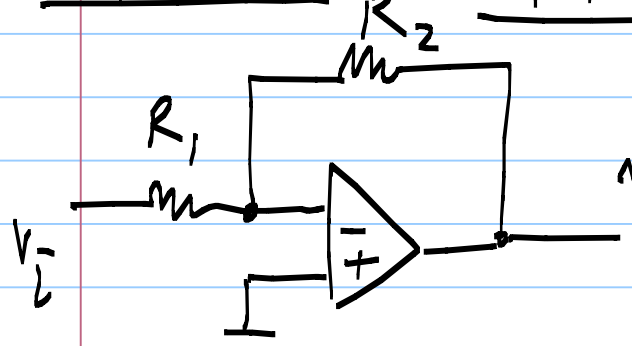
Lecture 3 — 13/1/2016

I'd like $\sigma(A_v) = 0.001$



$$A_v = \left|\frac{V_o}{V_i}\right| = \frac{R_2}{R_1} = \frac{R_0 + \Delta R_2}{R_0 + \Delta R_1}$$

$$= \frac{R_0\left(1 + \frac{\Delta R_2}{R_0}\right)}{R_0\left(1 + \frac{\Delta R_1}{R_0}\right)} \simeq 1 + \frac{\Delta R_2}{R_0} - \frac{\Delta R_1}{R_0}$$

