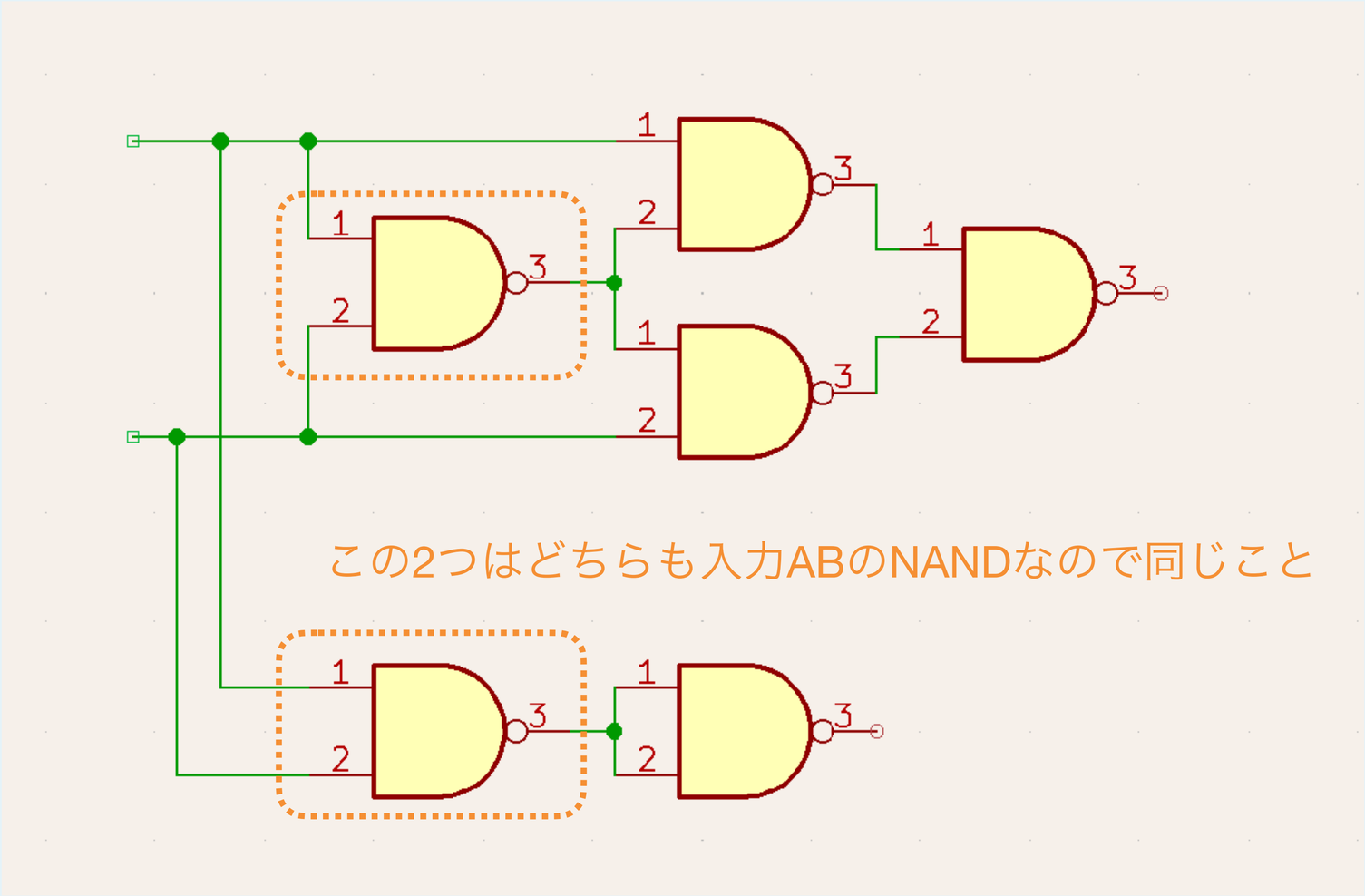


A	B	AND	XOR
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

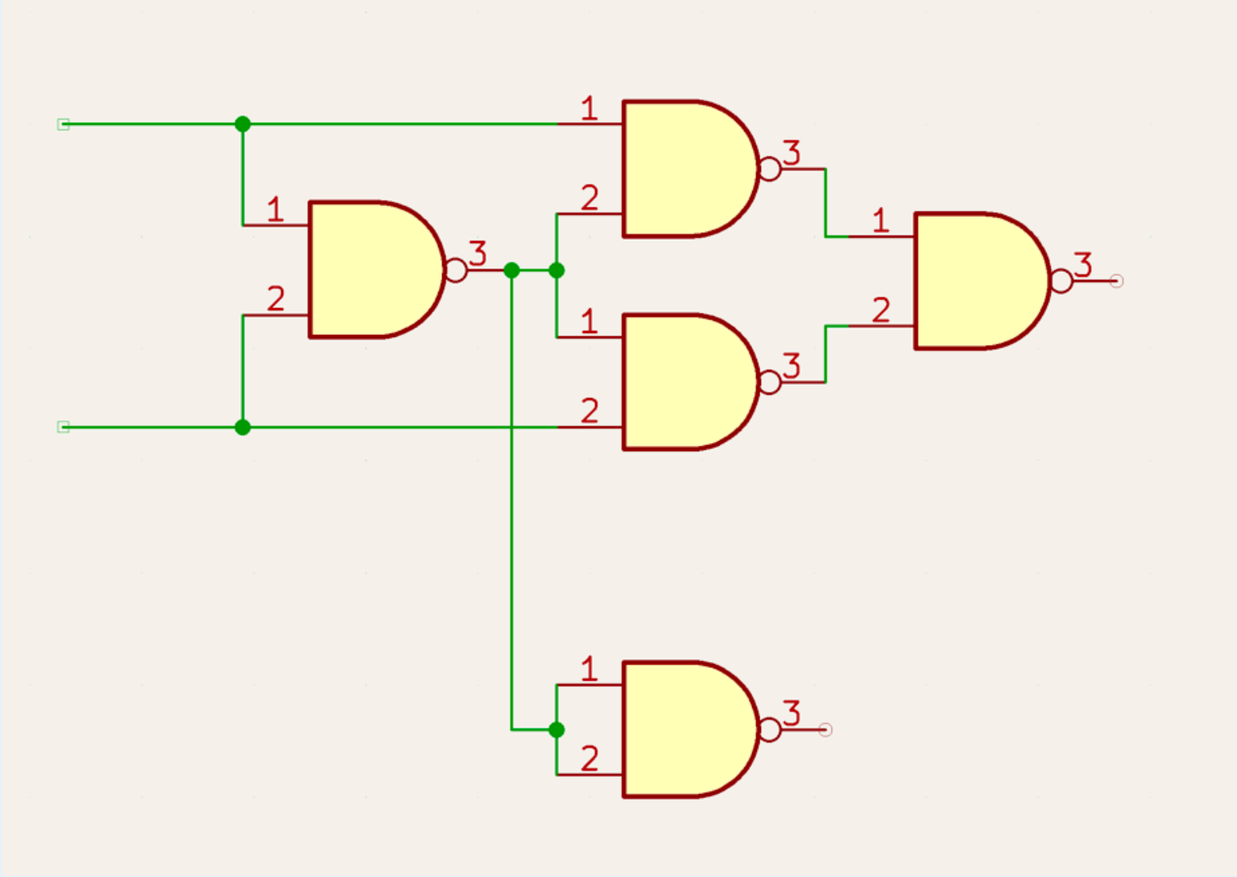
