APECE-302: Radio & Television Engineering

Applied Physics, Electronics & Communication Engineering

Lecture # 04

University of Dhaka | APECE DU

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Contents

Noise and its classification

- Noise: Unwanted Signal

- External
  - Atmospheric/static
  - Extraterrestrial
  - Man-made

- Internal
  - Thermal
  - Shot
  - Transit time
  - Misc (Flicker, Transistor thermal, partition)

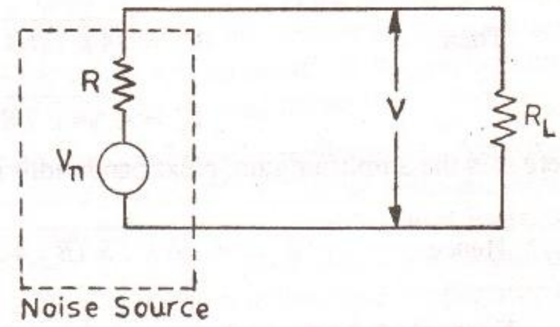
Thermal noise

Noise Power:

$$P_n = \bar{k}\,TB$$

$\bar{k}$ is the Boltzmann constant (1.38×10^{-23} Joule/deg. K)
T is the absolute temperature, K = 273° + deg. C
B is the bandwidth in hertz.

Resistor as a noise generator



$$P_n = \frac{V^2}{R_L} = \frac{V^2}{R} = \frac{(V_n/2)^2}{R} = \frac{V_n^2}{4R}$$

$$V_n^2 = 4R\,P_n = 4R\,\bar{k}\,TB$$

$$V_n = \sqrt{4R\,\bar{k}\,TB}$$

Thermal noise

[redacted] *A resistor of value 20 kΩ is connected at the input of an amplifier operating over the frequency range 10 to 11 MHz. Compute the rms noise voltage at the input of the amplifier if the ambient temperature is 24°C.*

$$V_n = \sqrt{4\,\bar{k}\,TRB} = \sqrt{4 \times 1.38 \times 10^{-23} \times (273+24) \times 20 \times 10^{3} \times (11-10)\,10^{6}} \text{ volt} = 18.1\ \mu\text{V}.$$

[redacted] *The noise output of a resistor is amplified by a noiseless amplifier having gain of 40 and bandwidth of 40 KHz. A meter connected to the output of the amplifier reads 4 mV rms (a). If the resistor is operated at 27°C, what is its resistance ? (b) If the bandwidth of the amplifier is reduced to 10 KHz, its gain remaining constant, what will the meter read now ?*

Thermal noise

Solution. (*a*) $V_n = \sqrt{4\bar{k}TRB}$

Hence $R = \dfrac{Vn^2}{4\bar{k}TB}$

The rms noise voltage generated in the resistor $= \frac{4\,mV}{40} = 100\,\mu\text{V}$

Hence $R = \dfrac{(100\times10^{-6})^2}{4\times1.38\times10^{-23}\times(273+27)\,40\times10^3}\,\Omega$

$= 15.1\times10^6\,\Omega$

(*b*) Initially $B = 40\text{ kHz}$

Then $V_n = \sqrt{4\bar{k}TRB}$

$V_o = A\sqrt{4\bar{k}TRB}$

where A is the amplifier gain. Next bandwidth is reduced to 10 kHz, *i.e.* $B' = B/4$.

Hence $V_o = A\sqrt{4\bar{k}TR\,(B/4)} = \frac{1}{2}A\sqrt{4\bar{k}TRB} = \frac{1}{2}\times4\text{ mV} = 2\text{ mV}.$

Shot noise

For a diode, rms shot noise current:

$$I_n = \sqrt{2\, q\, I_p\, B}$$

where q is the magnitude of the charge of an electron (1.6×10^{-19} Coulomb)
I_p is the direct diode current, Amp.
and B is the bandwidth of the system, hertz.

Adding thermal noise and shot noise component??

