2's complement

$+3$

$$\begin{array}{r} 011 \\ 100 \\ + \quad 1 \\ \hline 101 \end{array}$$

-3

non-zero → negative

-2^8

$1\,11111111 = -1$

$111 = -1$

$11 = -1$

$1 \cdots 11 = -1$

$-4+2+0 = -2$

$110 \quad -2$

$$\begin{array}{r} 110 \\ - \quad 1 \\ \hline 101 \\ 010 \end{array}$$

$110 \quad -2$

$1111111110 = -2$

$1010 = -6$

$-8 \quad +2$

$1111111110 = -2$

$0000000001 = +1$

①

overflow. (2's complement)

$$\boxed{\begin{array}{r} p \\ +\ p \\ \hline n \end{array} \qquad \begin{array}{r} n \\ +\ n \\ \hline p \end{array}}$$

$$\begin{array}{r} p \\ +\ n \\ \hline 1\ p \end{array} \times \qquad \cancel{\begin{array}{r} p \\ p \times \\ \hline p \end{array}} \quad \cancel{\begin{array}{r} n \\ n \times \\ \hline n \end{array}}$$

$$\begin{array}{rl} \text{111} & n\ -1 \\ +\ \text{100} & n\ -4, \text{ overflow} \\ \hline \text{1011} & p \quad \text{occurs} \end{array}$$

$-8 \quad +3 \quad -5$ adopt $\underline{\underline{C_2}}$

$$\begin{array}{rl} \text{111} & n\ -1 \\ +\ \text{101} & n\ -3 \\ \hline \text{1100} & n\ -4 \end{array}$$

no overflow

duplicate S_2 to C_2

$S_2 S_1 S_0$

$$\begin{array}{rl} \text{011} & p \quad 3 \\ +\ \text{011} & p \quad 3 \\ \hline \text{0110} & n \end{array}$$

$$\begin{array}{rl} \text{111} & n\ -1 \\ +\ \text{011} & p\ 3 \quad = +2 \\ \hline \text{1010} & p\ +2 \end{array}$$