半加算器(一桁入力の足し算)



半加算器(一桁入力の足し算)



半加算器(一桁入力の足し算)

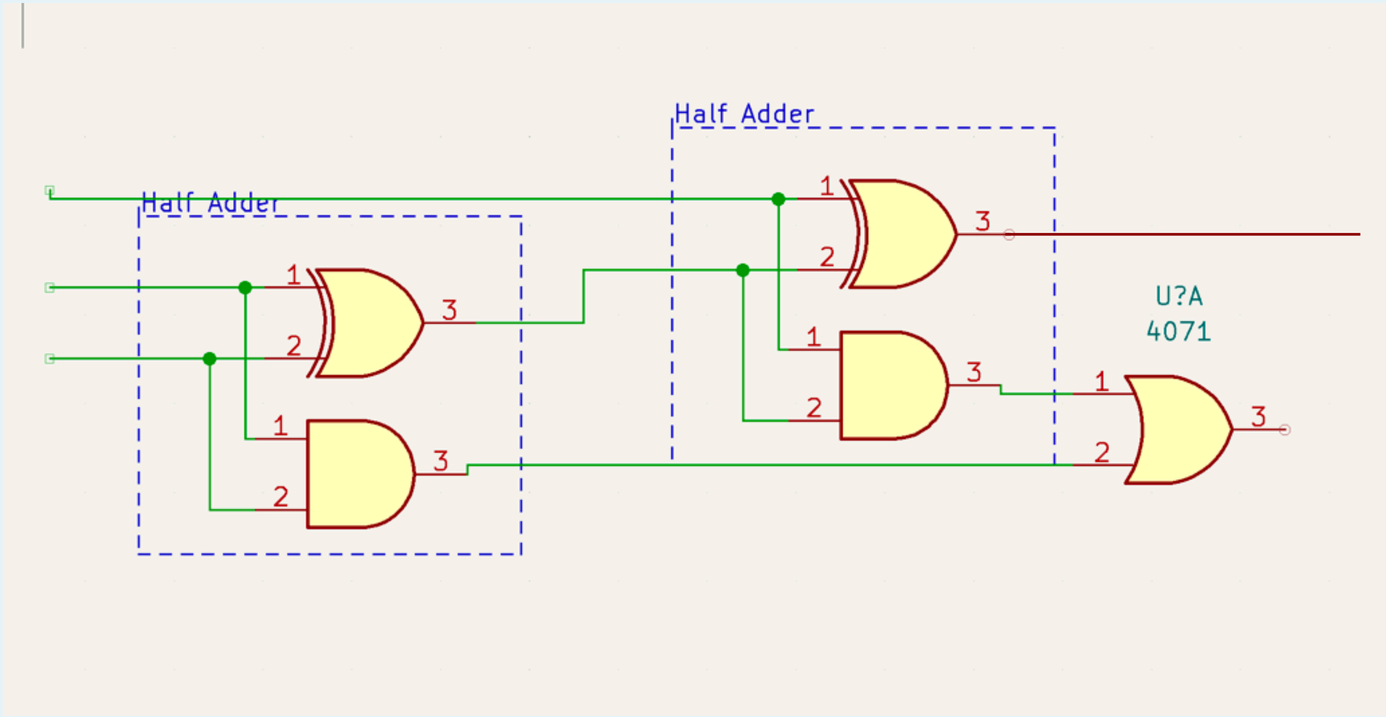


全加算器(一桁入力の足し算、桁上がり対応)

