Lecture 11 10/2/2016

$$S_x(f) = 2\cdot\int_{-\infty}^{\infty} R_x(\tau)\exp(-j2\pi f\tau)\,d\tau$$

$x(t)$: random process. current (A)

zero mean.

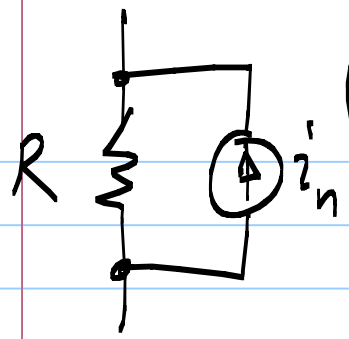
$E[x^2(t)]$: variance A^2 C^{A^2}

Autocorrelation: $E[x(t)x(t+\tau)] = R_x(\tau) = R_x(-\tau)$

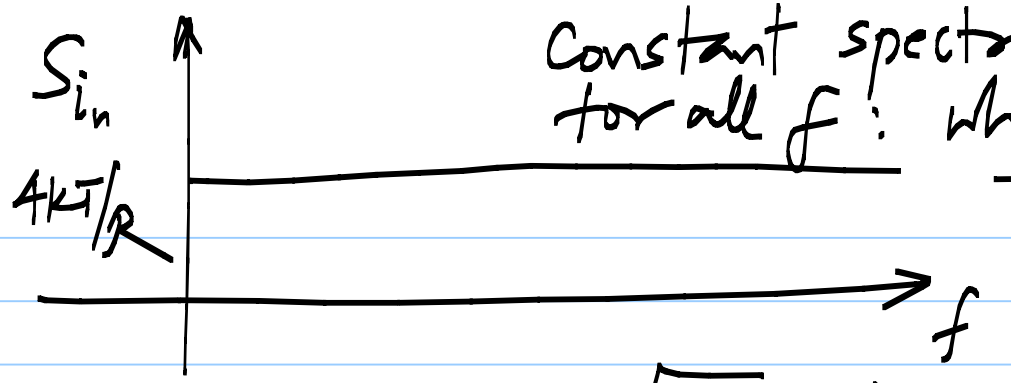
$$R_x(0) = \int_0^{\infty} S_x(f)\,df$$

Power spectral density : $\mathcal{F}[R_x(\tau)] = \underbrace{S_x(f)}$ $\frac{A^2}{Hz}$

Fourier transform One sided PSD



$\frac{A^2}{Hz}$



Constant spectral density for all f: white noise

$\frac{4kT}{R}$ A^2/Hz , $\sqrt{\frac{4kT}{R}}$ $\frac{A}{\sqrt{Hz}}$

k: Boltzmann's constant

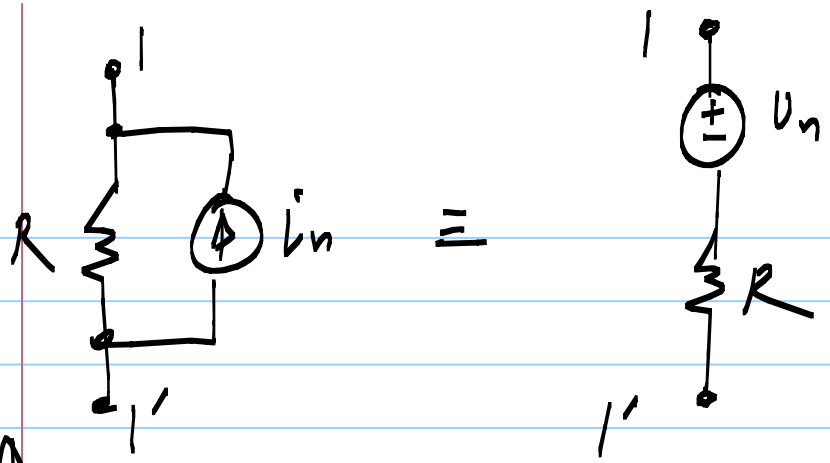
T: absolute temp.

