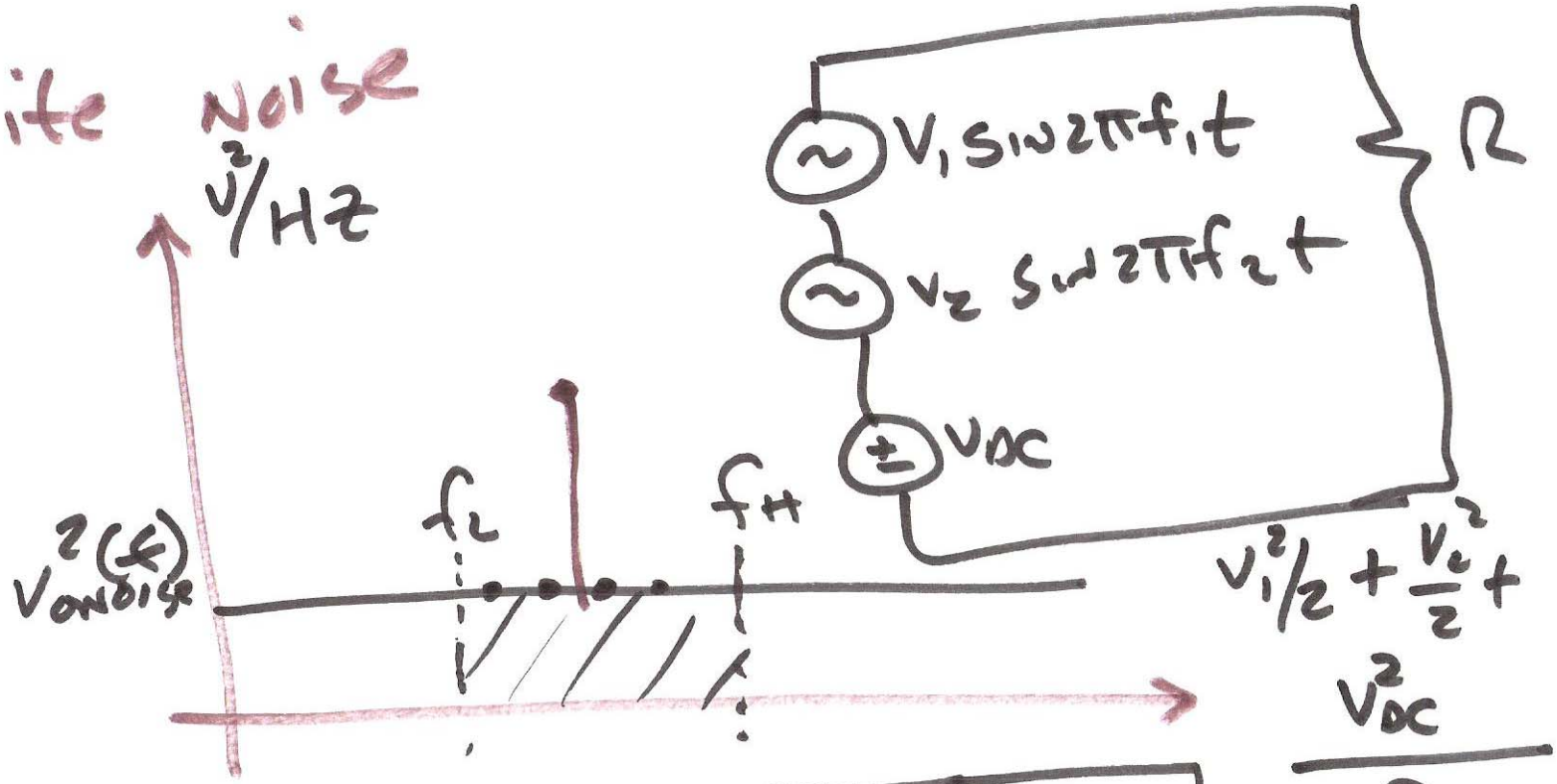
ECE 614 Advanced Analog IC

BOISE STATE UNIVERSITY

Lecture 9 Sept. 20, 2011

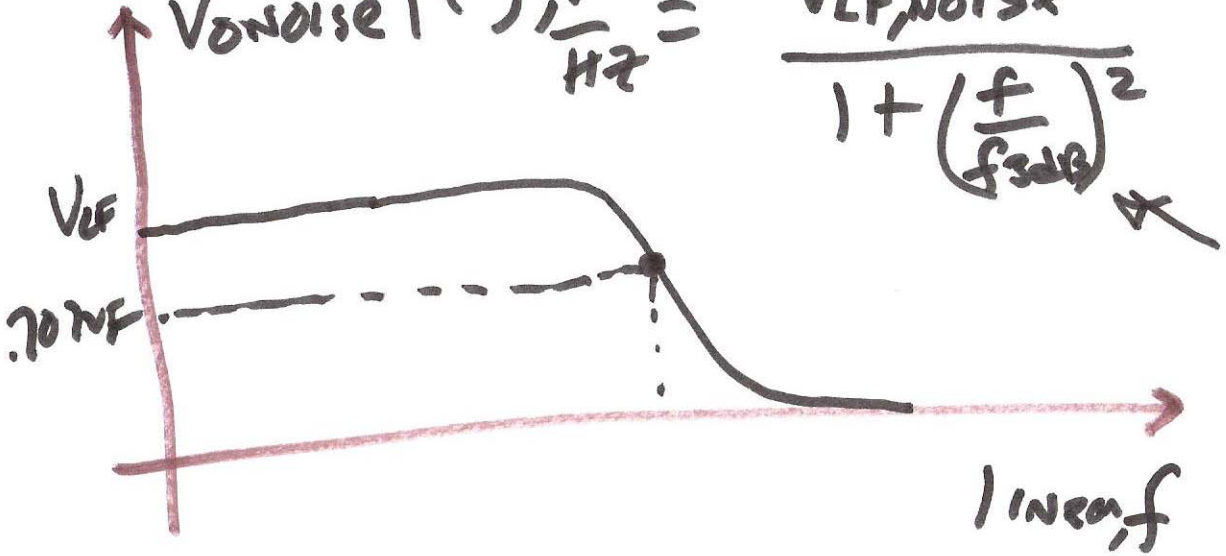
White Noise

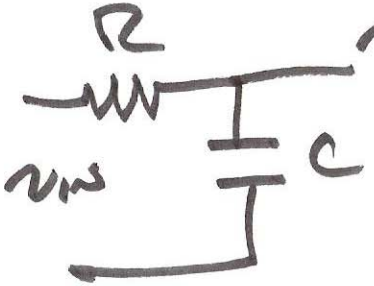


$$V_{RMS} = \sqrt{\int_{f_L}^{f_H} V_{ONOISE}^2(f)\, df} \quad P_{total}$$

1)

$$V_{ONOISE}^2(f), \frac{V^2}{Hz} = \frac{V_{LF,NOISE}^2}{1+\left(\frac{f}{f_{3dB}}\right)^2}$$





$$v_{OUT} = v_{IN} \cdot \frac{1/j\omega C}{1/j\omega C + R}$$

$$\frac{v_{OUT}}{v_{IN}} = \frac{1}{1+j\omega RC}$$

$$\frac{1}{\sqrt{1+\left(\frac{f}{f_{3dB}}\right)^2}} = \left|\frac{v_{OUT}}{v_{IN}}\right| = \frac{1}{\sqrt{1+(2\pi f RC)^2}}$$

$$f_{3dB} = \frac{1}{2\pi RC}$$

2)

$$V_{o,rms}^2 = \int_0^\infty \frac{f_{3dB}^2 V_{LF,Noise}^2}{1+\left(\frac{f}{f_{3dB}}\right)^2} \cdot df \Rightarrow V^2$$

