ECE 513 - Lecture 8

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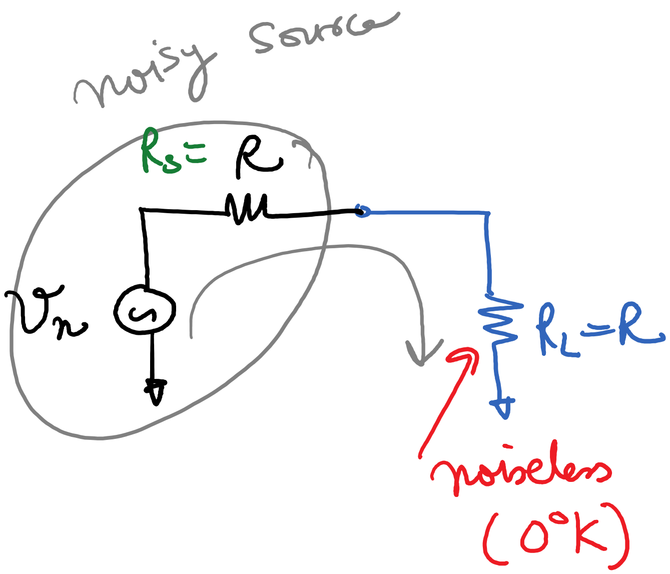
Available noise power: power that can be transferred from a noise source to a "conjugately matched" "noiseless" load.

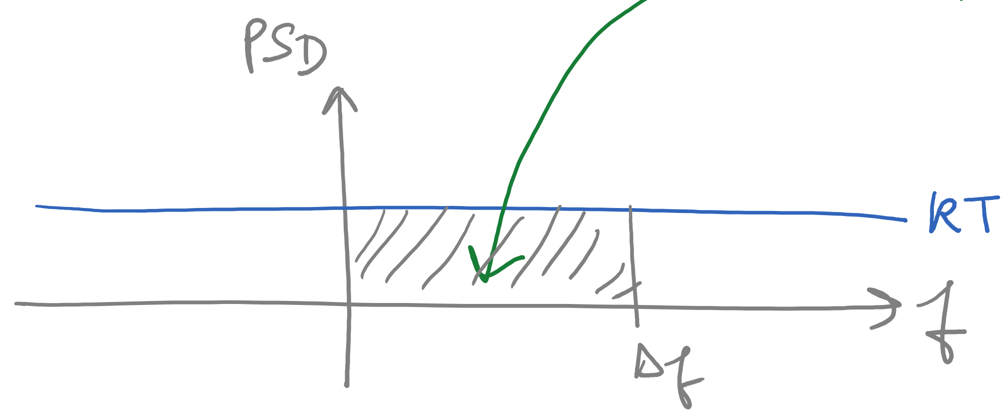
↳ so that the load don't reflect back its own noise



$$P_{available} = \frac{v_n}{2} \cdot \frac{v_n^*}{2R} = \frac{|v_n|^2}{4R} = \frac{\cancel{4}kT\cancel{R} \cdot \Delta f}{\cancel{4R}} = \boxed{kT\Delta f}$$