$\frac{4 \cdot 4 \cdot 10^{-21}}{10^3} \frac{A^2}{Hz} = 16 \cdot 10^{-24} \frac{A^2}{Hz}$

kT: 4×10^{-21} J @ 300 K

4×10^{-21} $\frac{W}{Hz}$

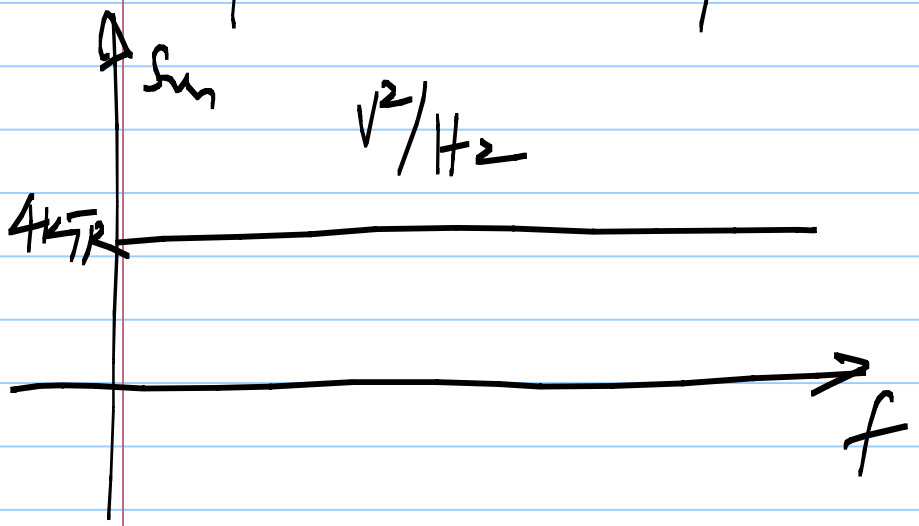
$4 \cdot 10^{-12} \frac{A}{\sqrt{Hz}} = \frac{4pA}{\sqrt{Hz}}$