A

B

Carry In



X

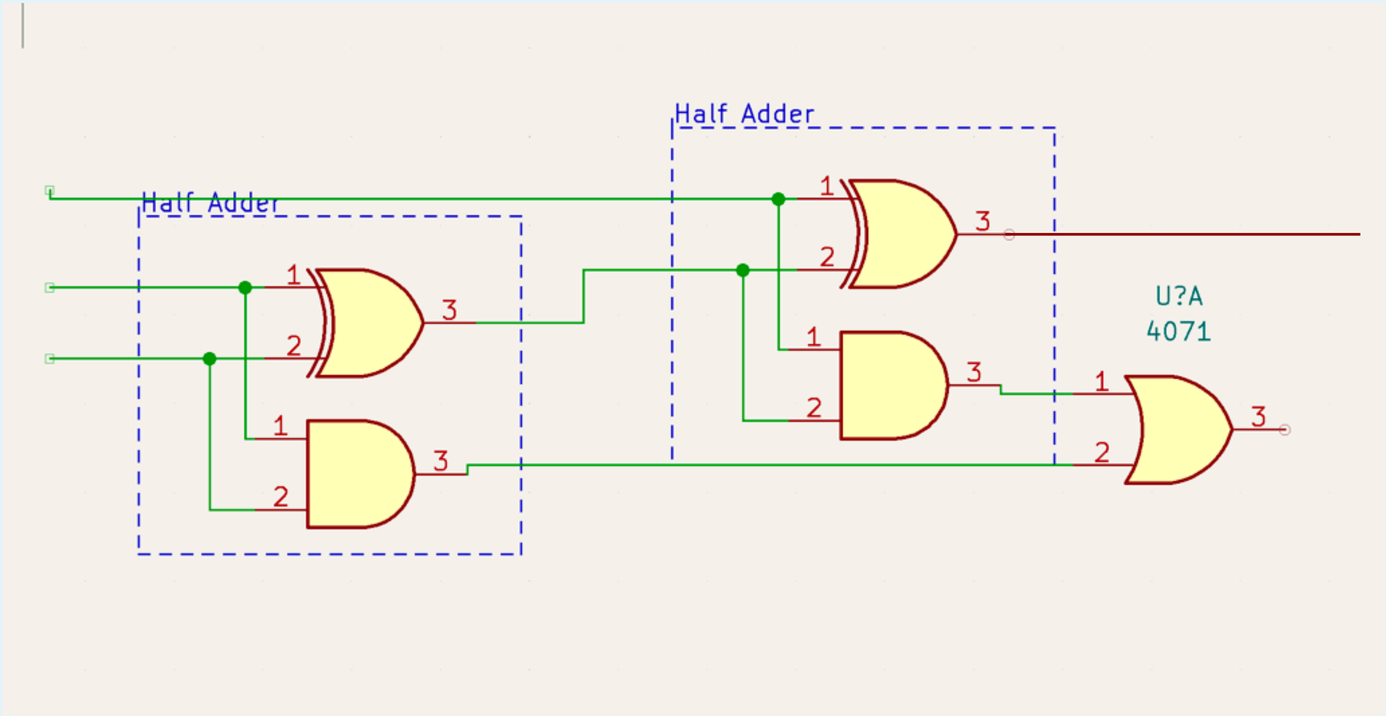
Carry Out

全加算器(一桁入力の足し算、桁上がり対応)

A

B

Carry In



X

ABCのうち1が奇数個

Carry Out

ABCのうち1が2個以上

実は入力端子はどの順番に入れ替えても同じ働きをする

全加算器(一桁入力の足し算、桁上がり対応)

A

B

Carry In

A	B	Carry In	X	Carry Out
0	0	0	0	0
0	1	0	1	0
1	0	0	1	0
1	1	0	0	1
0	0	1	1	0
0	1	1	0	1
1	0	1	0	1
1	1	1	1	1

