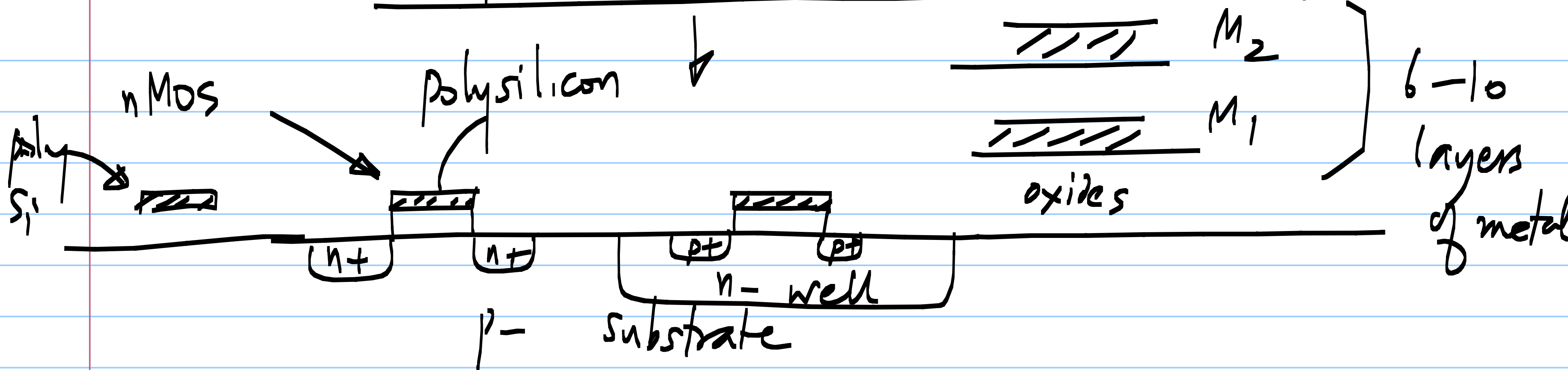
Lecture 20 : Components available in a CMOS process

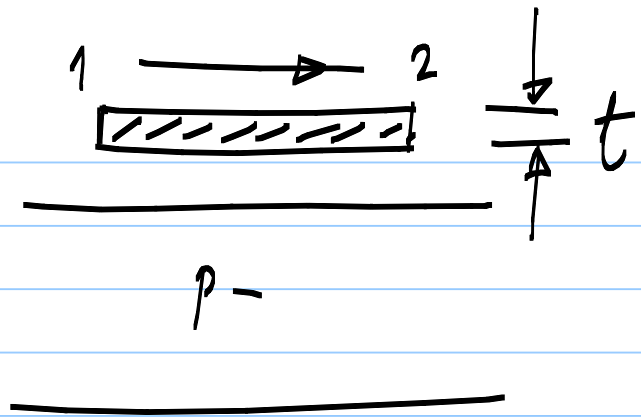


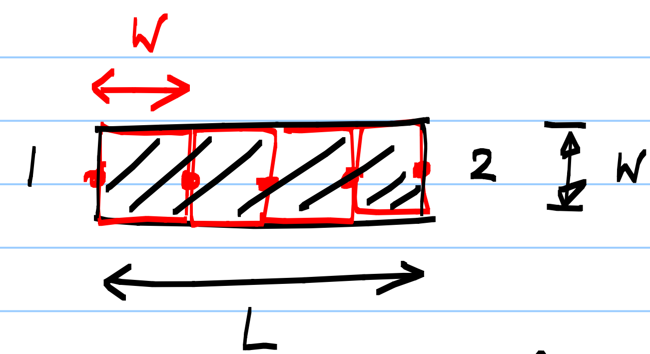
Resistors: poly Si [poly Si used for MOS gates is highly conductive] → more resistive

Metal layers.

Capacitors: Metal plates separated by dielectrics.