$$v_n = i_n \cdot R$$

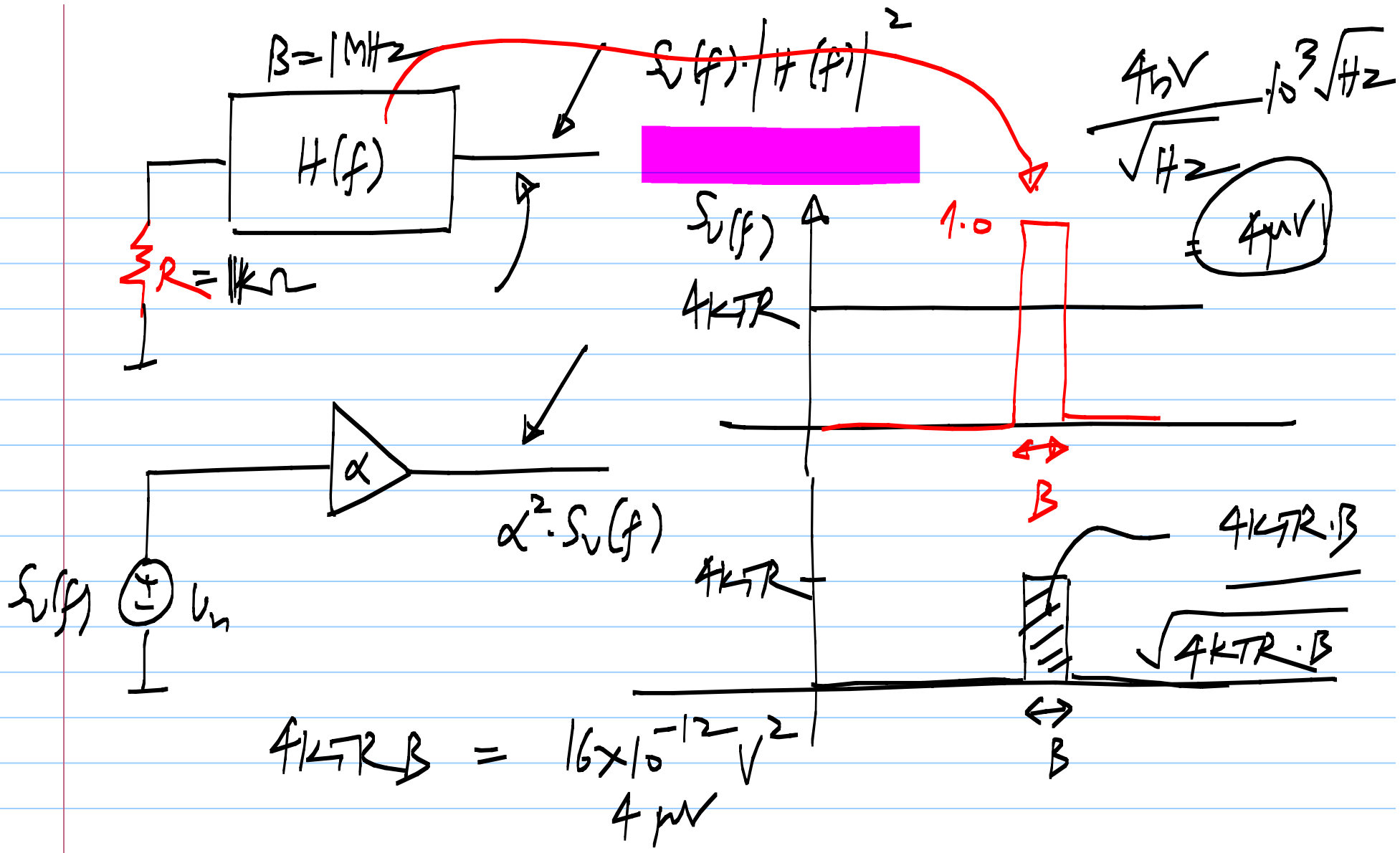
$$S_{v_n} = S_{i_n} \cdot R^2$$

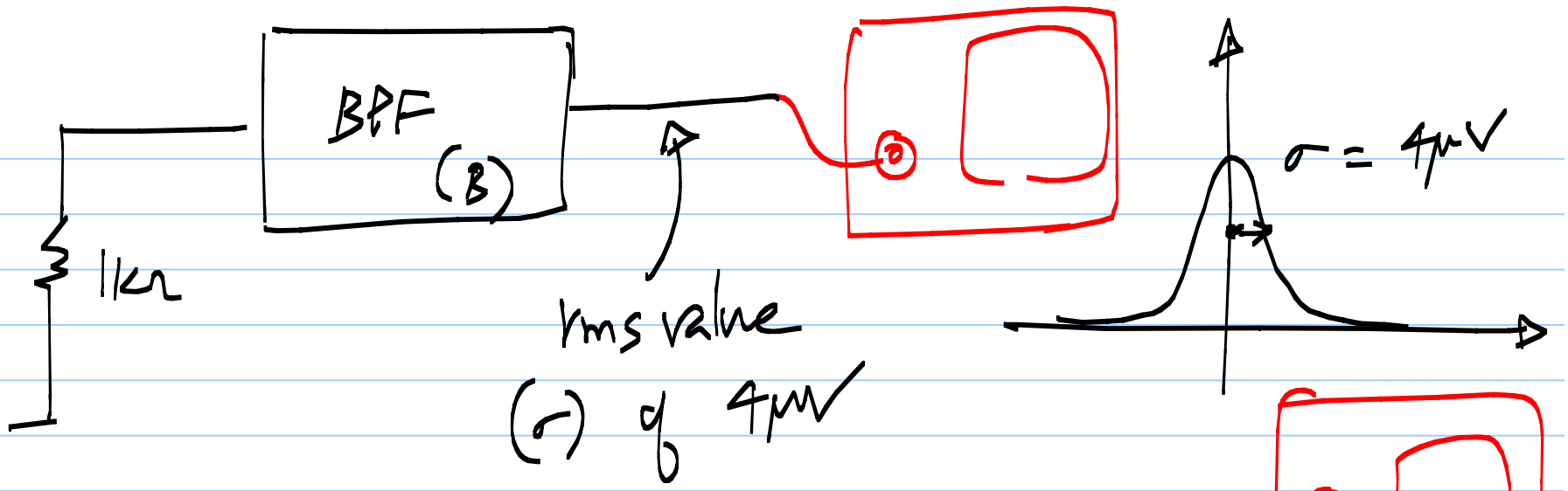
$$= \frac{4kT}{R} \cdot R^2 = \underline{4kTR}$$

