Thermal Noise Power:

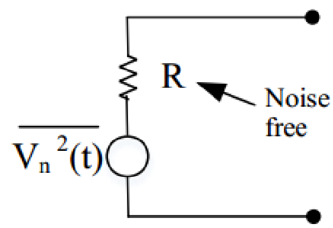
The thermal noise power in a resistor R can be found either using voltage model or current model.

Voltage model:

$$\overline{V_n^2(t)} = \frac{1}{2\pi}\int_{-2\pi B}^{2\pi B} 2kTRd\omega \quad = 4kTRB \ \text{volt}^2$$

(Or $4kTB$ watt)

r.m.s noise voltage= $\sqrt{\overline{V_n^2(t)}}$ volt

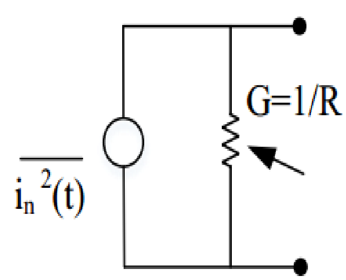


Current model:

$$\overline{V_n^2(t)} = \frac{1}{2\pi}\int_{-2\pi B}^{2\pi B} 2kTRd\omega \quad = 4kTRB \ \text{volt}^2$$

(Or $4kTB$ watt)

r.m.s noise voltage= $\sqrt{\overline{i_n^2(t)}}$ volt



Ex 1:

Calculate the r.m.s noise voltage arising from thermal noise in two resistors 100 Ω and 150 Ω at T=300 ok:

a) Connected in series

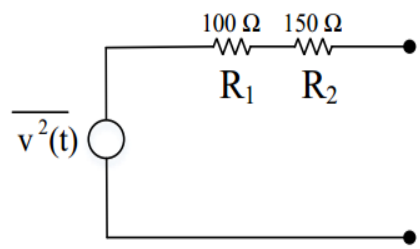
b) Connected in parallel

Solution:

a) $\overline{v_n^2(t)} = 4kTRB$ v^2

$= 4kTB(R_1 + R_2) = 4 \text{ x } 1.38 \times 10^{-23} \times\ 10^6 \times (100 + 150) \times 300$

$= 4.14 \times 10^{-12}$ $volt^2$



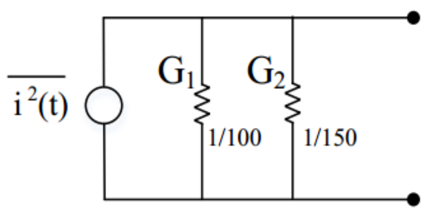
$V_n rms = \sqrt{\overline{v_n^2(t)}}$=2.3 μv

b) $\overline{i_n^2(t)} = 4kTGB$ amp^2

$= 4kTB(G_1 + G_2)$

$= 4 \text{ x } 1.38 \times 10^{-23} \times\ 300 \times 10^6 \times (\frac{1}{100} + \frac{1}{150})$

$= 2.76 \times 10^{-16}$ $ampers^2$



$i_n rms = \sqrt{\overline{i_n^2(t)}}$=0.0166 μA

The equivalent parallel resistance $R_{eq} = \frac{1}{G_1+G_2} = 60\ \Omega$

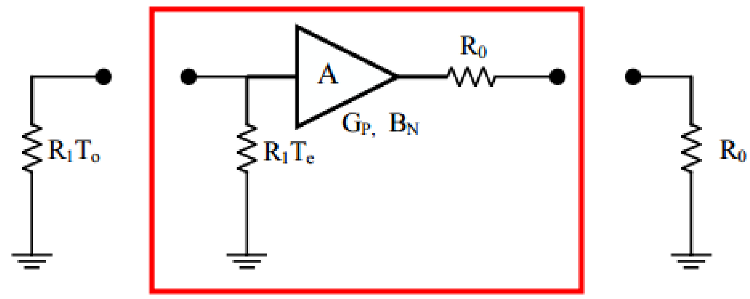
$\therefore V_{rms} = i_n rms \times R_{eq}$

$=(0.166*10^{-6})*60$

$=0.997$ μV

Thermal noise in Amplifiers:

The thermal noise power in amplifier having bandwidth B and Gain Gp is referred to what is so called "noise temperature Te" raised at amplifier input resistance

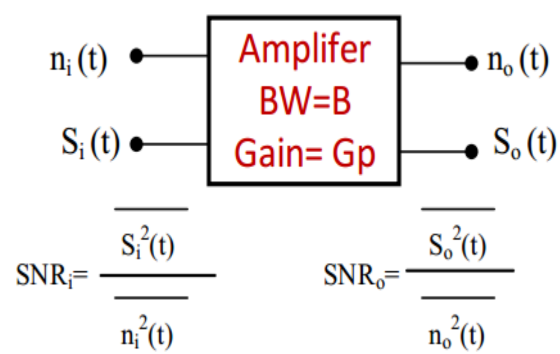


Available noise power in amplifier $P_a = KT_eB$ ..

Noise Figure:

It is a ratio of signal-to-noise ratio at amplifier input to the signal-to-noise ratio at amplifier output.

$$F = \frac{SNR_i}{SNR_o} \geq 1$$



For ideal amplifier

F=1

Input noise power: $N_i = kT_oB$ (referred to resistance connected to amplifier at ..