$-8+2=-6$

7

3

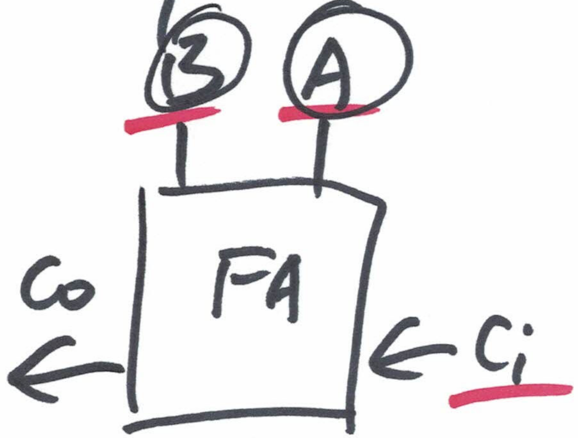
10

$\{S_2, S_2, S_1, S_0\}$

$\{C_2, S2, S1, S0\}$

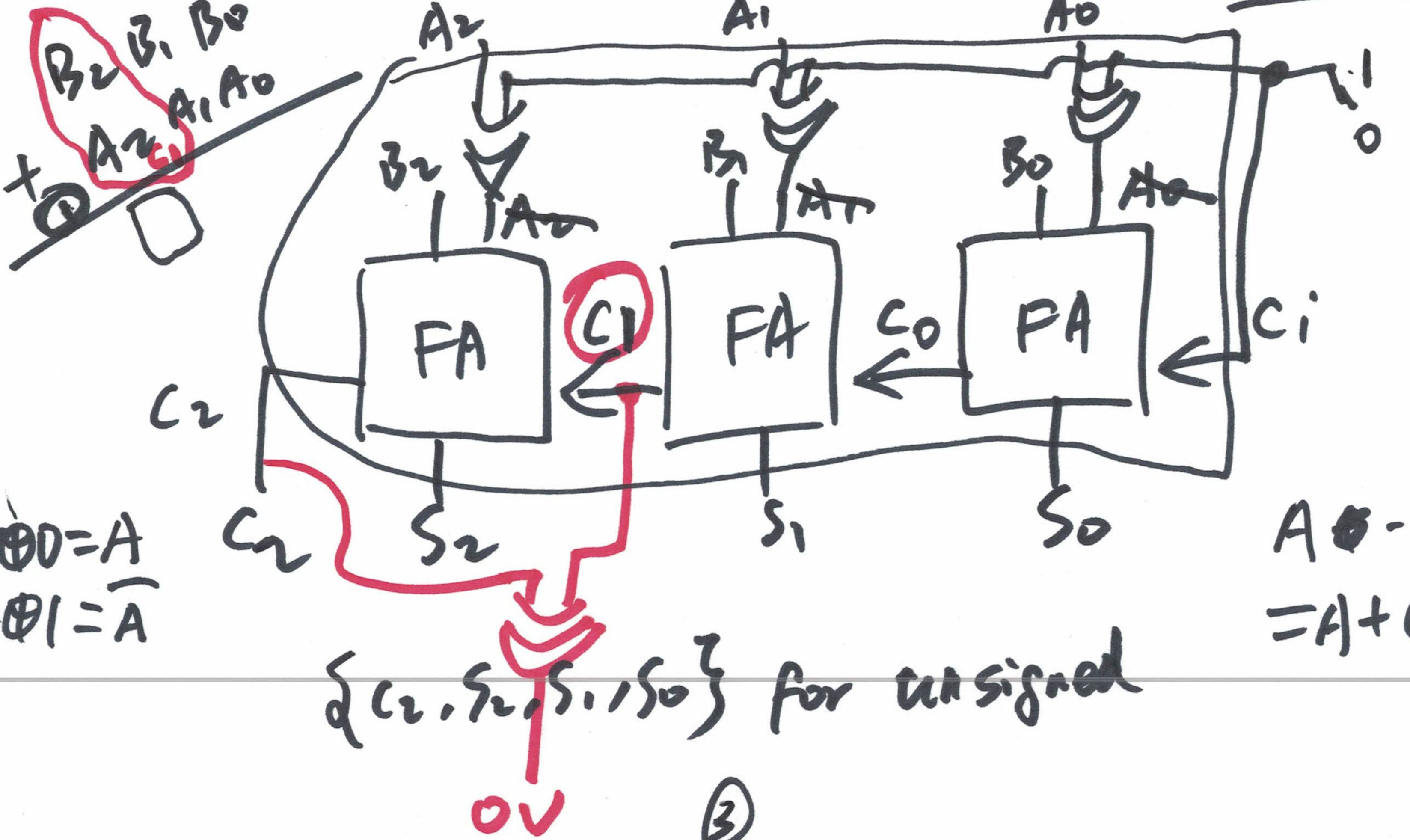
②

2's Complement 3-bit Adder/subtractor



FA: $C_o = (A+B)C_i + AB$

$S = A \oplus B \oplus C_i$



$A \oplus 0 = A$

$A \oplus 1 = \overline{A}$

$A - B$

$= A + (-B)$

$\{C_2, S_2, S_1, S_0\}$ for unsigned

overflow (indicator)

C_2	S_2	A_2	B_2	C_1	OV	C_2 final
0	0	0	0	0	0	0
0	1	0	0	1	1	0
0	1	0	1	0	0	1
1	0	0	1	1	0	0
0	1	1	0	0	0	1
1	0	1	0	1	0	0
1	0	1	1	0	1	1
1	1	1	1	1	0	1

Method I: $OV = \bar{A}_2 \bar{B}_2 C_1 + A_2 B_2 \overline{C_1}$

Method II: $OV = C_1 \wedge C_2$

C_2final: C_2final $= \bar{C}_2 S_2 \overline{OV} + \bar{C}_2 S_2 \overline{OV} + C_2 \bar{S}_2 OV + C_2 S_2 \overline{OV}$

