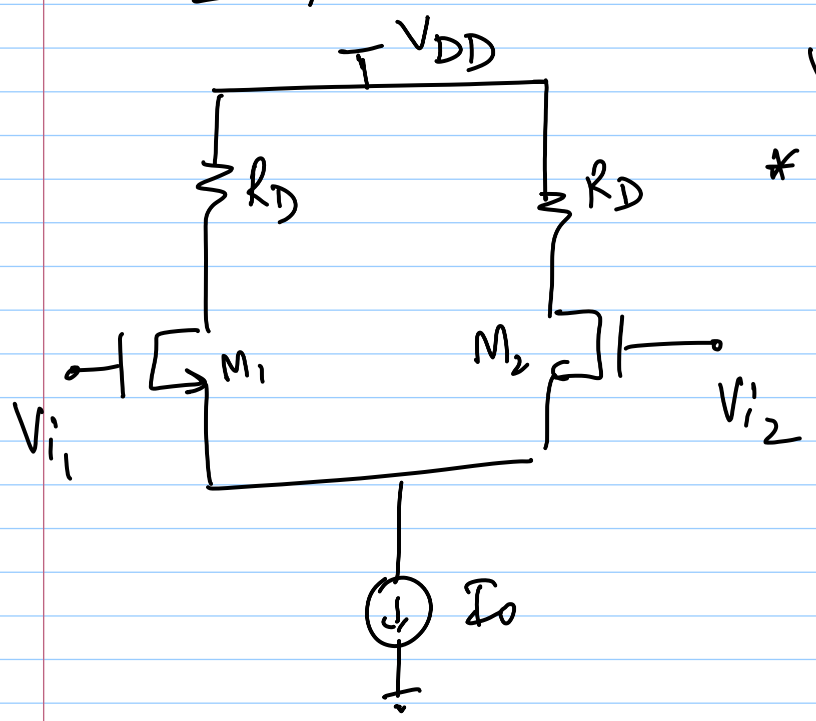
13/1/12

Lec 7

Diff pairs



$V_{i_1} - V_{GS_1} + V_{GS_2} - V_{i_2} = 0$

* Assume M_1, M_2 in sat. and identical

$$V_{GS_1} = V_T + \sqrt{\frac{2 I_{D_1}}{k'(W/L)}}$$

$$V_{GS_2} = V_T + \sqrt{\frac{2 I_{D_2}}{k'(W/L)}}$$

$$V_{id} = V_{i_1} - V_{i_2} = V_{GS_1} - V_{GS_2}$$

$$V_{id} = \frac{\sqrt{I_{D_1}} - \sqrt{I_{D_2}}}{\sqrt{\frac{1}{2} k'(W/L)}} \longrightarrow (1)$$

also $\quad I_{D_1} + I_{D_2} = I_o \longrightarrow (2)$

solve quadratic equations ...

$$I_{D_1} = \frac{I_0}{2} + \frac{k'}{4}\left(\frac{W}{L}\right) V_{id} \sqrt{\frac{4 I_0}{k'(W/L)} - V_{id}^2}$$

DC bias value

$$V_{DSAT} = \sqrt{\frac{2 \cdot (I_0/2)}{k'(W/L)}} = \sqrt{\frac{I_0}{k'(W/L)}}$$

$V_{ov} = V_{GS} - V_T$

$$g_m = k'\left(\frac{W}{L}\right)(V_{GS} - V_T) = k'\left(\frac{W}{L}\right) V_{DSAT}$$

$$\therefore I_{D_1} = \frac{I_0}{2} + \frac{k'}{4}\frac{W}{L} V_{id}\sqrt{4V_{DSAT}^2 - V_{id}^2}$$

$$= \frac{I_0}{2} + \frac{1}{2} \cdot g_m V_{id} \sqrt{1 - \left(\frac{V_{id}}{2V_{DSAT}}\right)^2}$$

$$I_{D_2} = \frac{I_0}{2} - \frac{1}{2} g_m V_{id} \sqrt{1 - \left(\frac{V_{id}}{2V_{DSAT}}\right)^2}$$

for "small" signals:

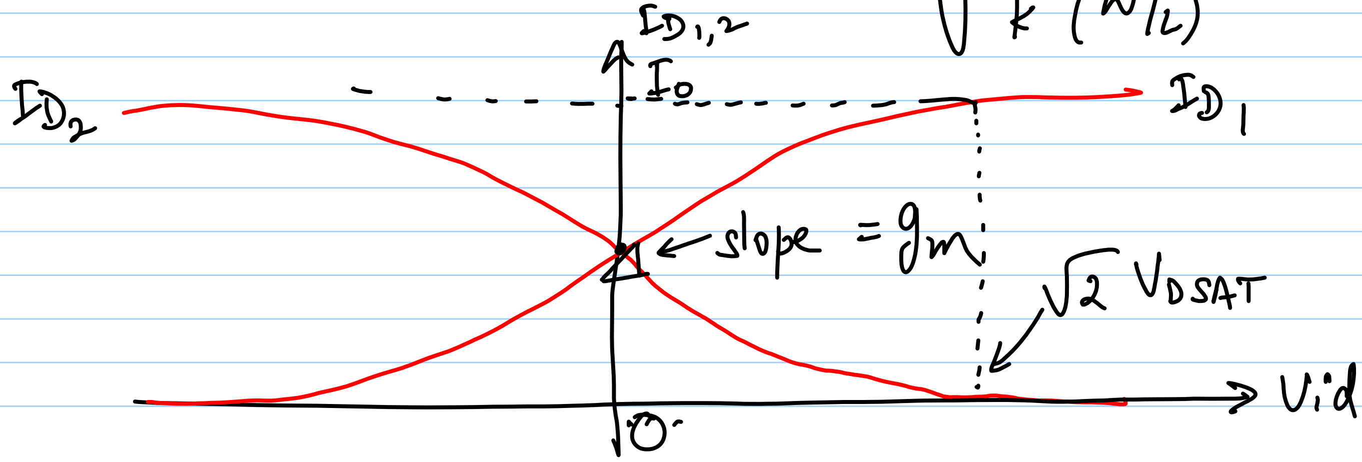
i.e. $V_{id} \ll 2V_{DSAT}$

$$\Delta I_D = g_m V_{id} \Rightarrow \boxed{V_{out} = g_m R_D V_{id}}$$

$I_{D_1} = I_0$ (full switching)
when M_2 is off

$$G_m = \frac{\partial \Delta I_D}{\partial V_{id}}$$ ← set this to zero

$$\Rightarrow V_{id} = \sqrt{2}\, V_{DSAT} = \sqrt{\frac{2 I_0}{k'(W/L)}}$$



Large-signal analysis
→ used to quantify <u>linearity</u> performance of analog ckts.

Can signal size be reduced arbitrarily?
→ No, because of effects of <u>noise</u>

Noise

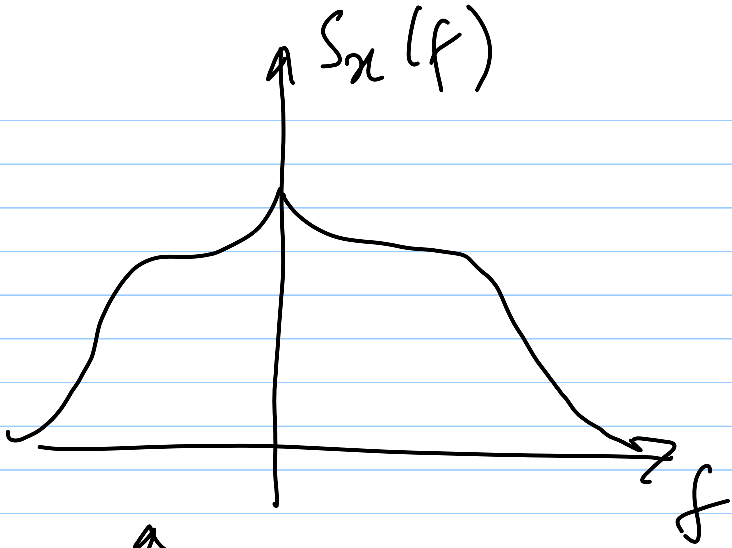
- any random interference unrelated to signal of interest
- represents inherent uncertainties @ physical level
- Use PDF (prob. dens. fn.) to represent
  - statistical quantity