Resistors;





$$R_{12} = \rho \cdot \frac{L}{W \cdot t}$$

$$= \left(\frac{\rho}{t}\right) \cdot \frac{L}{W}$$

$$= R_{sh} \cdot \left(\frac{L}{W}\right)$$

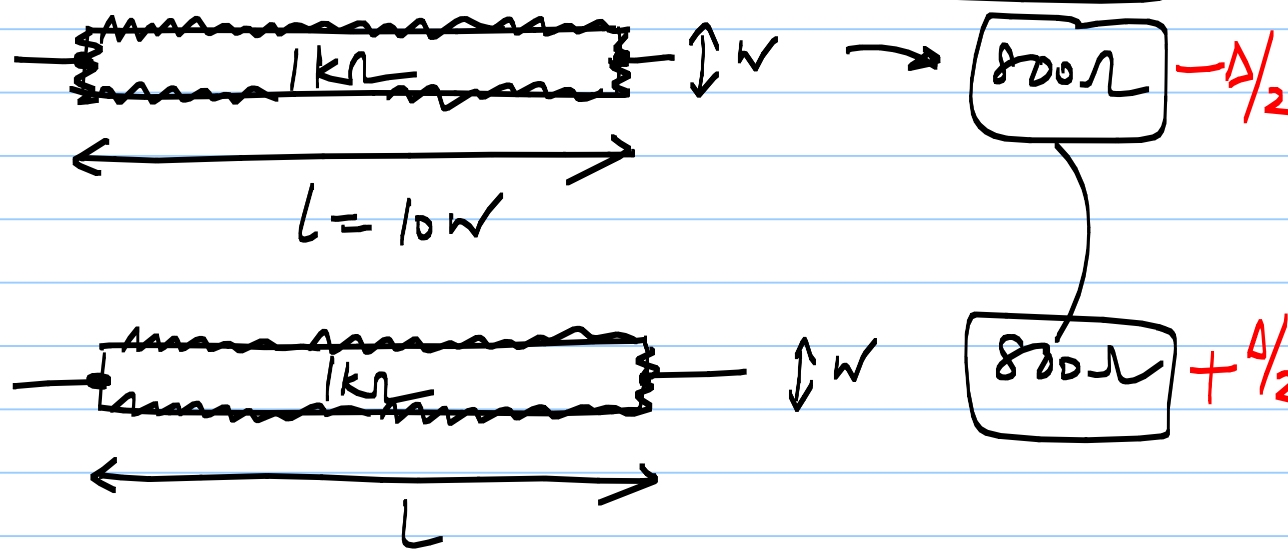
$$R_{sh} \equiv R_{\square}$$

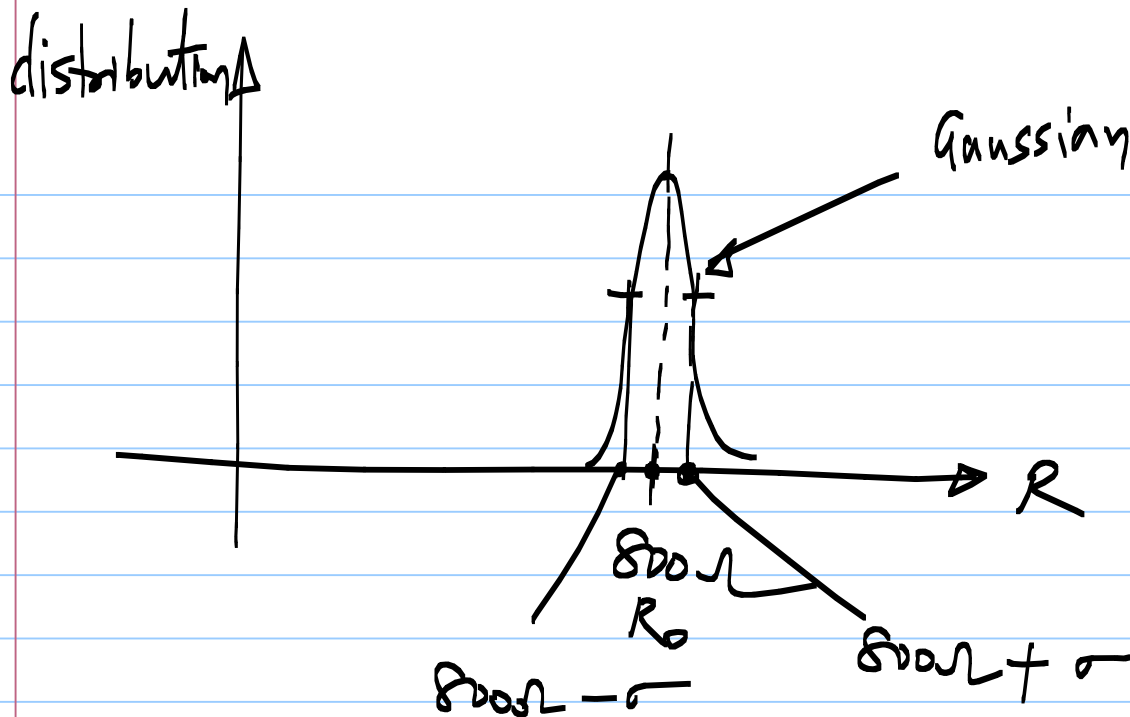
R_{sh}: sheet resistance $= \frac{\rho}{t} \left(\Omega / sq. \right)$