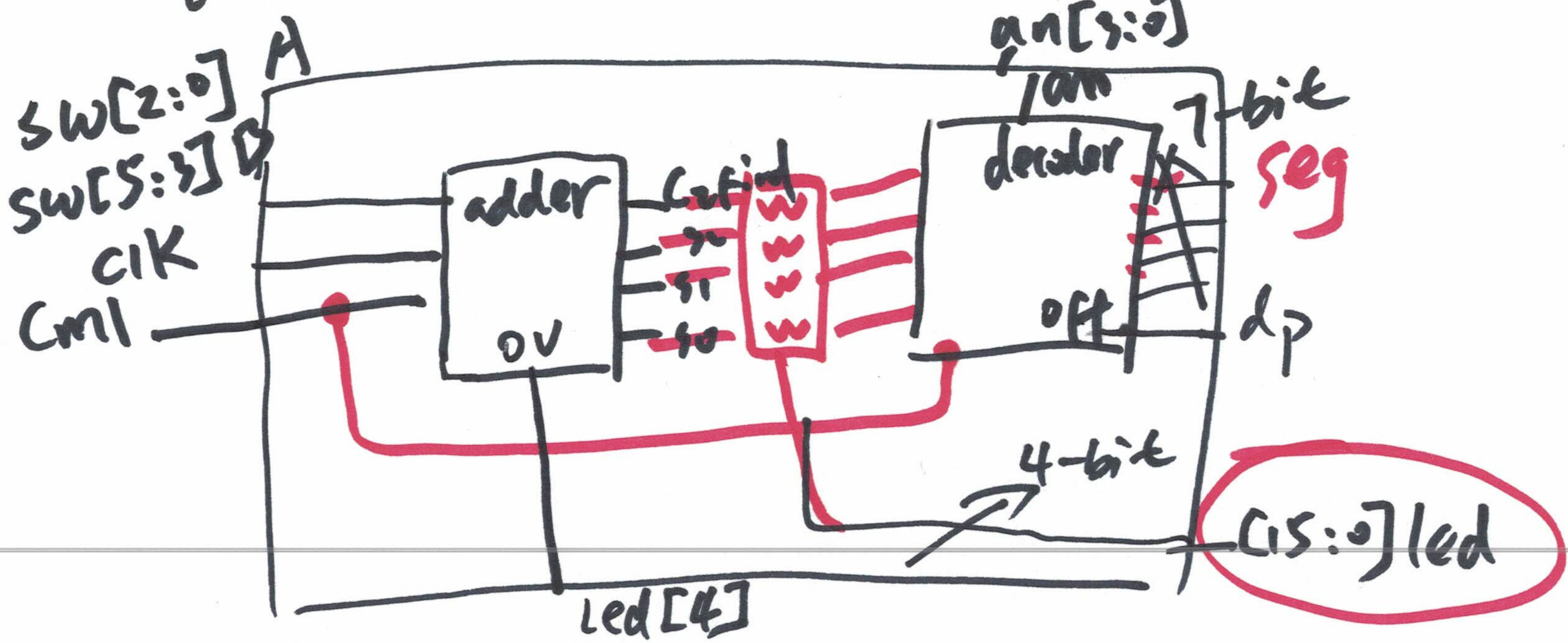
$$C_2 \text{final} = \overline{C_2} S_2 \overline{OV} + C_2 \overline{S_2} OV + C_2 S_2 \overline{OV}$$

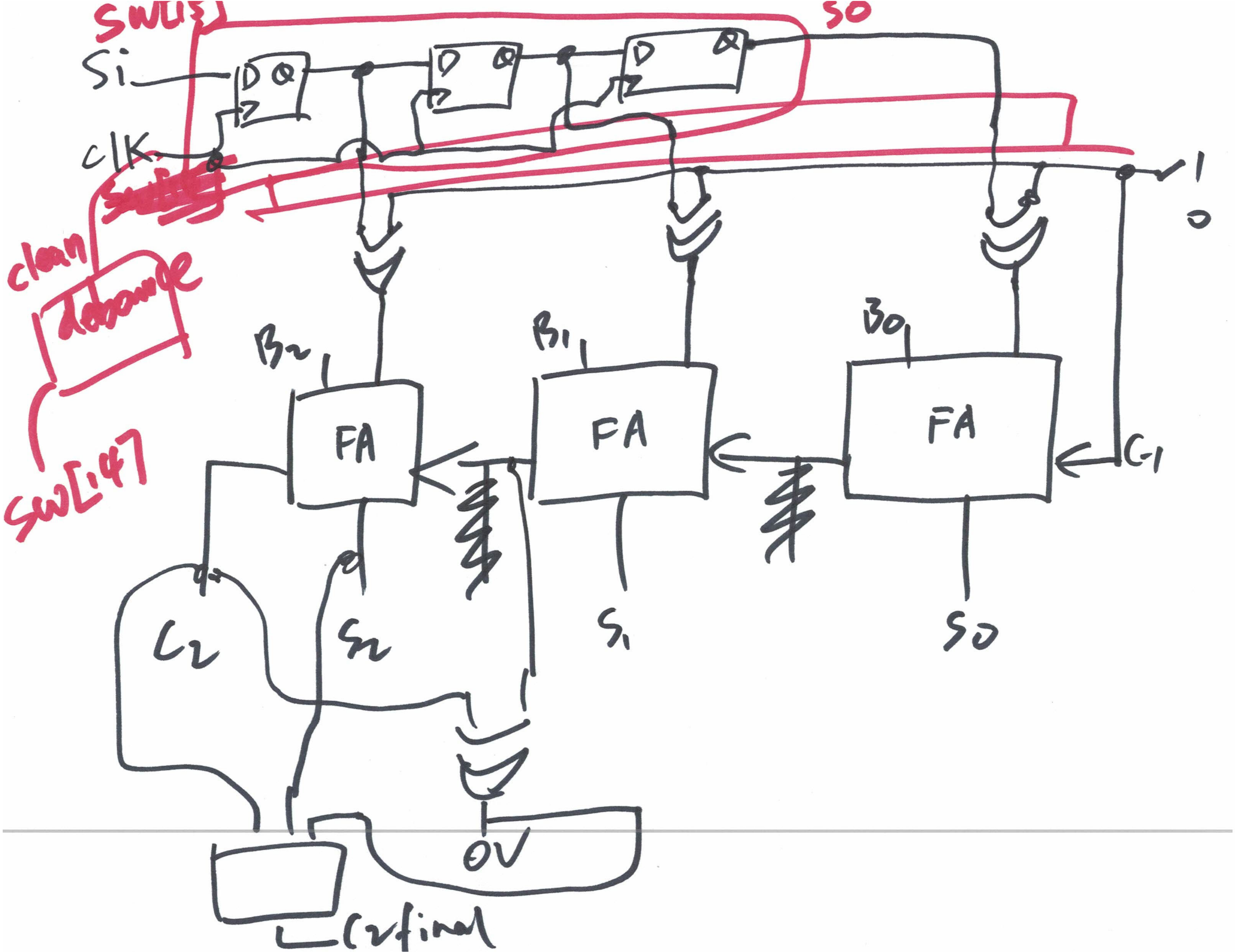
$$= \cancel{(\overline{C_2} + C_2)} \cdot S_2 \overline{OV} + C_2 \overline{S_2} OV$$