X

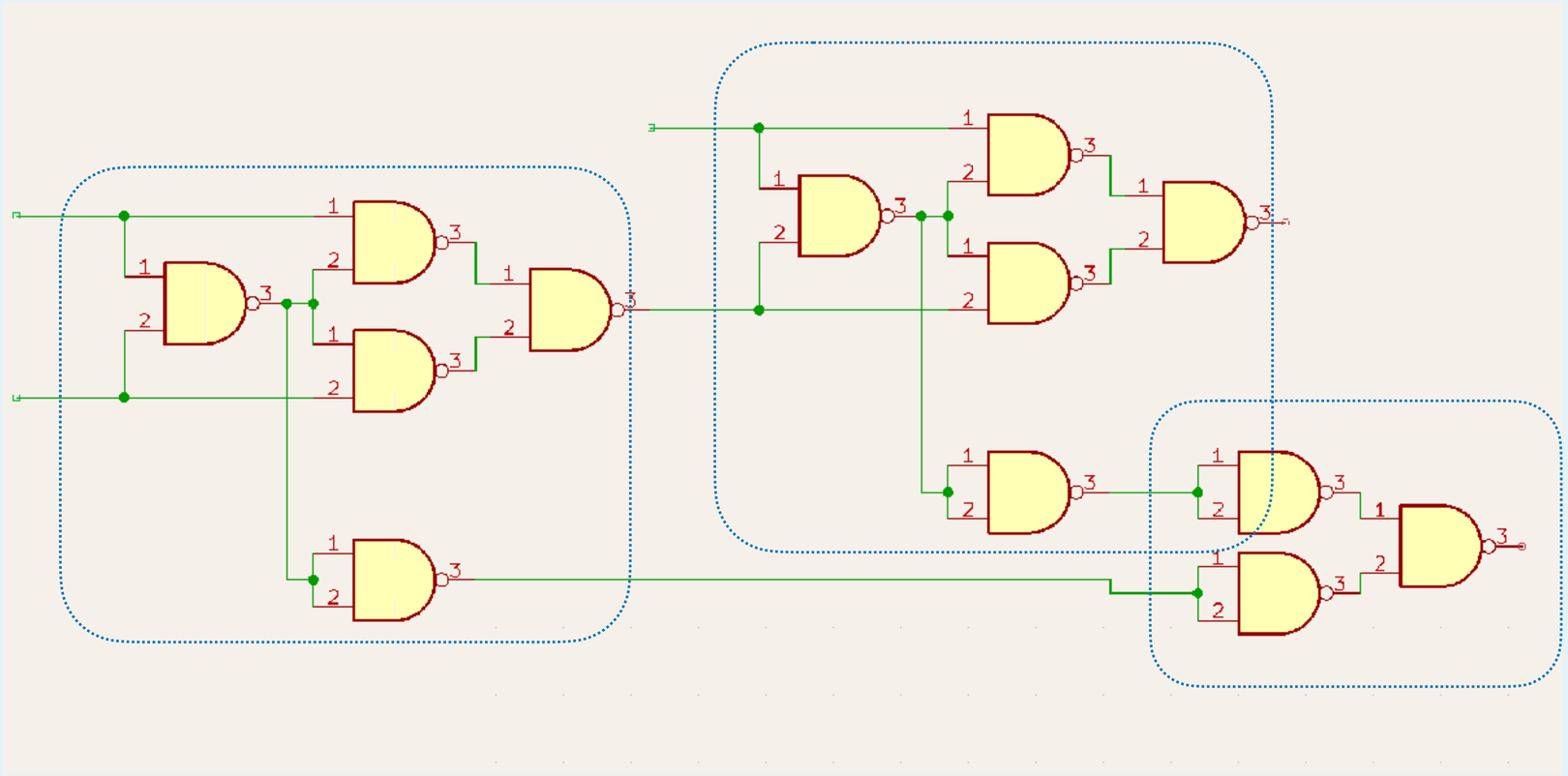
ABCのうち1が奇数個

Carry Out