$R_1 = R_2 = R_0$

$\text{mean} = R_0$

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

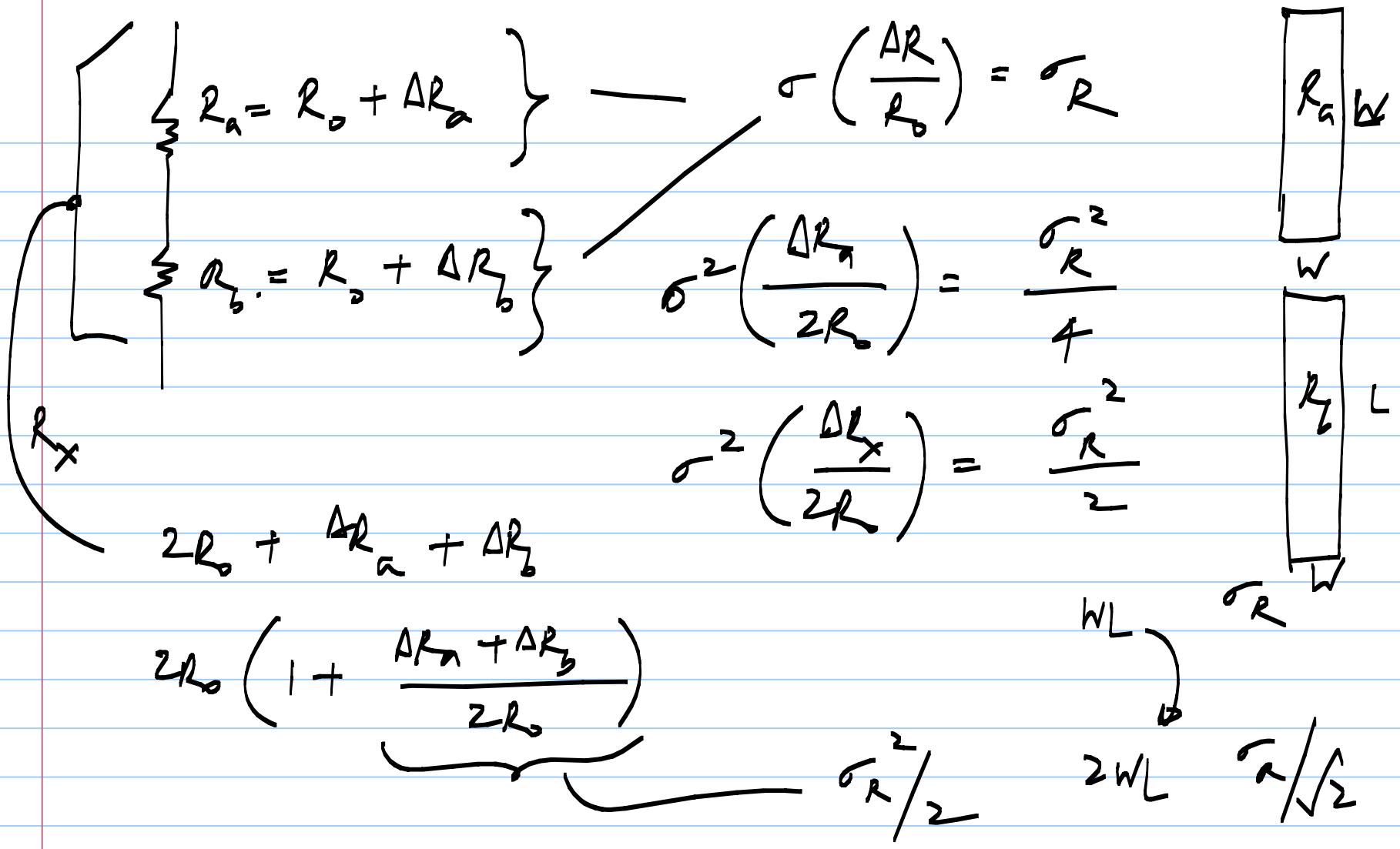
$\Delta R = R_k - R_0$

$\text{mean}(A_v) = 1$

$$\sigma^2(A_v) = \sigma^2\left(\frac{\Delta R_2}{R_0}\right) + \sigma^2\left(\frac{\Delta R_1}{R_0}\right) = 2\sigma_R^2$$

$$\sigma(A_v) = \sqrt{2}\,\sigma_R$$

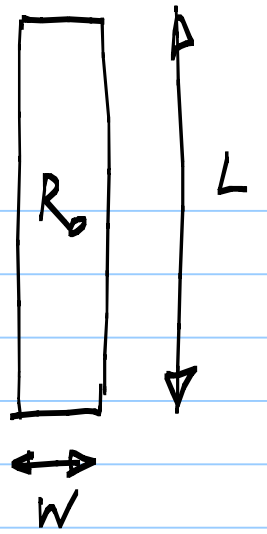
e.g. 0.002


$R_a = R_0 + \Delta R_a$
$R_b = R_0 + \Delta R_b$
R_x
$2R_0 + \Delta R_a + \Delta R_b$
$2R_0\left(1 + \frac{\Delta R_a + \Delta R_b}{2R_0}\right)$
$\sigma\left(\frac{\Delta R}{R_0}\right) = \sigma_R$
$\sigma^2\left(\frac{\Delta R_a}{2R_0}\right) = \frac{\sigma_R^2}{4}$
$\sigma^2\left(\frac{\Delta R_x}{2R}\right) = \frac{\sigma_R^2}{2}$
$\sigma_R^2/2$
R_a
W
W
R_L
L
W
σ_R
WL
2WL
$\sigma_R/\sqrt{2}$

deviations from R_0

$$\sigma_R = \sigma\left(\frac{\Delta R}{R_0}\right) = \frac{A_R}{\sqrt{WL}}$$

mean

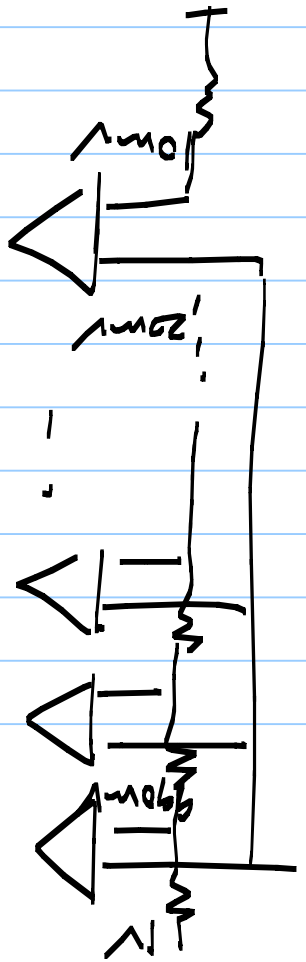


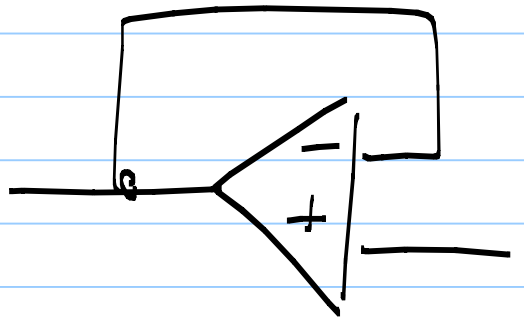
$$R_0 = R_{sh} \cdot \frac{L}{W}$$

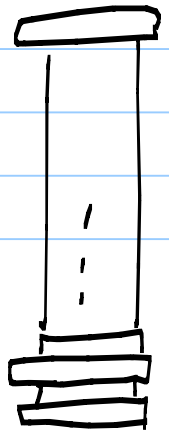
$1\mu m^2$ $\left[\frac{10\mu m}{0.1\mu m}\right]$ $\left[\frac{100\mu}{1\mu m}\right]$ $100\mu m^2$