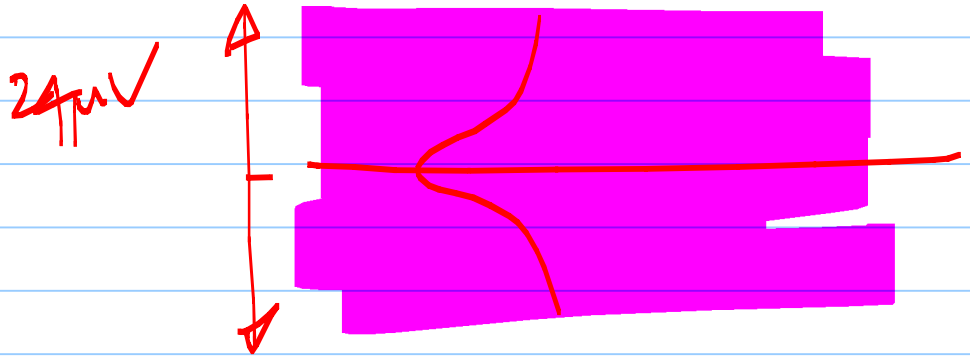


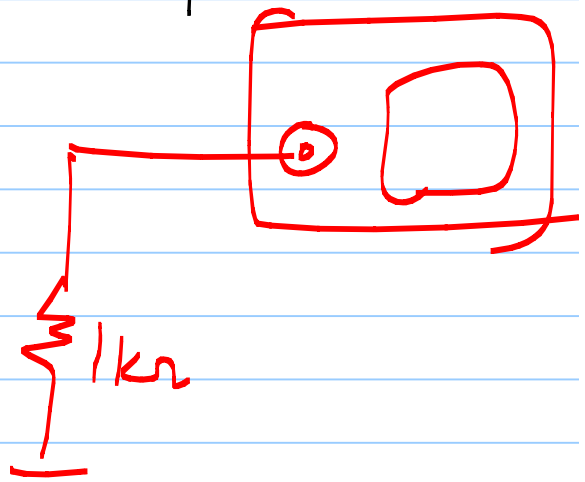
1kΩ : $16 \times 10^{-18}\ V^2/Hz$

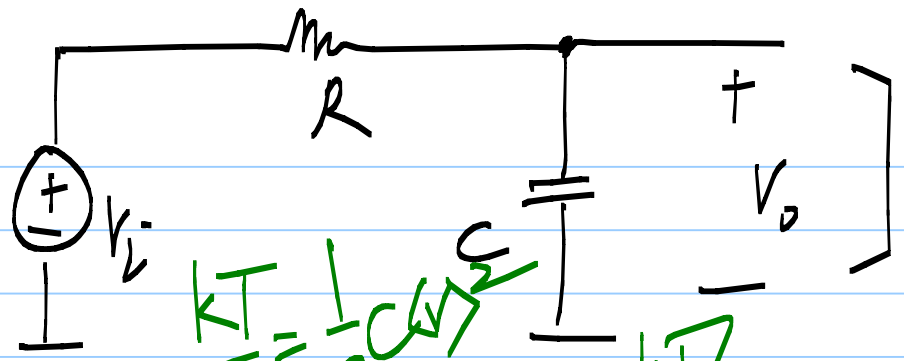
$4nV/\sqrt{Hz}$


B = 1MHz
H(f)
R = 1kΩ
$S_v(f) \cdot |H(f)|^2$
$S_v(f)$
4KTR
1.0
B
4KTR·B
$\sqrt{4KTR \cdot B}$
4μV
α
$\alpha^2 \cdot S_v(f)$
$S_v(f)$
V_n
$4KTRB = 16 \times 10^{-12} V^2$
4 μV