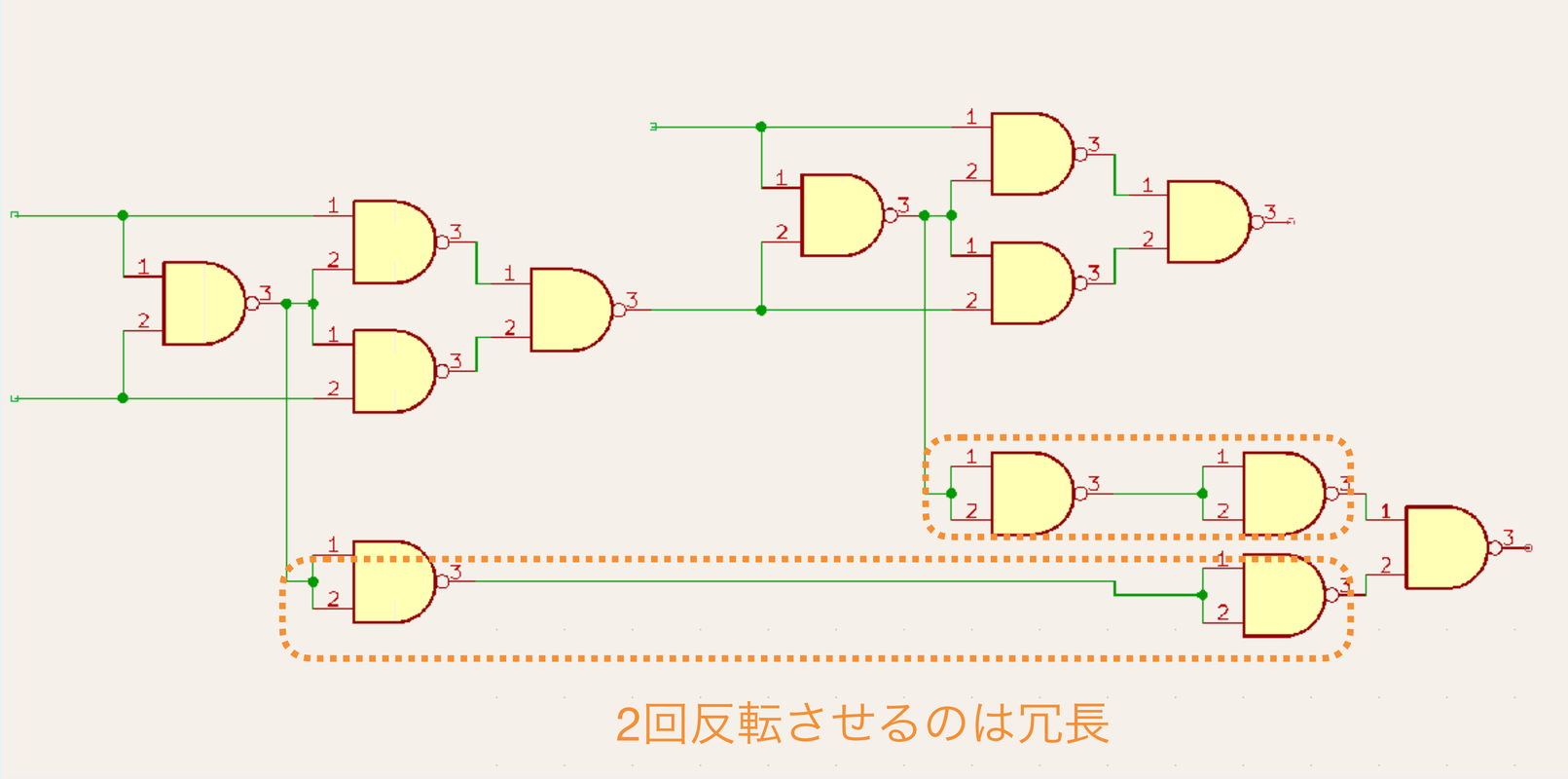
ABCのうち1が2個以上

実は入力端子はどの順番に入れ替えても同じ働きをする

全加算器(一桁入力の足し算、桁上がり対応)