* typically interested in "mean square power" of noise

$\overline{n^2(t)}$

* power spectral density PSD is used to represent noise in f-domain

$S_x(f)$ = noise power in a unit BW around f



2-sided

even fn' of f

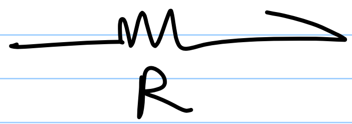
$S_x(f) = S_x(-f)$

* used in graph. analysis

-ve portion is "folded" over

* used in ckt calculations

1) **Resistor** – thermal noise

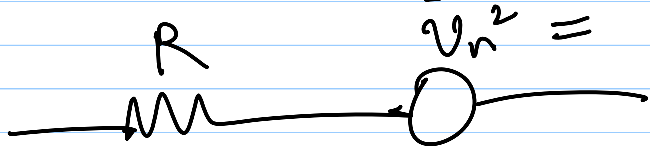


$S_x(f) = 2KTR$

abs. temp

Boltzmann's const.

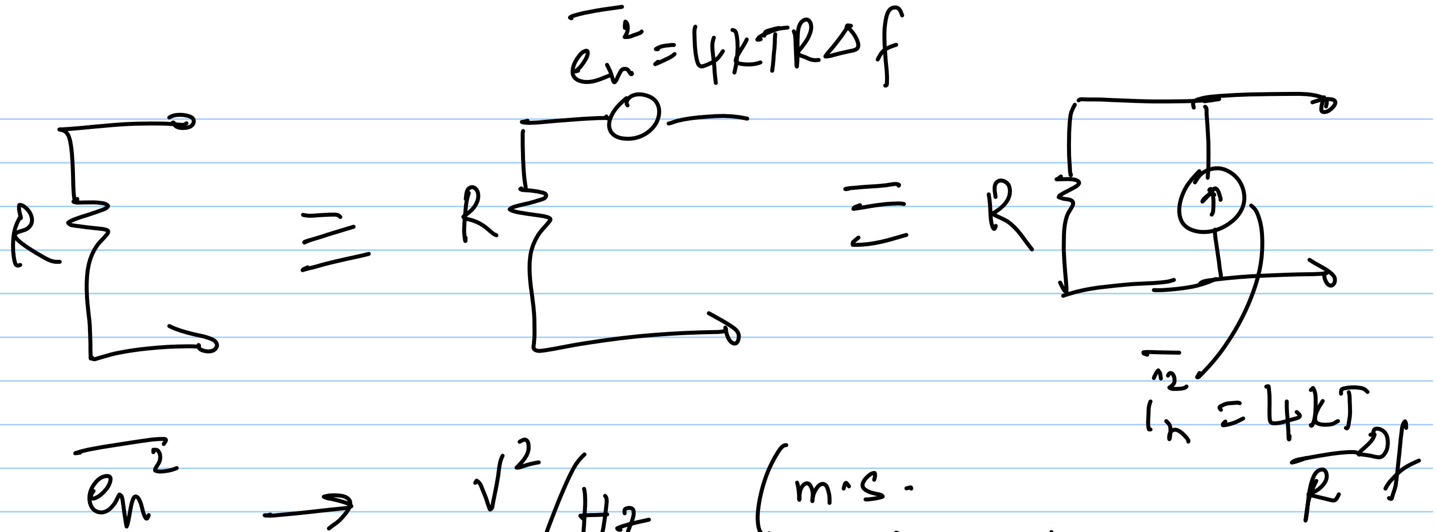
In ckt calculations



$\overline{v_n^2} = 4KTR\,\Delta f$

mean square noise voltage

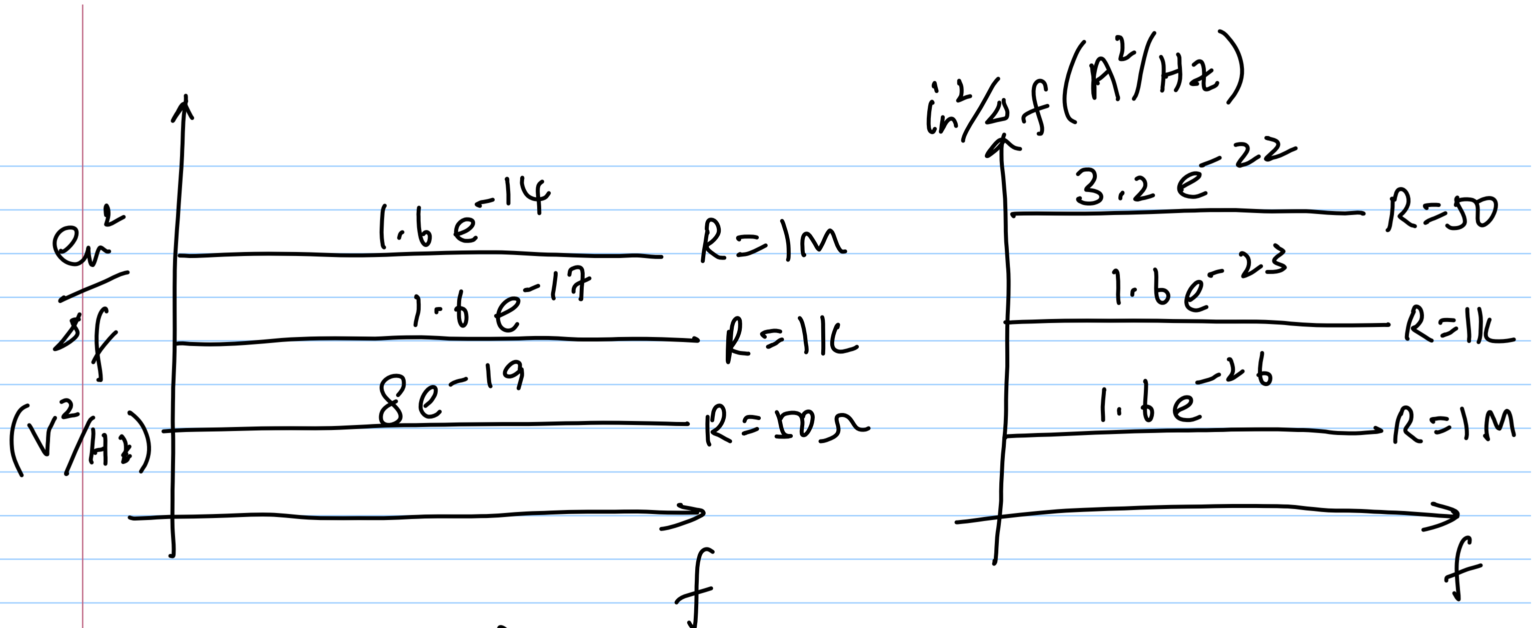
Δf = BW of interest



$\frac{\overline{e_n^2}}{\Delta f} \rightarrow V^2/Hz$ (m.s. noise voltage density)

$\frac{\overline{i_n^2}}{\Delta f} \rightarrow A^2/Hz$ (m.s. noise current density)

$\overline{e_n^2} = \overline{i_n^2} \cdot R^2$ (powers)