$R_s = R + jX$

$R_L = R - jX$



$R_L = R - jX$

for Maximum power transfer

Thermal noise - white noise

Noise Figure

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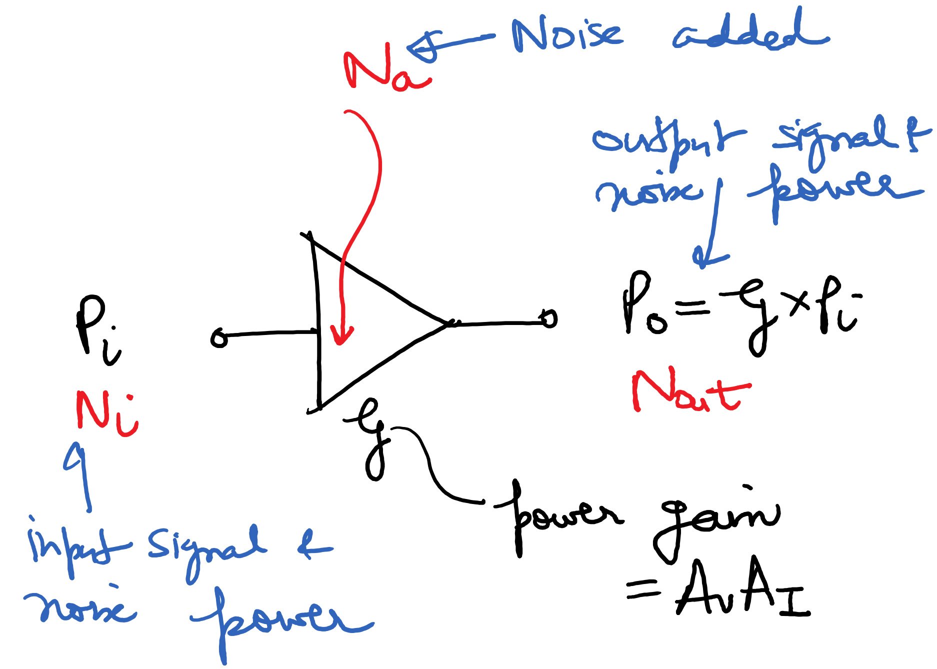
Noise factor:

Signal-to-noise-ratio

SNR



$$SNR_i = \frac{P_i}{N_i}$$

$$SNR_o = \frac{P_o}{N_{out}} = \frac{g \cdot P_i}{gN_i + N_a}$$

$$F = \frac{SNR_i}{SNR_o} = \frac{\cancel{P_i}}{N_i} \times \frac{gN_i + N_a}{g\cancel{P_i}}$$

$$\Rightarrow \boxed{F = 1 + \frac{N_a}{gN_i}} \geq 1$$

0dB

A lower 'F' the better

NF = 10 log F

(dB)

Noise figure $\boxed{NF = 10\log_{10} F}$ (dB)

Noise Temperature:

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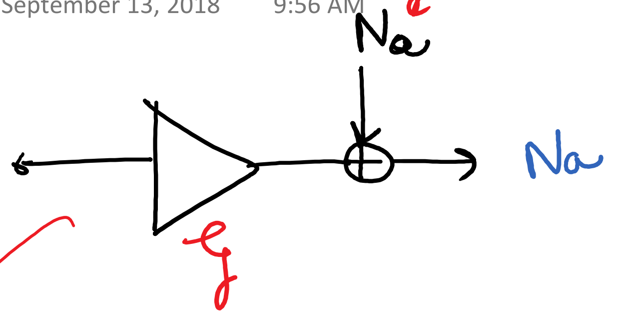
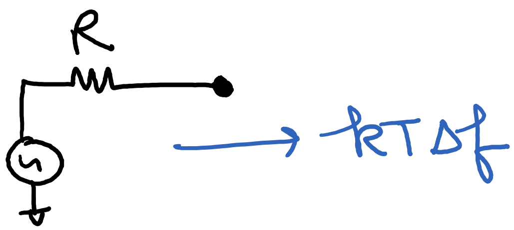
added noise by the circuit



Equivalent temperature for a block as if all the noise is generated due to thermal noise.



Equivalent "Noise Temperature"

$$kT_e \Delta f G = N_a$$

$$\boxed{T_e = \frac{N_a}{kG\Delta f}}$$

has nothing to do with the actual physical temperature.

$$F = 1 + \frac{N_a}{G N_i}$$

$$= 1 + \frac{\cancel{k}\,\cancel{G}\,T_e\,\cancel{\Delta f}}{\cancel{G}\cdot(\cancel{k}\,T\,\cancel{\Delta f})} = 1 + \frac{T_e}{T}$$

