Noise

- External Noise
  - Manmade (sparking)
  - Natural (lighting
- Internal Noise
  - Shot Noise (Active device)
  - thermal Noise (Passive component)

Shot Noise

- Partition Noise
  Ex → BJT & FET
- Flicker Noise
  (also known as low freq Noise)

→ Thermal Noise are also called as Johnson Noise or Gaussian Noise

Shot Noise → produced due to shot effect

the shot noise is produced because of the random variation in arrival of electrons (or holes) at the output electrode of an Amplifying device

The Exact formula for shot Noise can be obtained only for diode. For all other device an

Approximation Equation is stated.

The Mean square shot Noise current for diode is given as

$$\boxed{I_n^2 = 2(I + 2I_0)qB \text{ ampere}^2}$$

$I \rightarrow$ DC current across Junction (in Amp)

$I_0 \rightarrow$ Reverse saturation current (in Amp)

$q \rightarrow$ electronic charge (1.6×10^{-19})

$B \rightarrow$ effective Noise bandwidth (in Hz)

Partition Noise :-

is generated when current get divided between two or more path. it is generated due to Random flucations in divisions. therefore partition Noise in transistor is higher than that in diode.

Ques A Noise generator using diode is required to produced $15 \mu V$ Noise voltage in a receiver which has I/p Impedence of 75Ω. The Receiver has a Noise power bandwidth of 200 KHz. Calculate current through diode.

Ans Given $V_n = 15 \mu V$ $R = 75$ $B = 200$ KHz

$$I_n = \frac{V_n}{R} = \frac{15 \times 10^{-6}}{75} = 2 \times 10^{-7} \text{ Amp}$$

$$\because \quad I_n^2 = 2(I + 2I_0)qB$$

$$I_n^2 = 2 I \times q B \quad (\text{Neglect } I_0)$$
as I_0 is very small

$$(0.2 \times 10^{-6})^2 = 2 I \times 1.6 \times 10^{-19} \times 200 \times 10^3$$

$$\boxed{I = 0.625 \text{ Amp or } 625 \text{ mA}}$$

Flicker Noise

Flicker Noise will appear at freq. below a few Kilohertz. It is sometime called as $\frac{1}{f}$ Noise. In semiconductor device, the flicker noise is generated due to fluctation in the carrier density. These flucation in carrier density will cause fluctuation in conductivity of material. This will produce a fluctation voltage drop when a direct current flow through a device. This fluctating voltage is called Flicker Noise voltage

Thermal Noise or Johnson Noise

The free electron within a conductor are always in Random Motion. This Random Motion is due to thermal energy Received by them. The distribution of these free electron within a conductor at a given instant of time is not uniform. It is possible than excess ~~electron~~ No. of electron may appear at one end or the other of conductor.

The average voltage Resulting from this Non-uniform distribution is zero but average power is Not zero.

At this power Result from thermal energy It is or called as thermal Noise ~~power~~ power.

$$\boxed{P_n = KTB} \text{ (Watt)}$$

$K \rightarrow$ Boltzman Constt $= 1.38 \times 10^{-23}$ Joule/kelvin

$T \rightarrow$ Temp. of conductor

$B \rightarrow$ Bandwidth of Noise Spectrum (Hz).

Qus) A Receiver has Noise power bandwidth of 12 KHz A Resistor which matches with the Receiver Input Impedence is connected across the antenna terminal what is Noise power Contributed by Resistor in the Receiver Bandwidth? Assume temp. to be 30°C.