BPF
(B)
1kΩ
rms value
(σ) of 4μV
σ = 4μV


24μV


1kΩ

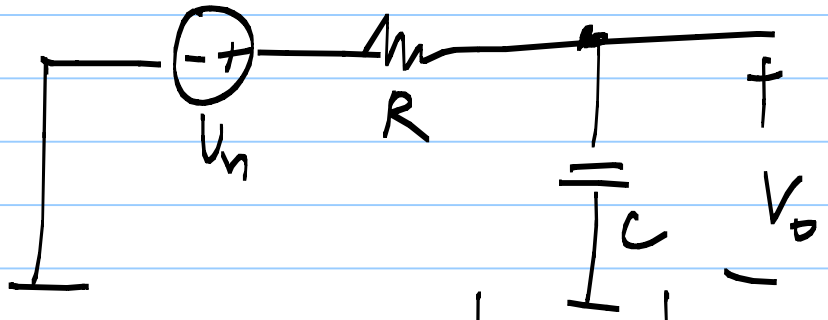


$$\frac{kT}{2} = \frac{1}{2}C\langle v^2 \rangle$$

$$\langle v \rangle^2 = kT/C$$

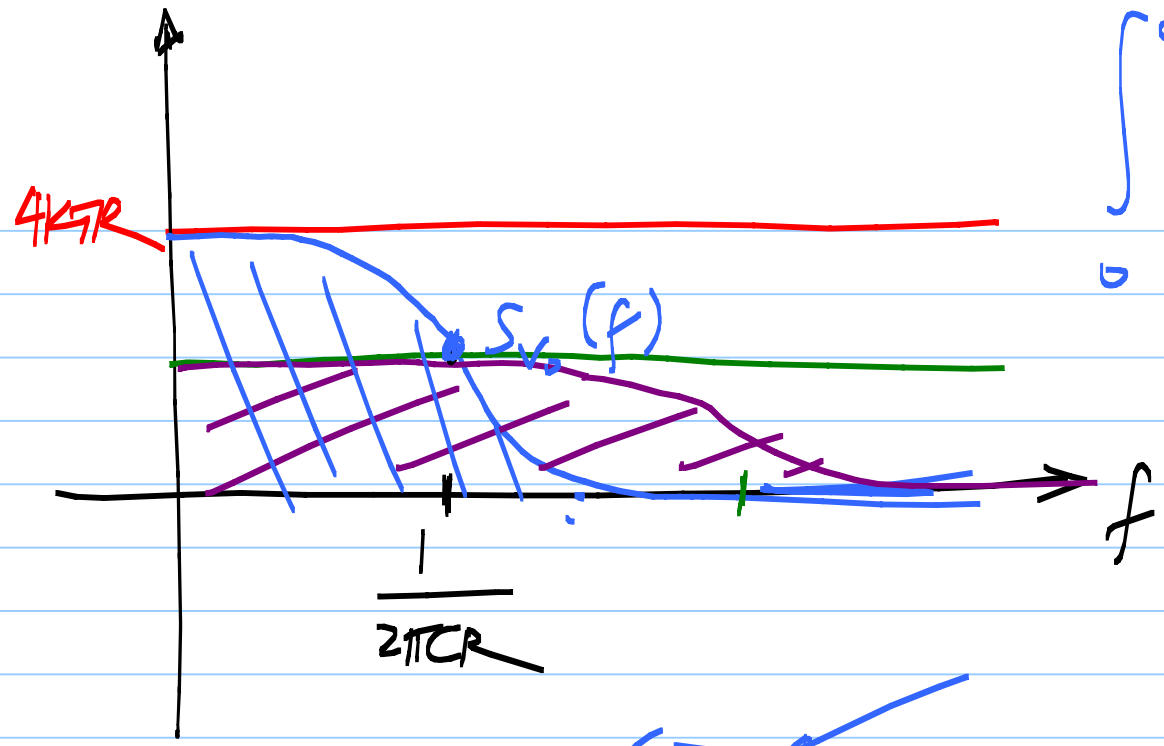
spectral density & mean square value

$s = j2\pi f$



$$\frac{V_o}{V_n} = \frac{1}{1+sCR}$$

$$S_{V_o}(f) = 4kTR \cdot \left| \frac{1}{1+j2\pi fCR} \right|^2 = \frac{4kTR}{1+4\pi^2 f^2 C^2 R^2}$$



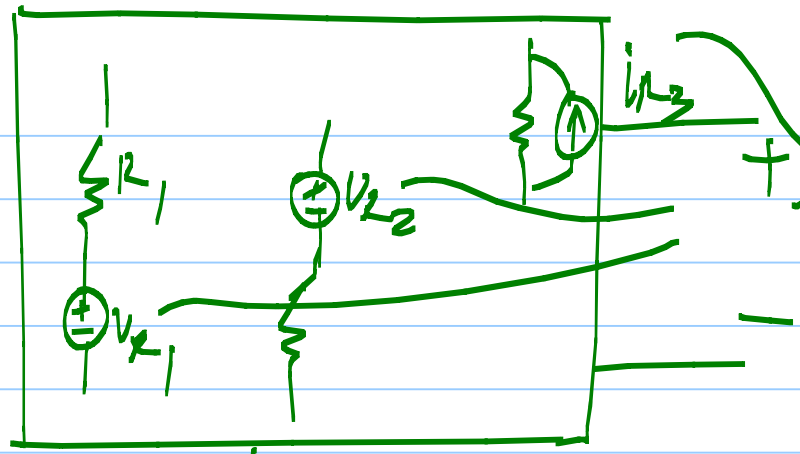
$$\int_0^\infty \frac{4KTR}{1 + 4\pi^2 f^2 C^2 R^2}\, df$$