Sheet resistance: poly: $100\,\Omega/\text{sq.}$

$80\,\Omega/\text{sq}$ to $120\,\Omega/\text{sq}$

Two identically laid out components will be electrically identical





$$\left(\frac{\Delta R}{R_0}\right) = \%$$

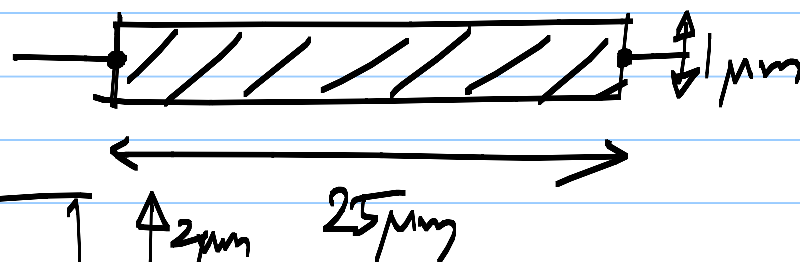
ΔR: difference in the value of 2 resistors

99.9% —— 800Ω ± 3σ

$R_1 - R_2 = \Delta R$

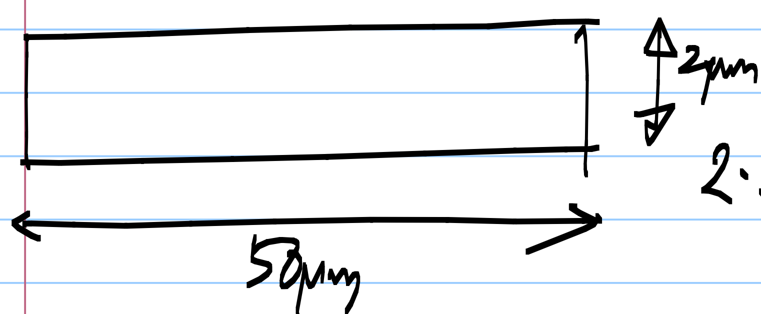
$$\sigma\left(\frac{\Delta R}{R_0}\right) = \frac{A_R}{\sqrt{W\cdot L}} = \frac{2\%\cdot\mu m}{\sqrt{25\mu m\cdot 1\mu m}}$$