Ans) $B = 12\text{ KHz}$ $T = 30°C = 30 + 273$

$= 303° K$

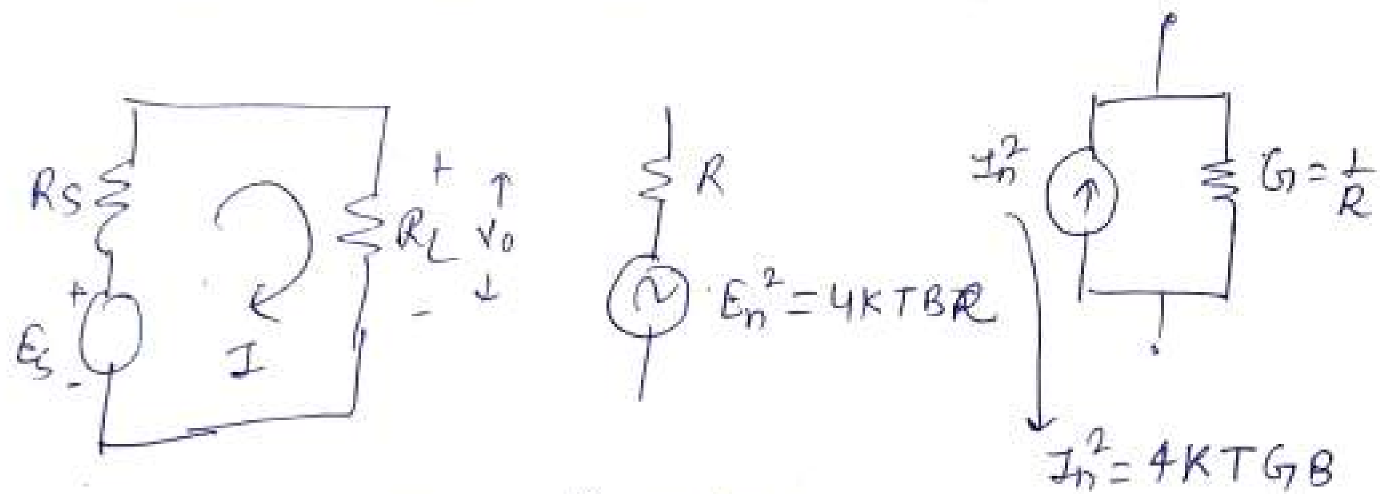
$P_n = KTB$

$P_n = 1.38 \times 10^{-23} \times 303 \times 12 \times 10^{3}$

$$\boxed{P_n = 5.01768 \times 10^{-17}\ W}$$

Equivalent Ckt for Thermal Noise

As the conductor is generating an electrical noise energy, it must have an equivalent voltage or equivalent current generator ~~co~~ circuit which will represent the noise source.



a) voltage generator for a noise source

b) voltage generator equivalent circuit

c) A current generator equivalent circuit for a noise source

from (a)

$$V_0 = \frac{R_L E_s}{R_s + R_L}$$

for maximum power to delivered,

from max. Power transfer theorem

$$R_S = R_L$$

$$\Rightarrow \boxed{V_0 = \frac{E_s}{2}}$$

~~POWER~~ $\cancel{= \frac{V_n^2}{4R}}$

$$\because I_n = \frac{V_n}{R} = \frac{\sqrt{4KTBR}}{R}$$

$$I_n = \sqrt{\frac{4KTB}{R}}$$

$\Rightarrow$ POWER $= \dfrac{V_n^2}{4R}$

$\because$ POWER = KTB

$\Rightarrow V_n^2 = KTB\,4R$

$$\boxed{V_n = \sqrt{4KTBR}}$$

(Que) Calculate the Noise voltage at the I/p of a Receiver RF amplifier, using a device that has a 100Ω equivalent Noise Resistance and a 200 I/p Resistor. The bandwidth of amplifier is 1M, the temp. is 25°C and Boltzmann's const. = 1.38×10^{-23} J/K

Ans

$R_i = 200\,\Omega \quad R_n = 100\,\Omega \quad B = 1\,MHz$

$T = 25°C = 298\,°K$

$V_n = \sqrt{4KTB\,R_{eq}}$

$R_{eq} = R_i + R_n = 100 + 200 = 300\,\Omega$

$V_n = \sqrt{4 \times 1.38 \times 10^{-23} \times 298 \times 1 \times 10^{6} \times 300}$