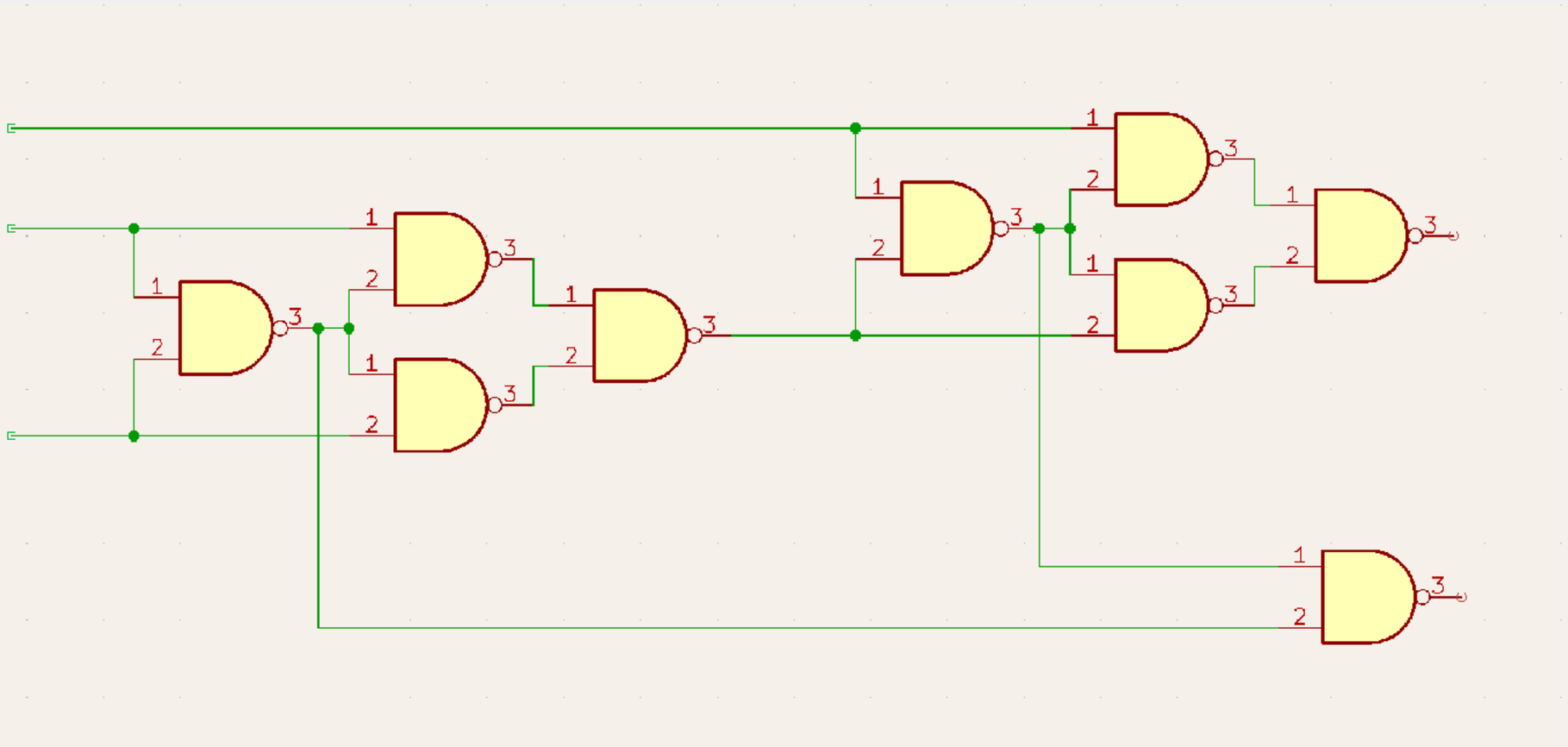


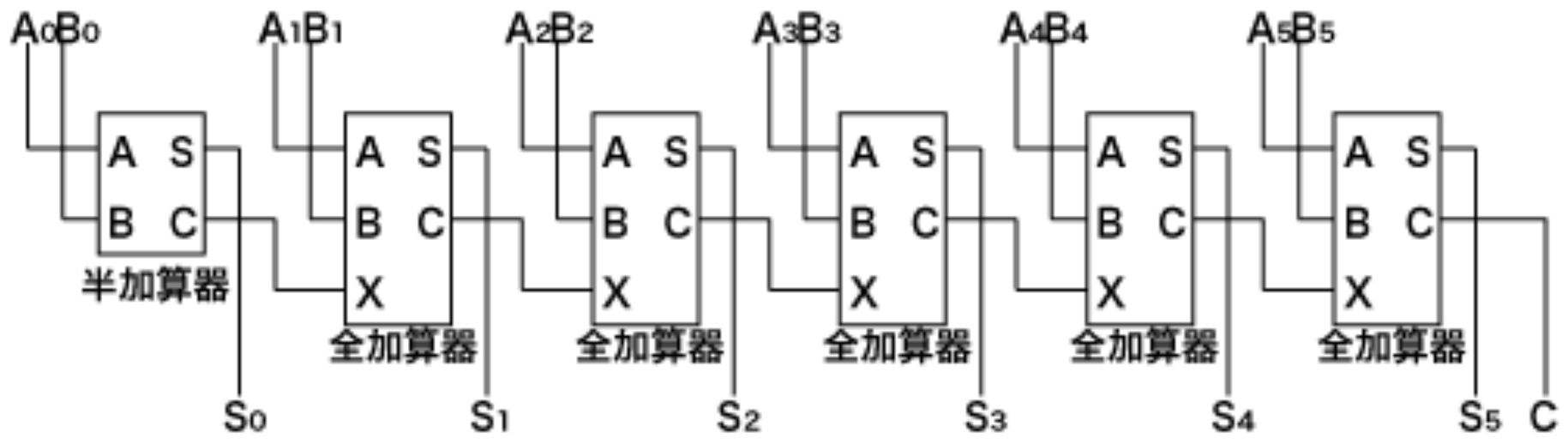
全加算器(一桁入力の足し算、桁上がり対応)