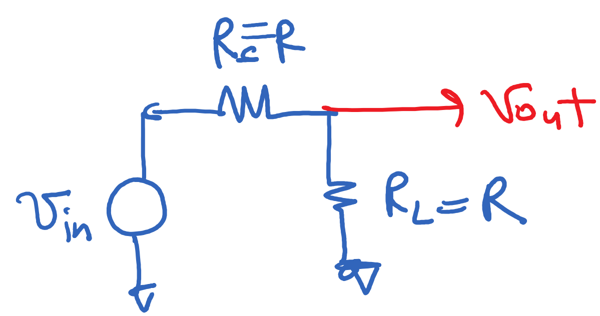
T_e: noise temperature of the circuit

T: ambient temp. of the source

physical temp

$$\boxed{F = 1 + \frac{T_e}{T}}$$

$$\Rightarrow \quad \boxed{T_e = (F-1)T}$$



$F = 2$

$NF = 3\text{dB}$

Noise Factor of a Chain of Two-Ports

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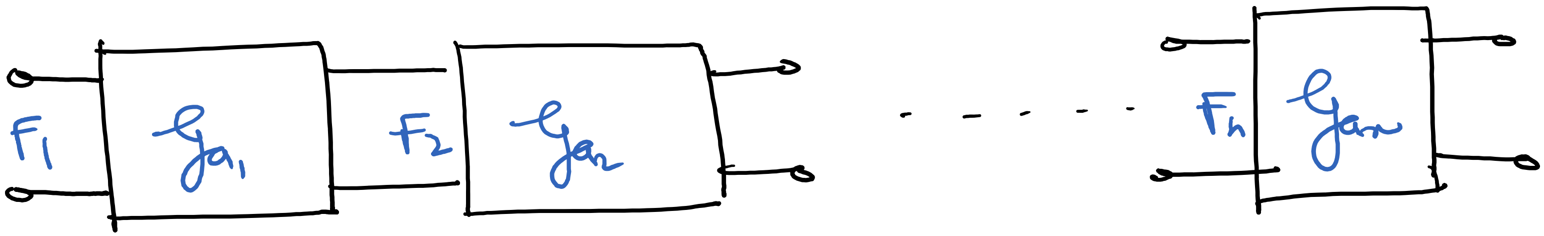

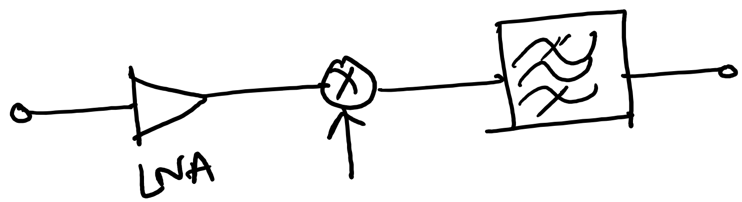

Need to calculate: the noise factor (figure) of the entire Rx chain as a function of F and gain of the individual blocks in the Rx chain.

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Total output Noise $= \left[\left(\left(kT_{e_1}\Delta f\, G_{a_1} + kT_{e_2}\Delta f\right)G_{a_2} + kT_{e_3}\Delta f\right)G_{a_3} + \cdots + kT_{e_n}\Delta f\right]G_{a_n}$

$\triangleq kT_e\Delta f \cdot G,$ $\qquad G = G_{a_1} \times G_{a_2} \times G_{a_3} \cdots \times G_{a_n}$

→ Noise temp of the full Rx chain

$$T_e = \frac{N_{out}}{k\Delta f \cdot G_{a_1}G_{a_2}\cdots G_{a_n}} = T_{e_1} + \frac{T_{e_2}}{G_{a_1}} + \frac{T_{e_3}}{G_{a_1}G_{a_2}} + \cdots + \frac{T_{e_n}}{G_{a_1}G_{a_2}\cdots G_{a_{n-1}}}$$

$$\because\ T_e = (F-1)T$$

$$(F-1)\cancel{T} = (F_1-1)\cancel{T} + \frac{(F_2-1)\cancel{T}}{G_{a_1}} + \frac{(F_3-1)\cancel{T}}{G_{a_1}G_{a_2}} + \cdots + \frac{(F_n-1)\cancel{T}}{G_{a_1}G_{a_2}\cdots G_{a_{n-1}}}$$

$$\boxed{F = F_1 + \frac{(F_2-1)}{G_{a_1}} + \frac{(F_3-1)}{G_{a_1}G_{a_2}} + \cdots + \frac{(F_n-1)}{G_{a_1}G_{a_2}\cdots G_{a_{n-1}}}}$$

Friis formula

$$\boxed{F = F_1 + \frac{(F_2 - 1)}{G_{a_1}} + \frac{(F_3 - 1)}{G_{a_1} G_{a_2}} + \cdots + \frac{(F_n - 1)}{G_{a_1} G_{a_2} \cdots G_{a_{n-1}}}}$$