x^2

$$\int_0^\infty \frac{4KTR}{1+x^2} \cdot \frac{dx}{2\pi CR}$$

$$\tan^{-1} x \Big|_0^\infty = \frac{\pi}{2}$$

$$\frac{4KTR}{2\pi CR} \cdot \frac{\pi}{2} = \frac{KT}{C}$$

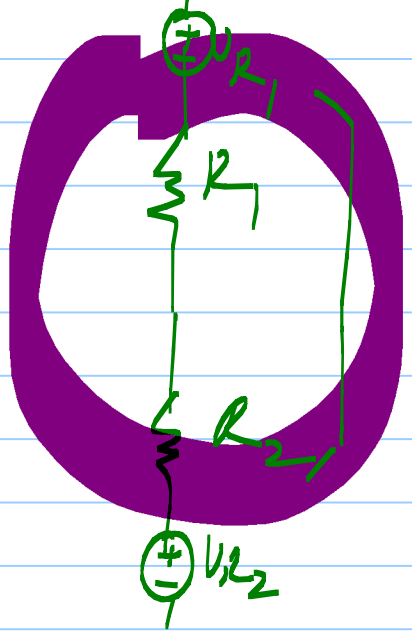


$4kTR_1 \left|H_{o,R_1}\right|^2 +$

$4kTR_2 \left|H_{o,R_2}\right|^2 +$

$4kT/R_3 \left|H_{o,R_3}\right|^2$ dim/em

Ω^2 $\quad \frac{V^2}{Hz}$

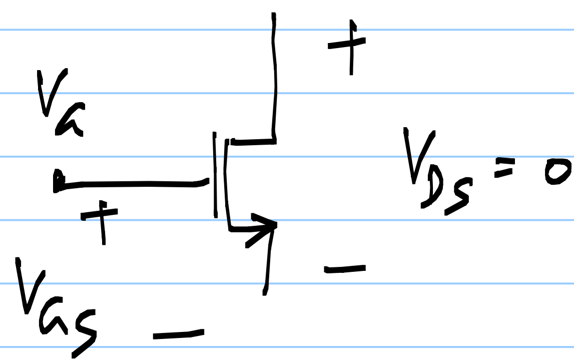


$v_{n_1} + v_{n_2}$

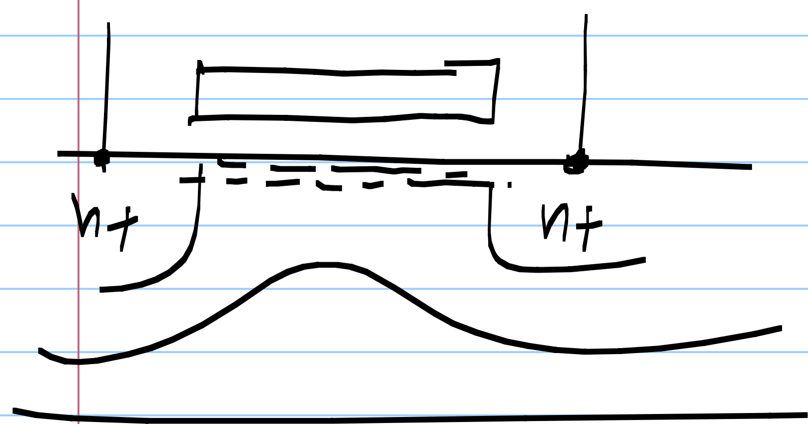
$4kTR_1 + 4kTR_2 = 4kT(R_1 + R_2)$

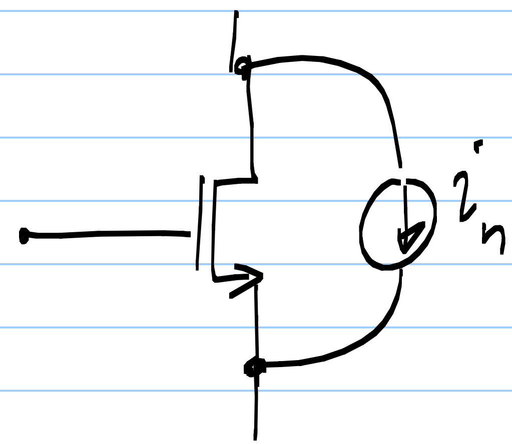
Noise in a MOS transistor:

$$I_D = \mu_n C_{ox} \frac{W}{L} \left[(V_{GS} - V_T) V_{DS} - V_{DS}^2 / 2 \right]$$



$$g_{ds} = \left. \frac{\partial I_D}{\partial V_{DS}} \right|_{V_{DS}=0} = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_T)$$





$\overline{i_n^2}$: $4kT \cdot \underline{G_{mos}}$