$a = 1$

$du = d\left(\frac{f}{f_{3dB}}\right) \rightarrow du = \frac{df}{f_{3dB}} \rightarrow df$

$$\frac{du}{a^2+u^2} = \frac{1}{a}\tan^{-1}\frac{u}{a} + C$$

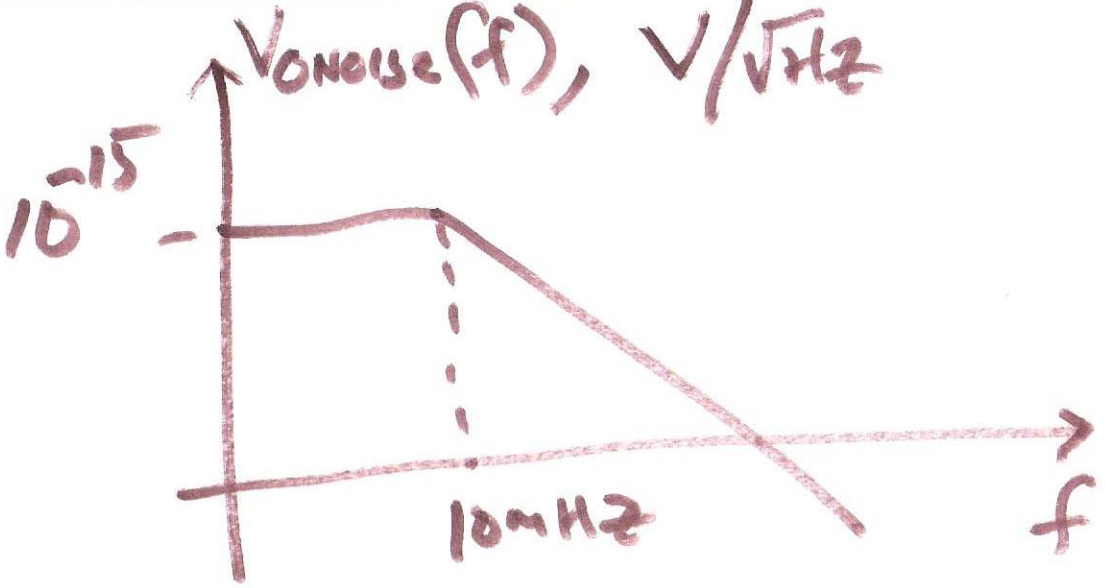
$f_{3dB}\, u = f$, $a^2 = f_{3dB}^2$

$$V_{ONOISE,rms}^2 = V_{LF,rms}^2 \cdot f_{3dB} \cdot \tan^{-1}\frac{2\pi f}{f_{3dB}}\Big|_0^\infty$$

$$= 1 \cdot \tan^{-1}\frac{f}{f_{3dB}}$$

$$V_{ONOISE,rms}^2 = V_{LF,rms}^2 \cdot \underbrace{f_{3dB} \cdot \frac{\pi}{2}}_{NFB}$$

3)