$R_{sh} = 100\,\Omega/\square$



$= 0.4\%$

0.2%



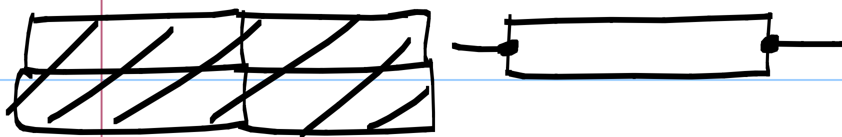
$2.5\,k\Omega$

$$0.4\% = \sigma\left(\frac{\Delta R}{R_0}\right)$$

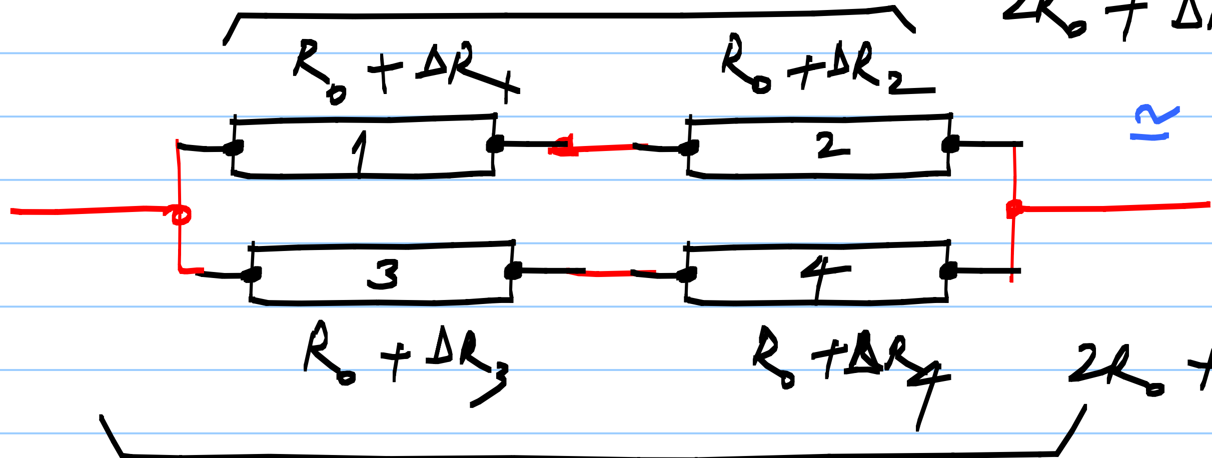
$$\sigma(\Delta R) = R_0\cdot(0.4\%) = \underline{\underline{10\,\Omega}}$$

$R_o + \Delta R$

$\frac{\Delta R}{R_o} : \sigma$



R_o



$$\frac{1}{2R_o + \Delta R_1 + \Delta R_2} \simeq \frac{1}{2R_o}\left(1 - \frac{\Delta R_1 + \Delta R_2}{2R_o}\right)$$

$\oplus$

$$\frac{1}{2R_o + \Delta R_3 + \Delta R_4} \simeq \frac{1}{2R_o}\left(1 - \frac{\Delta R_3 + \Delta R_4}{2R_o}\right)$$

$$\frac{1}{R_o}\left(1 - \frac{\Delta R_1 + \Delta R_2 + \Delta R_3 + \Delta R_4}{4R_o}\right)$$

$$R_o\left(1 + \left[\frac{\Delta R_1 + \Delta R_2 + \Delta R_3 + \Delta R_4}{4R_o}\right]\right)$$

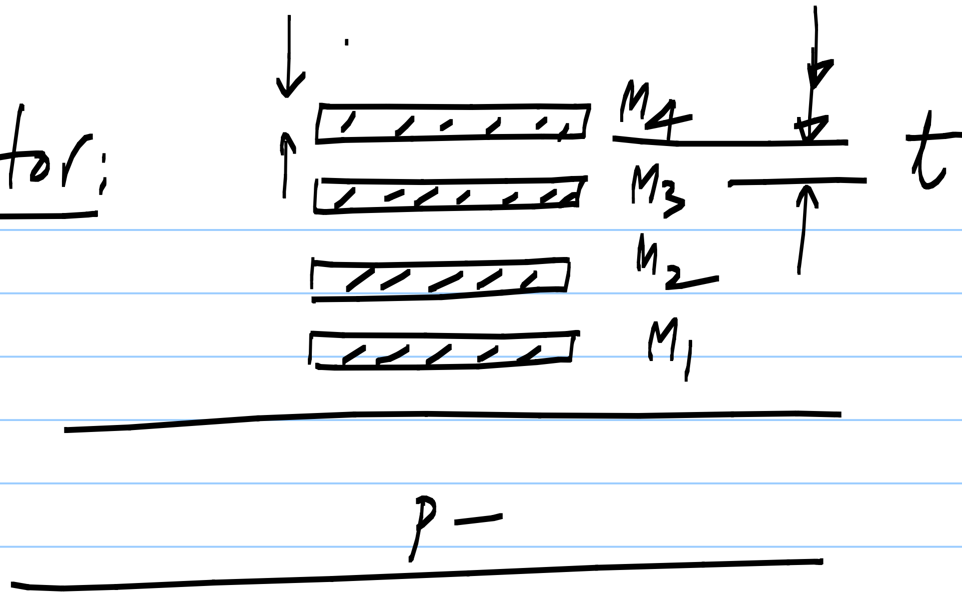
Standard deviation of $\dfrac{\Delta R_1 + \Delta R_2 + \Delta R_3 + \Delta R_4}{4R_0}$