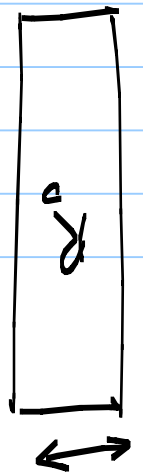
$\phi\%$ 0.1%

Random mismatch



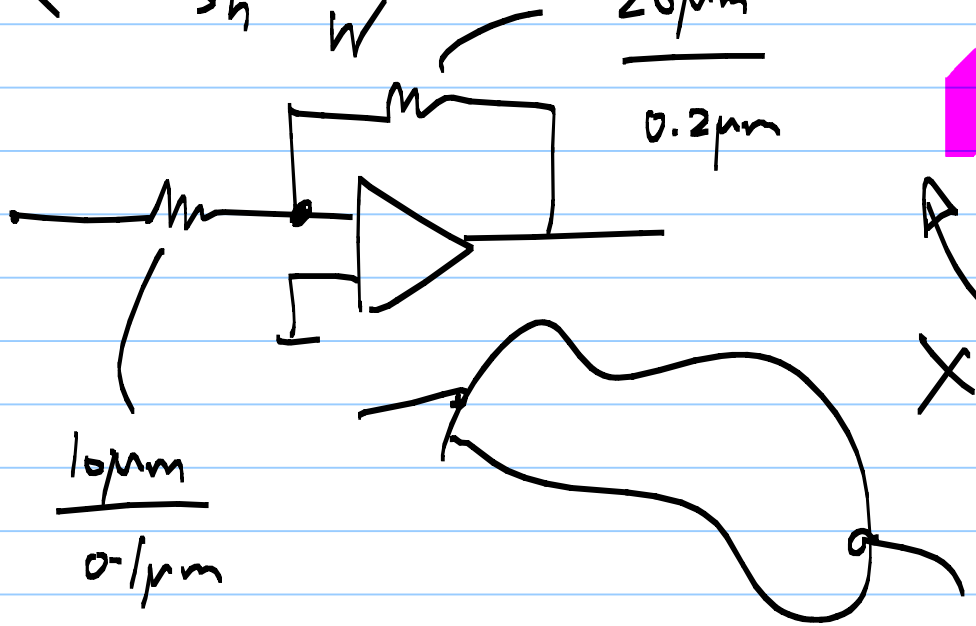


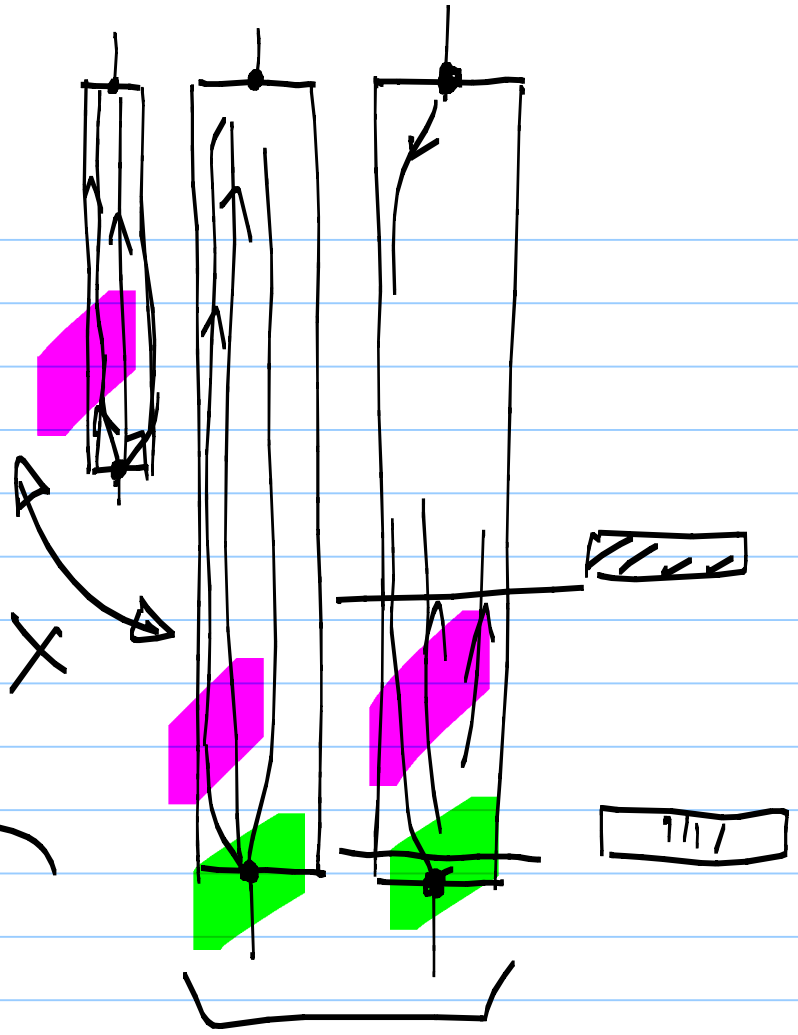




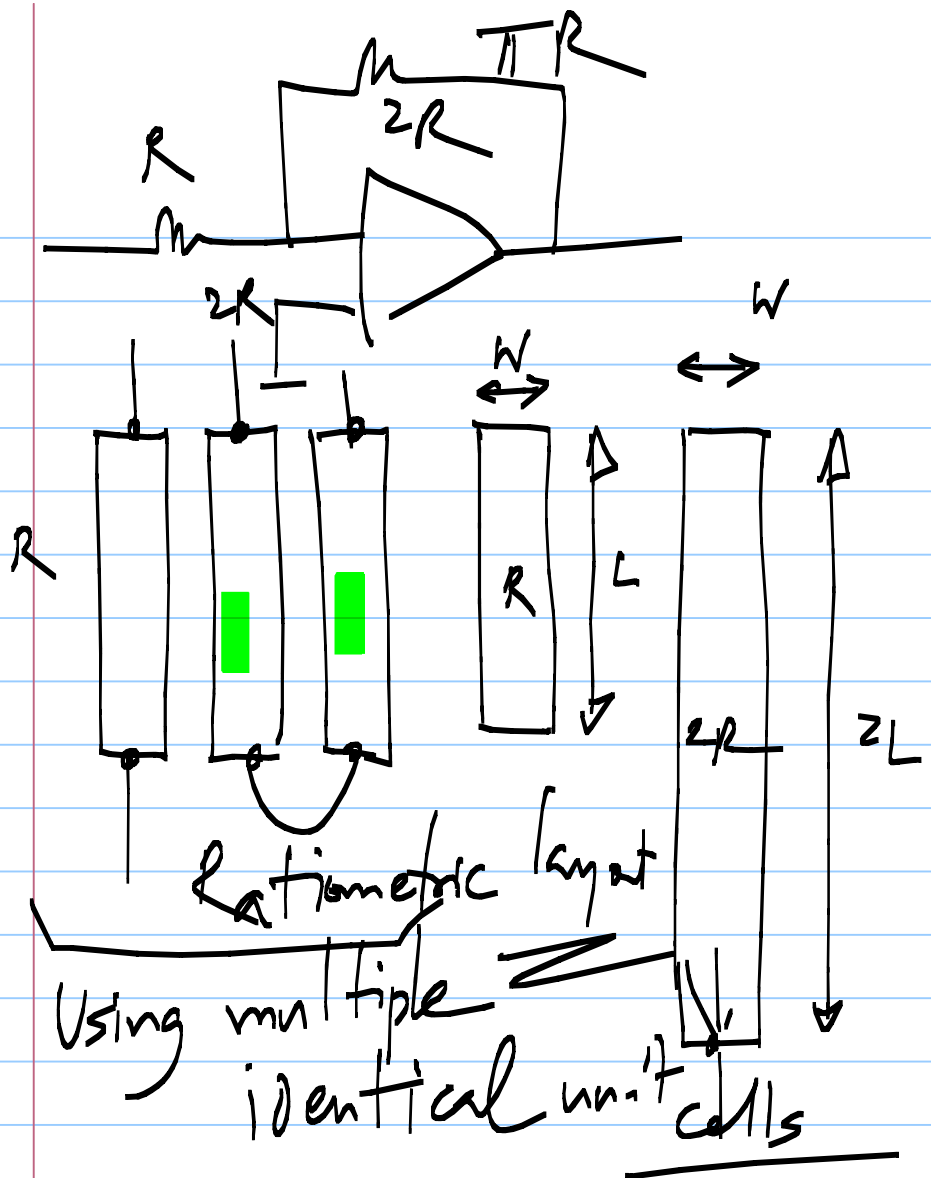
Systematic mismatch

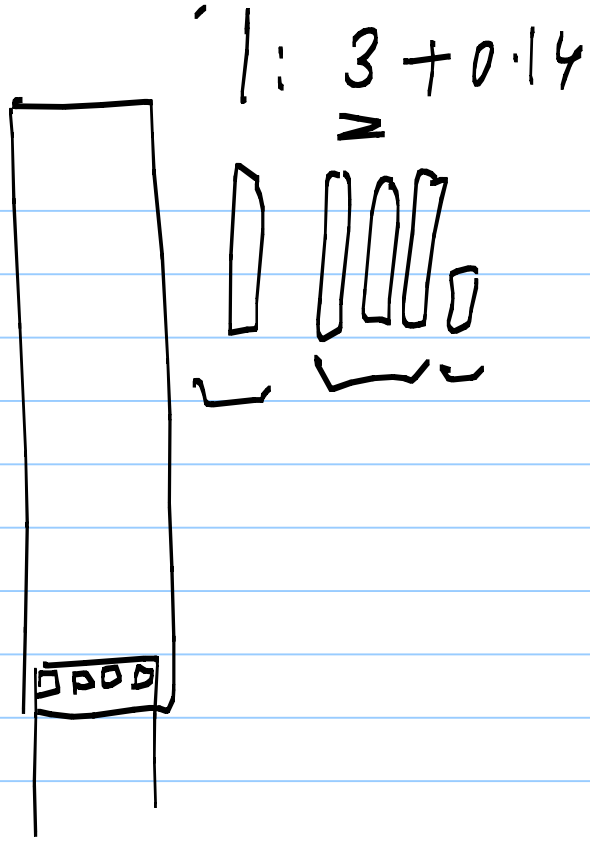
$$R = R_{sh} \cdot \frac{L}{W}$$

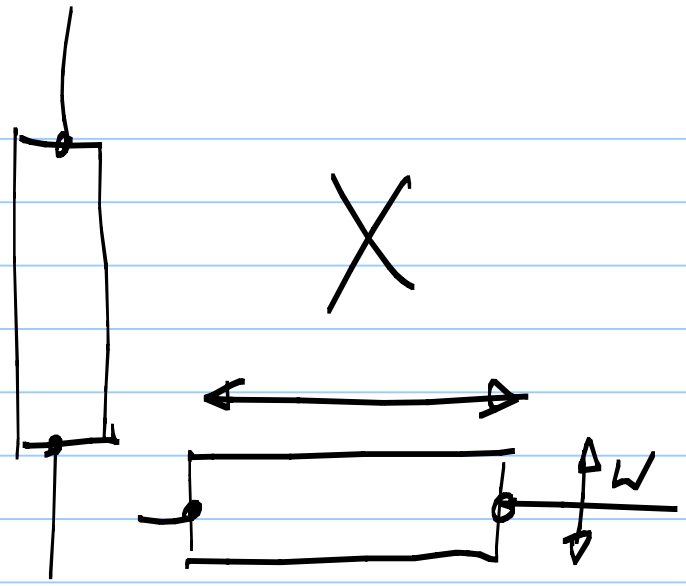