$V_n = 2.2\,\mu V$

Ques Calculate the thermal Noise power available from any Resistor at room temp (290°K) for a bandwidth of 2 MHZ. Also calculate the corresponding Noise voltage given that $R = 100\Omega$

Ans) $P_n = KTB = 1.38 \times 10^{-23} \times 290 \times 2 \times 10^{6}$

$= 8 \times 10^{-15}$ watt

Noise voltage $V_n = \sqrt{P_n R}$

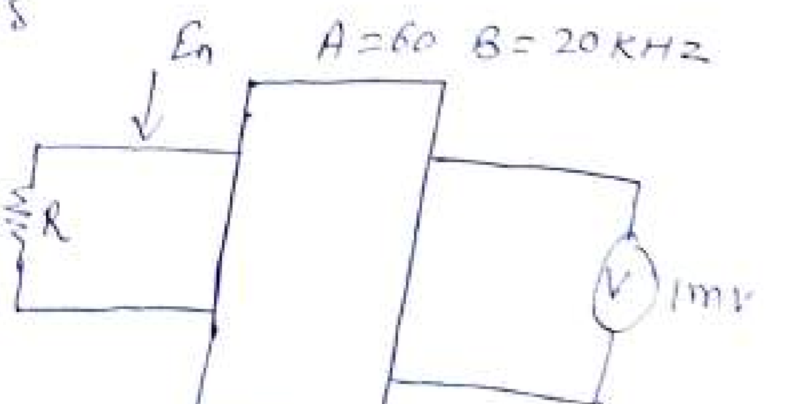
$= \sqrt{8 \times 10^{-15} \times 100}$

$\boxed{V_n = 0.894 \mu V}$

Ques The Noise output of a Resistor is amplified by a Noiseless amplifier having a gain of 60 and a bandwidth of 20KHZ. A Meter connected to output of the amplifier Read one millivolt (RMS).

(i) If the bandwidth of the amplifier is now Reduced to 5KHZ, its gain Remaining constt, what does the Meter Read?

ii) If the Resistor is operated at 80°C, what is its Resistance?



(Ans) $E_n = \frac{1 mv}{60}$

$E_n = 1.66 \times 10^{-5}$ volt

$E_n = \sqrt{4KTBR}$

$\Rightarrow E_n^2 = 4KTBR$

$\because B = 20\ KHz$

$$KTR = \frac{(1.66 \times 10^{-5})^2}{4 \times 20 \times 10^3} = 3.47 \times 10^{-15}$$

Now, gain of amplifier is constt. i.e $A = 60$ and bandwidth is changed to

$B = 5\ KHz$

$$E_n = \sqrt{4KTRB} = \sqrt{4 \times 3.47 \times 10^{-15} \times 5 \times 10^3}$$

$$E_n = 8.33 \times 10^{-6}\ Volt$$

Therefore Meter Reading will be $= A \times E_n$

$= 60 \times 8.33 \times 10^{-6}$

$= \underline{\underline{0.5\ mV}}$

ii) $T = 80^\circ C = 353^\circ K$

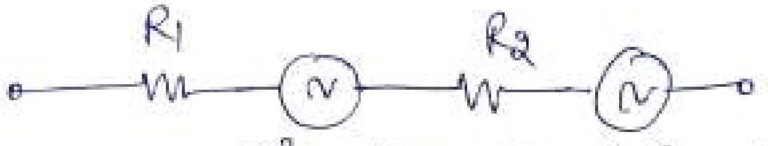
we know $KTR = 3.47 \times 10^{-15}$

$$R = \frac{3.47 \times 10^{-15}}{1.38 \times 10^{-23} \times 353}$$

$$R = 712.77\ K\Omega$$

NOISE CALCULATIONS (THERMAL NOISE)

The Resistor act as source of thermal Noise. Thus let us observe the effect of connecting two Noise source i.e two Resistor in Series with each other