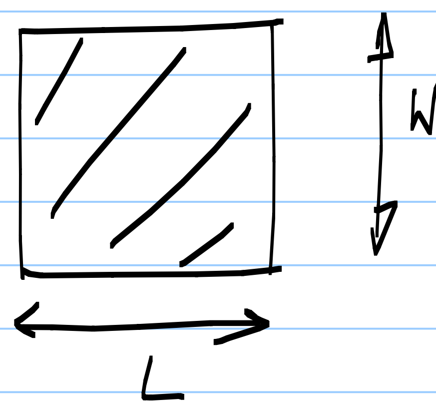
$$= \frac{1}{4}\left(\frac{\Delta R_1}{R_0} + \frac{\Delta R_2}{R_0} + \frac{\Delta R_3}{R_0} + \frac{\Delta R_4}{R_0}\right)$$

$$= \frac{1}{4}\sqrt{\sigma_1^2 + \sigma_1^2 + \sigma_1^2 + \sigma_1^2}$$

$$= \frac{\sigma_1}{2}$$

Capacitor:





$$C = \epsilon_r \epsilon_0 \cdot \frac{WL}{t} = \left(\frac{\epsilon_r \epsilon_0}{t}\right) WL$$

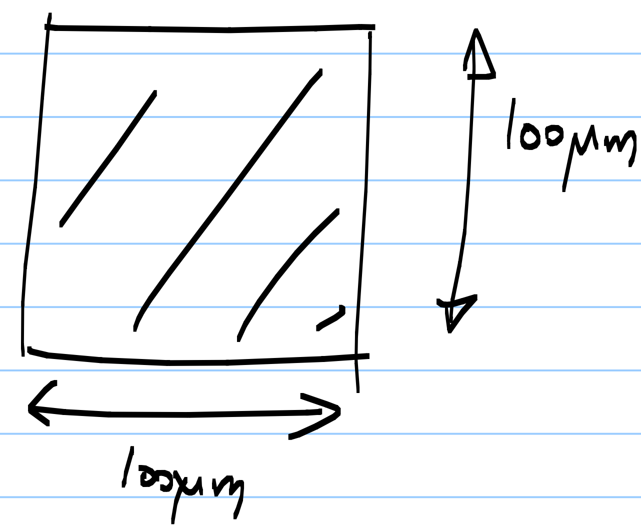
ϵ_r ← 4

Capacitance per unit area ($\frac{\epsilon_r \epsilon_0}{t}$)