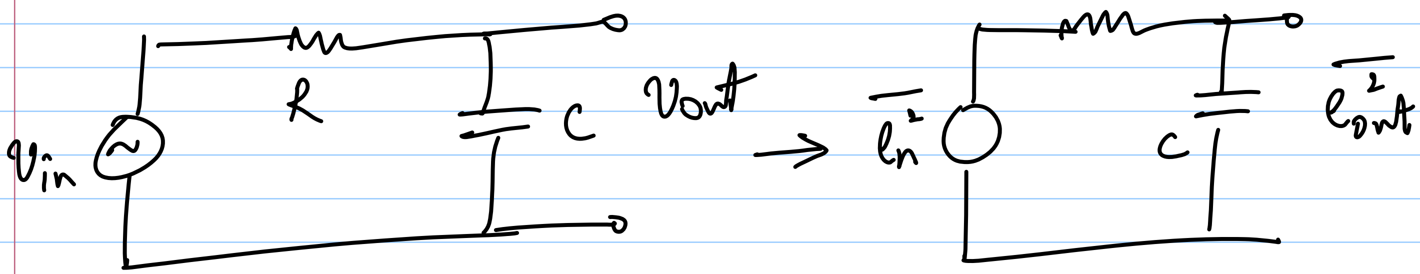


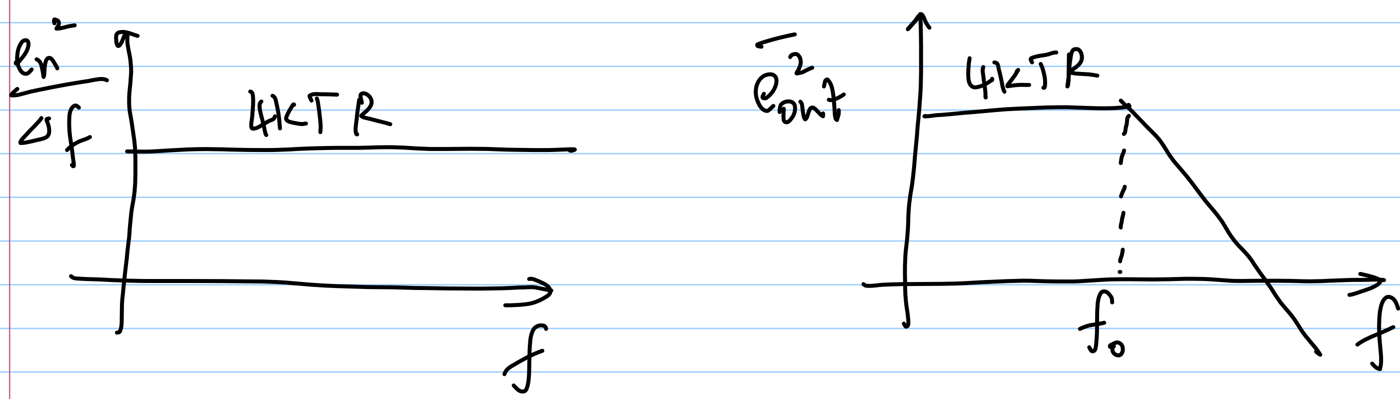
* <u>spot noise</u> = mean sq. noise density integrated over 1 Hz BW @ freq. of interest

* <u>white noise</u> – spot noise is independent of freq.

$1k\Omega \longleftrightarrow 4\,nV/\sqrt{Hz}$

Filtered Noise:





$$f_0 = \frac{1}{2\pi RC}$$

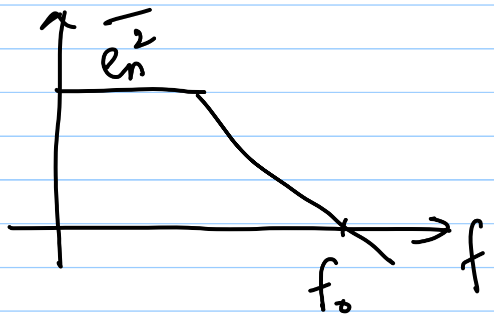
* Noise Low-pass-filtered
* Integrated m.s. noise:

$$\overline{e^2_{out,int}} = \int_0^{\infty} \frac{\overline{e_n^2}}{|1+j\,2\pi fRC|^2}\,df$$

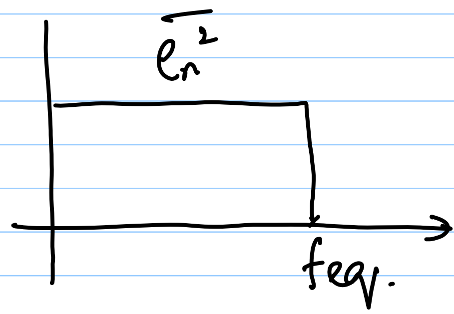
$$= \frac{\overline{e_n^2}}{2\pi RC} \cdot \frac{\pi}{2}$$

$$\boxed{\overline{e^2_{out,int}} = kT/C \quad V^2}$$

* Equivalent noise BW = BW of brick-wall filter whose o/p integ. noise is same as the above 1-pole LPF



$\Longleftrightarrow$



$$\frac{kT}{C} = \overline{e_n^2}\cdot f_{eq} = 4kTR \cdot f_{eq}.$$

$$\boxed{f_{eq} = \frac{1}{4RC} = \frac{\pi}{2}\cdot f_0}$$