$E_{n1}^2 = 4KTBR_1 \quad E_{n2}^2 = 4KTBR_2$

$\Updownarrow$

$E_n^2 = 4KTB(R_1+R_2)$

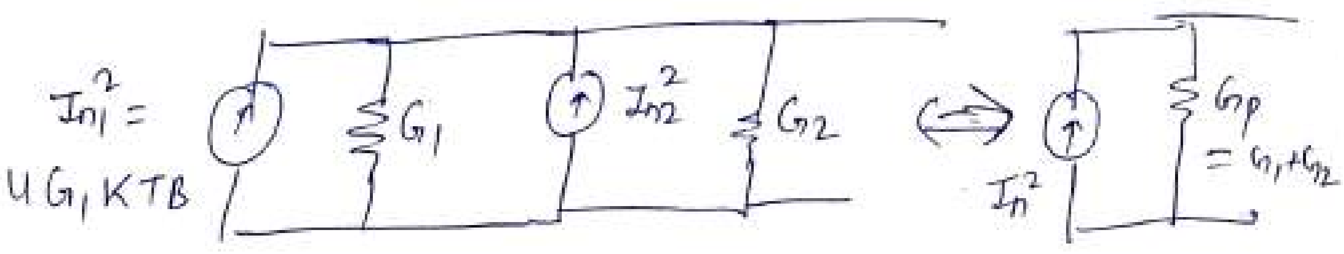
$$\Rightarrow \quad E_n^2 = 4KTBR$$

$$= 4KTB(R_1+R_2) = 4KTBR_1 + 4KTBR_2$$

$$\boxed{E_n^2 = E_{n1}^2 + E_{n2}^2}$$

$$E_n = \sqrt{E_{n1}^2 + E_{n2}^2 + \cdots}$$

If These are in parallel



$$I_n^2 = 4G_pKTB$$

As two conductor ~~or~~ G_1 & G_2 are in parallel.

$$\boxed{G_p = G_1 + G_2}$$

$$I_n^2 = 4 G_p KTB = 4(G_1 + G_2) KTB$$

$$= 4G_1 KTB + 4G_2 KTB$$

$$\boxed{I_n^2 = I_{n1}^2 + I_{n2}^2}$$

Que Two Resistor 20kΩ and 50kΩ are at Room temp determine for bandwidth 100 kHz the thermal Noise for following condition

i) For each Resistor.

ii) for two Resistor in series

iii) For two Resistor in parallel.

Ans

$$E_{n1}^2 = 4KTBR = 4 \times 1.38 \times 10^{-23} \times 290 \times 100 \times 10^3 \times 20 \times 10^3$$

$$= 32 \times 10^{-12}$$

$$E_{n1} = 5.66 \, \mu V$$

$$E_{n2}^2 = 8.95 \, \mu V$$

ii) Effective Resistor $R = R_1 + R_2 = 70k\Omega$

$$E_n = \sqrt{E_{n1}^2 + E_{n2}^2} = 10.59 \, \mu V$$

!!!/ for two Resistor in parallel.

$$R_p = \frac{20 \times 50}{20 + 50} = 14.28\,k\Omega$$

$$E_n = \sqrt{4KTBR_p} = 4.78\,\mu V$$

SNR (Signal to Noise Ratio)

In comm. systems, the comparison of signal power with noise power at the same point is important to ensure that noise at that point is not excessively large. It is defined as ratio of signal power to noise power at same point.

$$\boxed{\frac{S}{N} = \frac{P_s}{P_n}} \qquad \left(\frac{S}{N}\right)_{in} = \frac{P_{s_i}}{KT_0B_n}$$

$P_s \rightarrow$ Signal power

$P_n \rightarrow$ Noise power at same point.

$$\boxed{(S/N)_{dB} = 10 \log_{10}(P_s/P_n)}$$

NOISE FACTOR