Input signal power: S_i ...room temperature ^{0}12 c-^{0}25 c)

Output noise power: $N_o = kT_oBG_P + kT_eBG_P$
Output signal power: $S_o = S_iG_P$

$$F = \frac{S_i/N_i}{S_o/N_o} = \frac{S_i/kT_oB}{S_iG_P/(kT_oBG_P + kT_eBG_P)}$$

$$F = 1 + \frac{T_e}{T_o}$$

Notes:

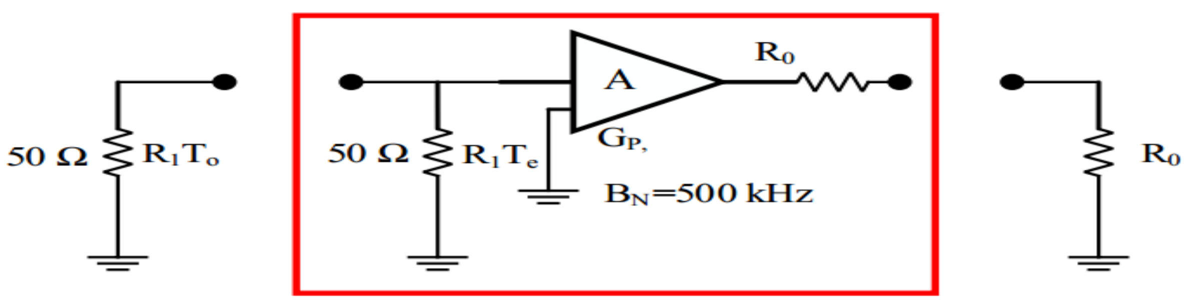
1- Sometimes F is represented in decibles

$$F_{dB} = 10\ log_{10}\ F \qquad \ldots$$

$$F = 10^{\left(\frac{F_{dB}}{10}\right)} \qquad \ldots$$

Ex2:

A given amplifier has 4*dB* noise figure, a noise bandwidth of 500 kHz and an input resistance of 50 Ω. Calculate the rms signal input, which yields an output signal-to-thermal noise ratio of unity when the amplifier is connected to a 50-Ω input at 290k.



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Solution:

$$N_i = kT_oB = 1.38 \times 10^{-23} \times 290 \times 500 \times 10^3 = 2 \times 10^{-15}\ watt$$

$$\overline{n_i^2(t)} = N_i \times R = 50 \times 2 \times 10^{-15} = 1 \times 10^{-13}\ volt^2$$

F=4 dB = 2.51

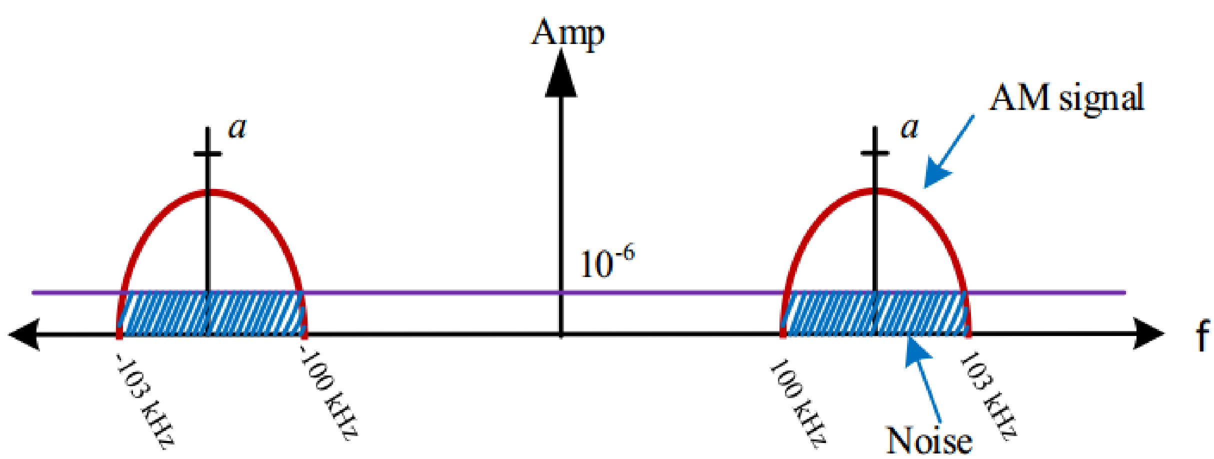
$$F = \frac{(S/N)_i}{(S/N)_o} \Longrightarrow (S/N)_i = F(S/N)_o = F \times 1 = F$$

$$\frac{\overline{S_i^2(t)}}{\overline{n_i^2(t)}} = 2.51 \Longrightarrow \overline{S_i^2(t)} = 2.51 \times\times 10^{-13}\ volt^2$$

$$\therefore Vrms_{si} = \sqrt{\overline{S_i^2(t)}} = 0.501\ \mu v$$

Ex 3:

An AM signal of 50 watt power is transmitted in a frequency range 100-103 kHz in a transmission channel. If the additive noise power spectral density (two sided) in a transmission channel is 1μ watt/Hz. Find the signal-to-noise ratio in the transmission channel.



Solution:

$$N = \frac{2}{2\pi}\int_{200\pi*10^3}^{206\pi*10^3} S_n(\omega)d\omega = \frac{1}{\pi}\int_{200\pi*10^3}^{206\pi*10^3} 10^{-6}d\omega = 6\times10^{-3}watt$$

$$SNR = \frac{S}{N} = \frac{50}{6\times10^{-3}} = 8333.33$$

$$SNR_{dB} = 10\log\ 8333.33 = 39.208\ dB$$