$1\,fF/\mu m^2$

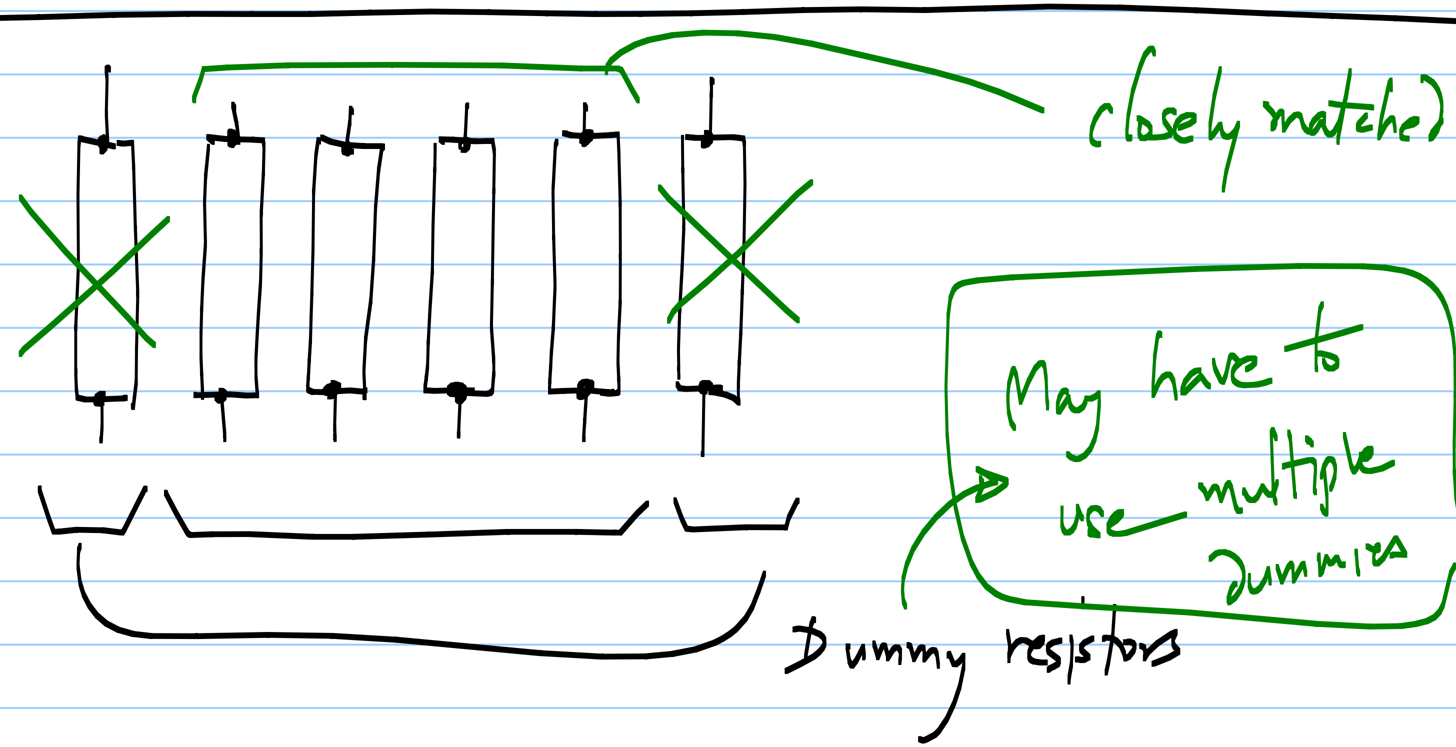
Capacitance / unit area : $1\ fF/\mu m^2$