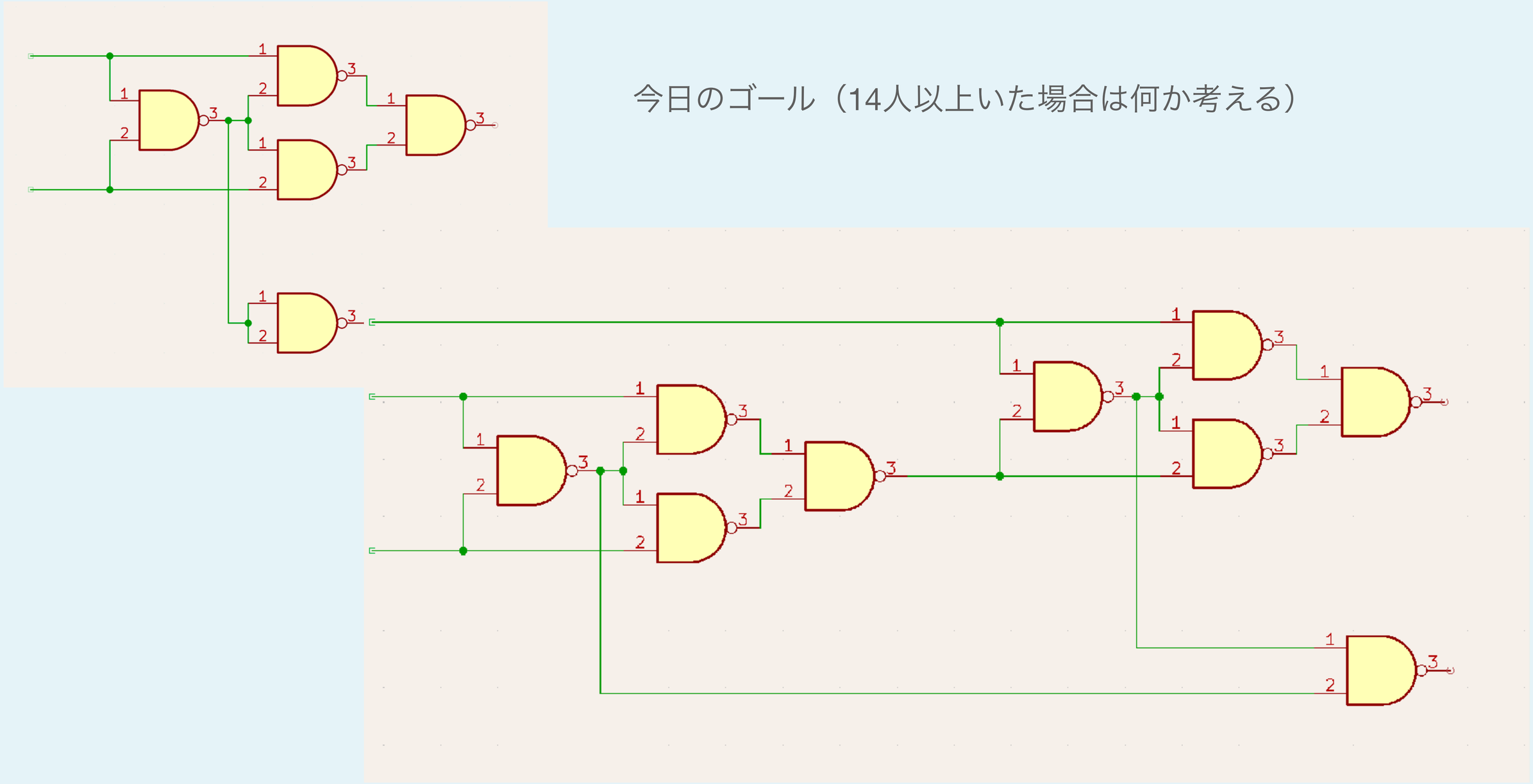
2回反転させるのは冗長

最小構成



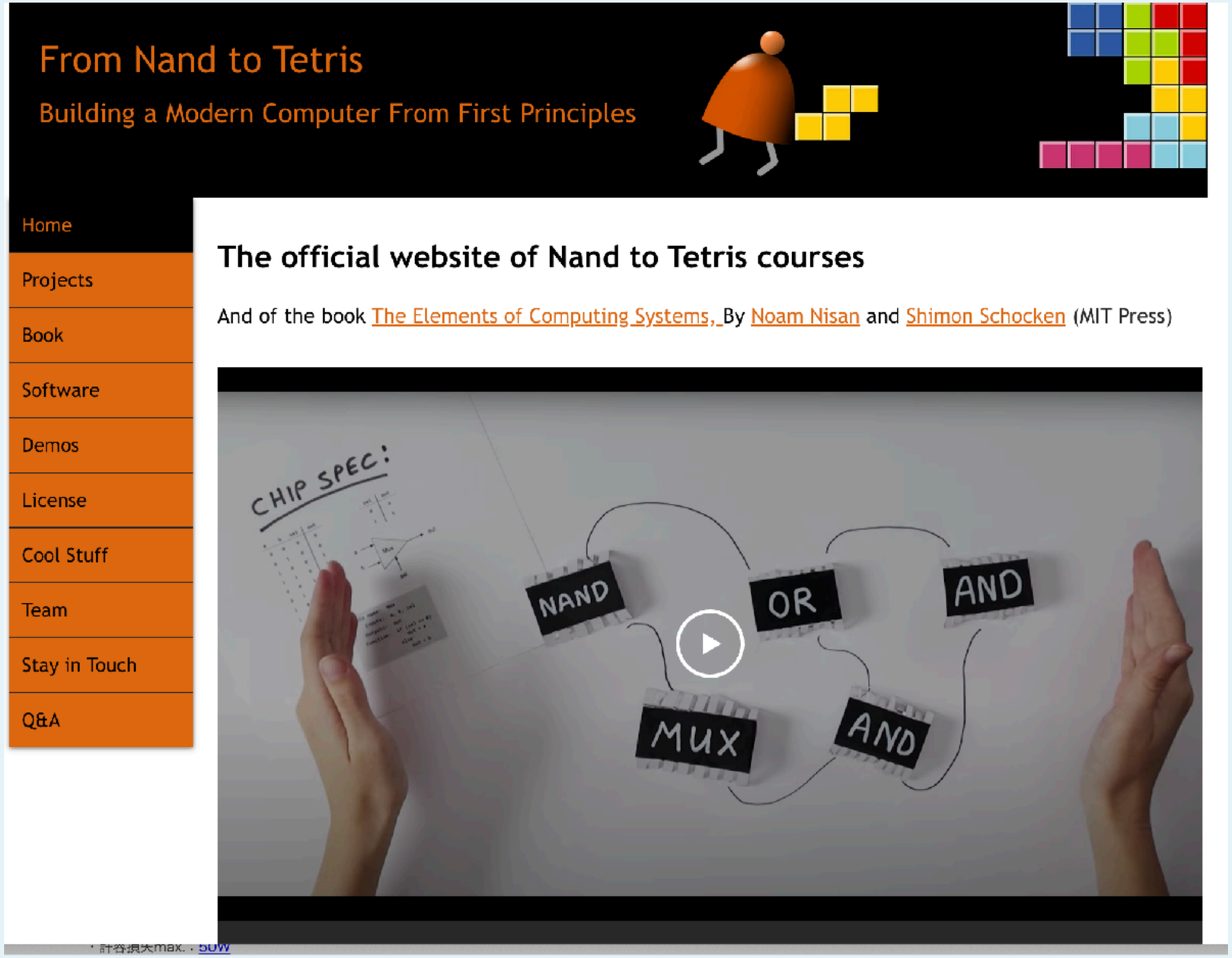

A0 B0
A1 B1
A2 B2
A3 B3
A4 B4
A5 B5
A S
B C
X
半加算器
全加算器
S0
S1
S2
S3
S4
S5
C

今日のゴール（14人以上いた場合は何か考える）

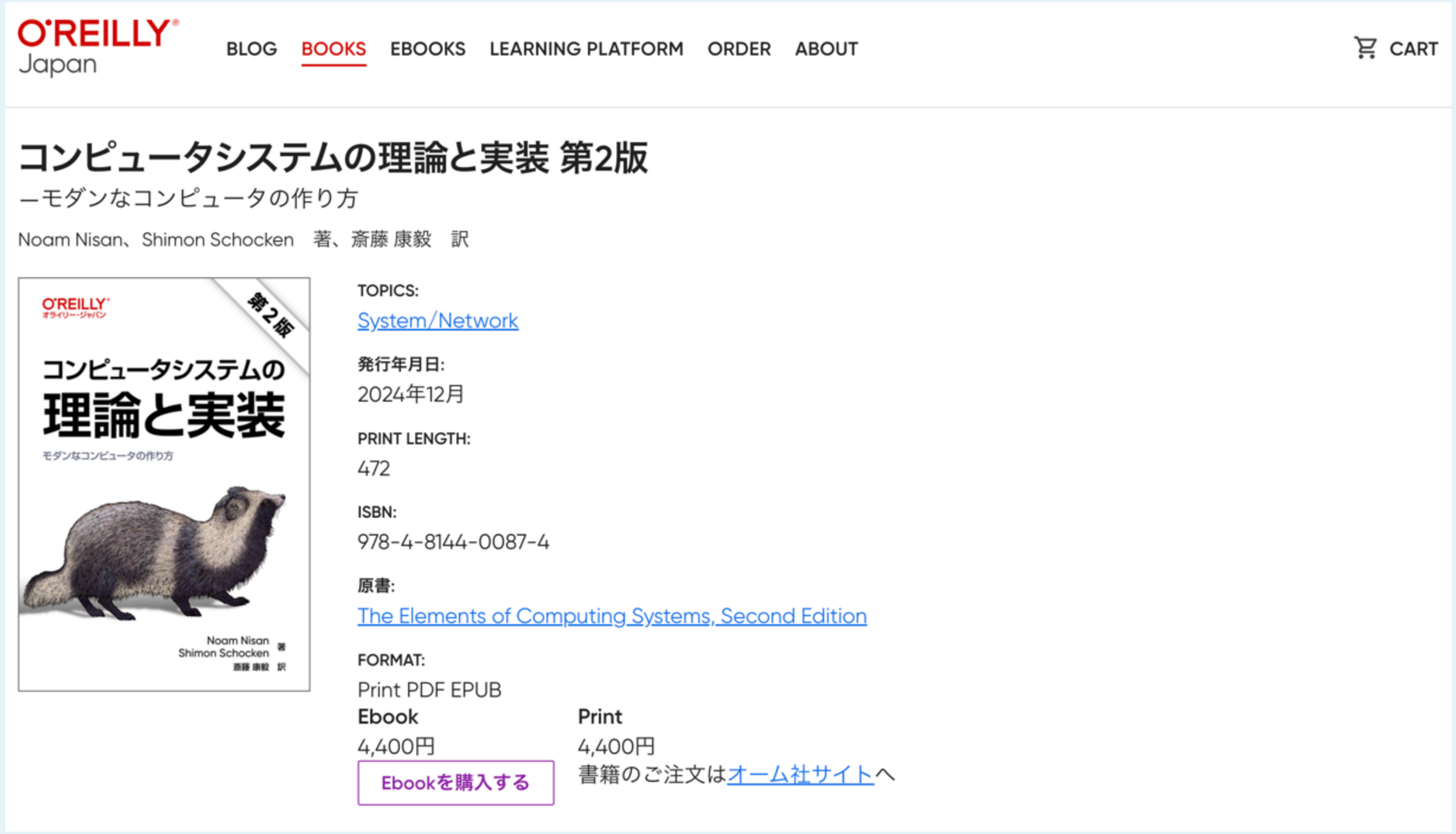


Turing Complete(LevelHead)

https://store.steampowered.com/app/1444480/Turing_Complete/



https://www.nand2tetris.org/



コンピュータシステムの理論と実装 第2版 ーモダンなコンピュータの作り方

Noam Nisan、Shimon Schocken著、斎藤 康毅訳 (Nand2Tetrisの邦訳書)

https://www.oreilly.co.jp/books/9784814400874/

次回の予告

- マイクロコントローラ（Arduino）を使って、プログラミングと電子工作を組み合わせていきます。
- Arduino IDEを自分のコンピューターで作業したい場合のインストール方法は後日共有します