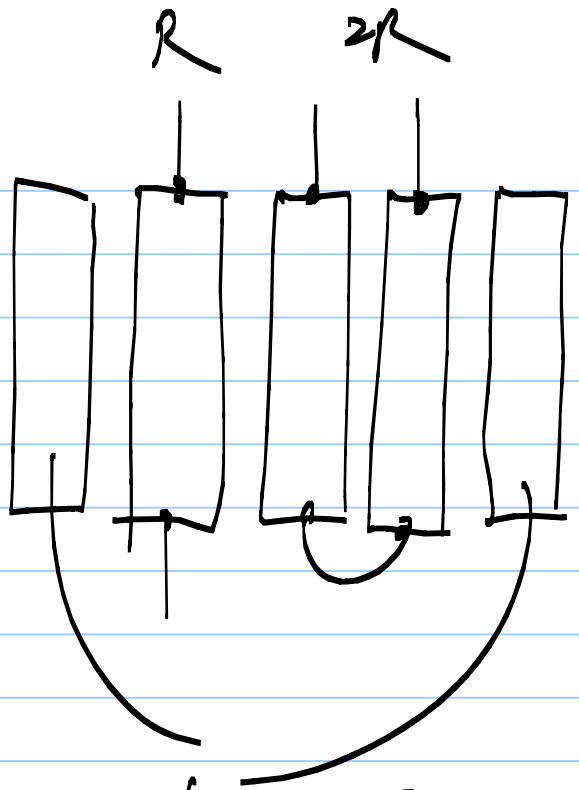
$$R = \rho \cdot \frac{L}{Wt}$$


R
2R
R
2R
W
W
R
L
2R
2L
Ratiometric layout
Using multiple identical unit cells


1 : 3 + 0.14



Lay them out in the same orientation



dummy device

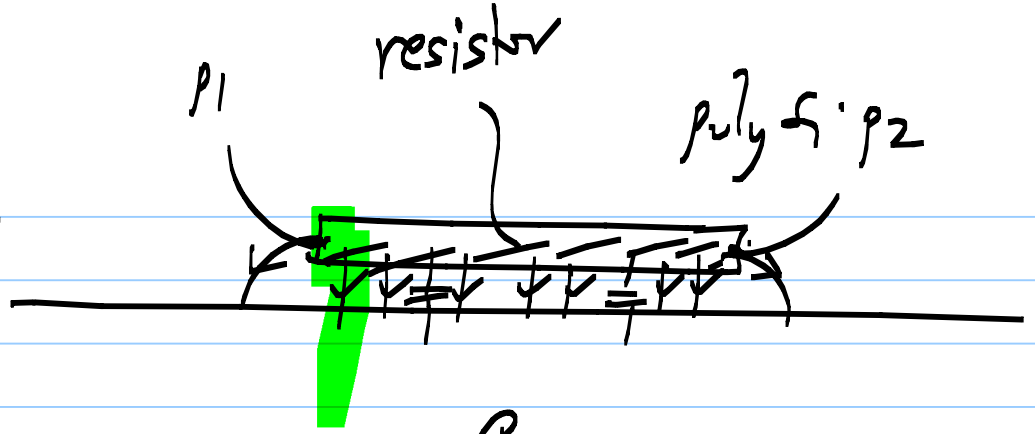
Resistors on a chip

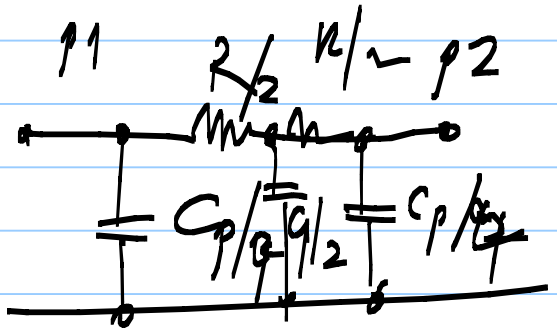