Friis formula

Receiver Sensitivity:

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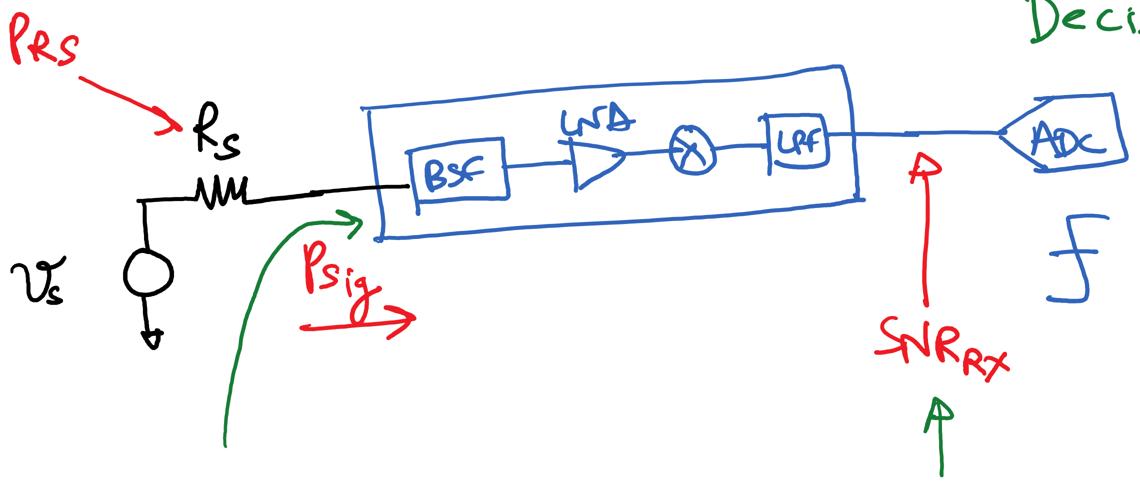
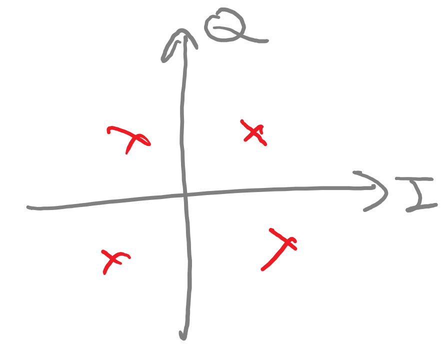


Decision circuit at the baseband



* Sensitivity is the minimum input signal that a RX can detect with "acceptable quality"

→ sufficient SNR at the decision circuit

↳ determines how much BER the RX can provide

bit error rate

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P_{sig} ⇒ Signal power p.u. Hz

P_{Rs} ⇒ Source noise p.u. Hz

$$F = \frac{SNR_{in}}{SNR_{out}} = \frac{P_{sig}/P_{Rs}}{SNR_{out}}$$

$$\Rightarrow \quad P_{sig} = P_{Rs} \cdot F \cdot SNR_{out}$$

$$P_{sig,tot} = P_{sig} \cdot \Delta f = \underbrace{P_{Rs}}_{kT} \cdot F \cdot \Delta f \cdot SNR_{out}$$

Signal power at the Rx input

$$P_{sig,tot} = F \cdot kT \cdot \Delta f \cdot SNR_{out}$$

SNR at the decision circuit

SNR_{RX} or SNR_{min}

$$\text{Sensitivity,} \quad S_i = F \cdot kT \cdot \Delta f \cdot SNR_{min}$$

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$$S_i = F \cdot kT \cdot \Delta f \cdot SNR_{min}$$

taking $10\log_{10}(\;)$ on both sides

$$P_{sen}\Big|_{dBm} = \underline{10\log_{10}(kT)} + \underbrace{10\log_{10} F}_{NF} + 10\log_{10}\Delta f + 10\log_{10} SNR_{min}$$

at 290K

$$\boxed{P_{sen}\Big|_{dBm \text{ at } 290K} = \underbrace{-174\,dBm + NF\Big|_{dB} + 10\log_{10}\Delta f\Big|_{Hz}}_{\text{Noise floor of the reciever}} + SNR_{min}\Big|_{dB}}$$