$$10pF : \frac{10pF}{1fF/\mu m^2} = 10{,}000\ \mu m^2$$

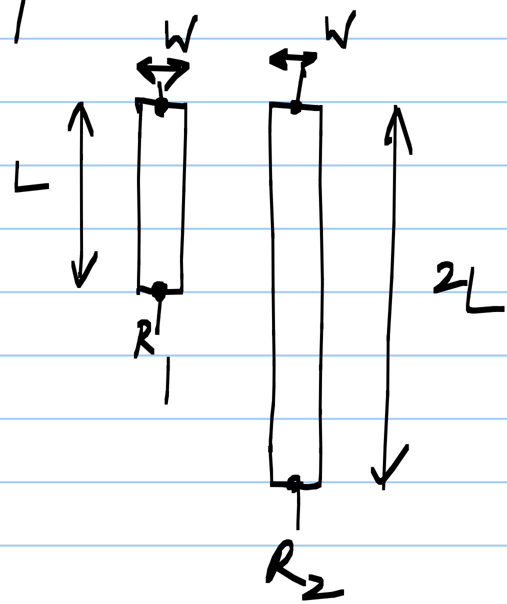


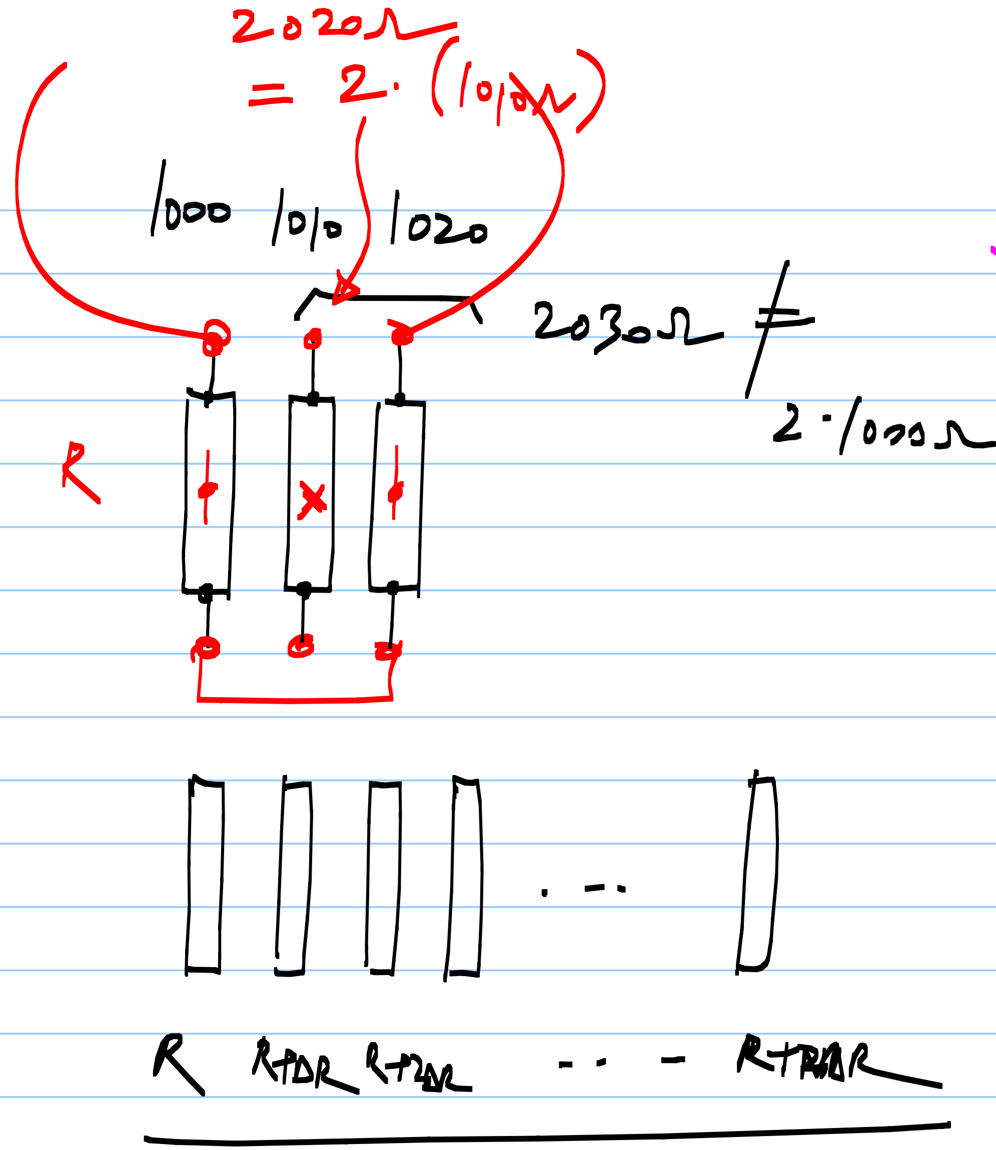
$$\sigma\left(\frac{\Delta C}{C_0}\right) = \frac{A_c}{\sqrt{WL}}$$

Random mismatch



$$\frac{R_2}{R_1} = 2$$


W
W
L
2L
R_1
R_2


2020Ω
= 2·(1010Ω)
1000 1010 1020
2030Ω ≠ 2·1000Ω
R
R+ΔR R+2ΔR . . . R+NΔR