$R = R_{sh} \cdot \frac{L}{W}$ (R_{sh}: process constant)

* Random mismatch $\sigma_R = \sigma\left(\frac{\Delta R}{R_0}\right) = \frac{A_R}{\sqrt{WL}}$
  - Large size to reduce mismatch
* Systematic mismatch
  - Identical unit layouts (same orientation)
  - Dummy devices

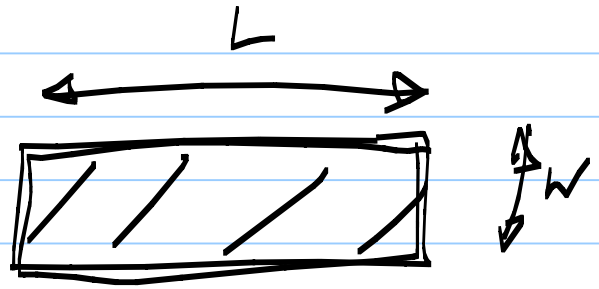
Process variation: $R_{sh} = 100\Omega/\square$ $\pm$ 20% — Absolute accuracy: poor

Resistor model





$$C_p = \underbrace{C_R'}_{\text{Cap. per area}} \cdot WL + \underbrace{C_R''}_{\text{fringe cap. per unit perimeter}} (2W+2L)$$



C_R': Cap. per area, $ff/\mu m^2$

C_R'': fringe cap. per unit perimeter, $ff/\mu m$