$$= S_2 \overline{OV} + C_2 \overline{S_2} OV$$

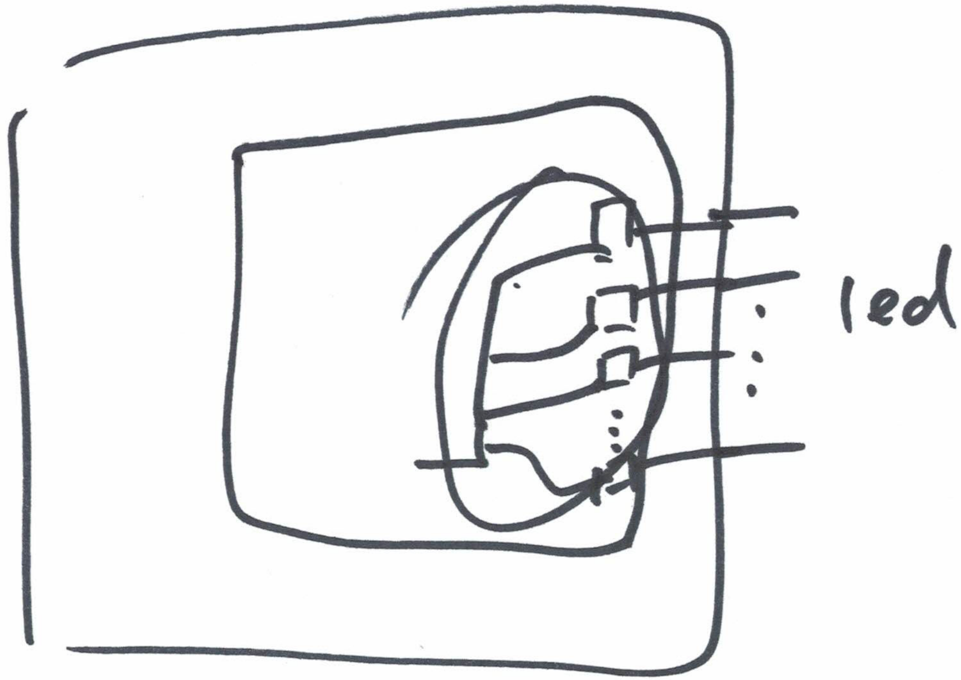
$$\{C_2 \text{final}, S_2, S_1, S_0\}$$

1001





SW[15]
SO
Si
D Q
D Q
D Q
clk
clean
debounce
SW[14]
B2
B1
B0
FA
FA
FA
C-1
C2
S2
S1
S0
OV
C2final


led