Overcome by taking R_eq

Addition of noise due to several sources

Several thermal noise sources in series:

$$V_{n_1} = \sqrt{4\bar{k}TBR_1}$$

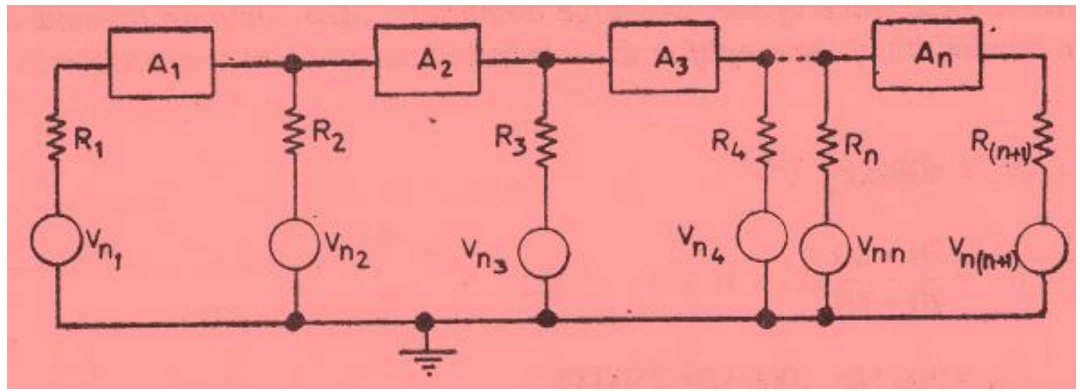
$$V_{n_2} = \sqrt{4\bar{k}TBR_2}$$

$$V_{nr} = \sqrt{V_{n1}^2 + V_{n_2}^2 + V_{n_3}^2 + \ldots\ldots} = \sqrt{4\bar{k}TB(R_1 + R_2 + R_3 + \ldots\ldots)}$$

$$= \sqrt{4\bar{k}TBR}$$

$$R = R_1 + R_2 + R_3 + \ldots\ldots$$

Addition of noise in cascaded amplifiers



Equivalent I/P noise voltage:

$$V_{n_3} = \sqrt{4\bar{k}TBR_3}$$

$$V_{n3}' = \frac{V_{n_3}}{A_2} = \frac{\sqrt{4\bar{k}TBR_3}}{A_2} = \sqrt{4\bar{k}TBR_3'}$$

$$R_3' = \frac{R_3}{A_2^2}$$

$$R_{2t} = R_2 + R_3' = R_2 + \frac{R_3}{A_2^2}$$

$$R_2' = \frac{R_{2t}}{A_1^2} = \frac{R_2 + R_3/A_2^2}{A_1^2} = \frac{R_2}{A_1^2} + \frac{R_3}{A_1^2 A_2^2}$$

$$R_{eq} = R_1 + R_2' = R_1 + \frac{R_2}{A_1^2} + \frac{R_3}{A_1^2 A_2^2}$$

Addition of noise in cascaded amplifiers

[redacted] *The first stage of a two stage amplifier has output resistance of 20 kΩ, voltage gain of 10, input resistance of 500 Ω and equivalent noise resistance 2000 Ω. The second stage has output resistance of 400 kΩ, voltage gain of 20, input resistance of 80 kΩ and equivalent noise resistance of 10 kΩ. Compute the equivalent input noise resistance of the two stage amplifier. Also compute the equivalent input noise voltage given that the bandwidth of the amplifier is 10 kHz and the ambient temperature is 300 K.*

$$R_3 = 400\text{k}\Omega$$

$$R_2 = \frac{20 \times 80}{20 + 80}\,\text{k}\Omega + 10\,\text{k}\Omega = 26\,\text{k}\Omega$$

$$R_1 = 500\,\Omega + 2000\,\Omega = 2500\,\Omega.$$

$$R_{eq} = R_1 + \frac{R_2}{A_1^2} + \frac{R_3}{A_1^2 A_1^2}$$

$$= 2500 + \frac{26,000}{(10)^2} = \frac{400,000}{(10 \times 20)^2}\,\text{ohms} = 2670\,\Omega$$

$$V_{neq} = \sqrt{4\bar{k}TBR_{eq}} = \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 10^4 \times 2670}\ \text{volt}$$

$$= 0.677\,\mu\text{V}.$$

Signal to Noise Ratio (SNR)

- Purpose?
  - Comparing two system's performances
  - To know the relative signal strength at the same point

$$\frac{S}{N} = \frac{P_s}{P_n} = \frac{V_s^2/R}{V_n^2/R} = \left(\frac{V_s}{V_n}\right)^2$$

Noise Figure:

$$F = \frac{S/N \text{ at the input}}{S/N \text{ at the output}}$$

Greater than unity

>>> Noise Figure & Noise Temperature>>> Next Lecture>>>

Q & A