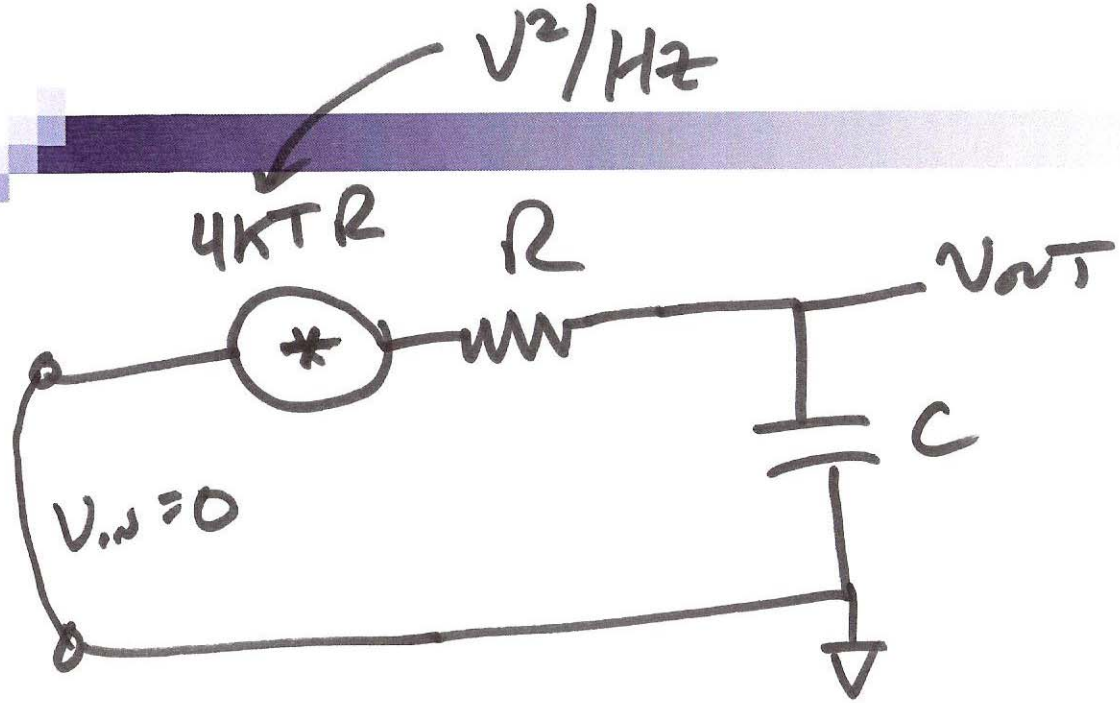


$$V_{Rms}^2 = \left(10^{-15}\right)^2 \cdot \underbrace{10^7 \cdot \frac{\pi}{2}}_{NEB}$$

$$V_{Rms}^2 = 10^{-23} \cdot \frac{\pi}{2}$$

$$V_{Rms} = \sqrt{10^{-23} \cdot \frac{\pi}{2}}$$

4)



$$V^2_{ONoise}(f), \frac{V^2}{Hz} = 4KTR \cdot \left| \frac{1/j\omega C}{1/j\omega C + R} \right|^2$$

$$= 4KTR \cdot \frac{1}{1+\left(\frac{f}{f_{3dB}}\right)^2}$$

$$V^2_{Rms} = \int_0^\infty V^2_{ONoise}(f) \cdot df \qquad f_{3dB} = \frac{1}{2\pi RC}$$

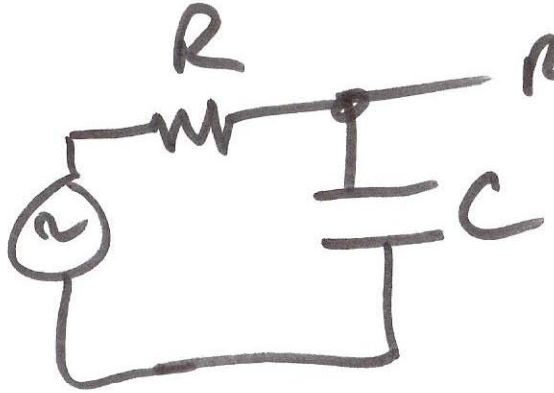
5)

$$V_{i,rms}^2 = 4kTR \cdot \frac{\pi}{2} \cdot f_{3dB}$$

$$= 4kT \cdot R \cdot \frac{\pi}{2} \cdot \frac{1}{2\pi RC} = \frac{kT}{C}$$

mean-squared value $= \frac{kT}{C}$

$$rms = \sqrt{\frac{kT}{C}}$$



$rms = \sqrt{\frac{kT}{C}}$

Kay-Tee-over-Cee

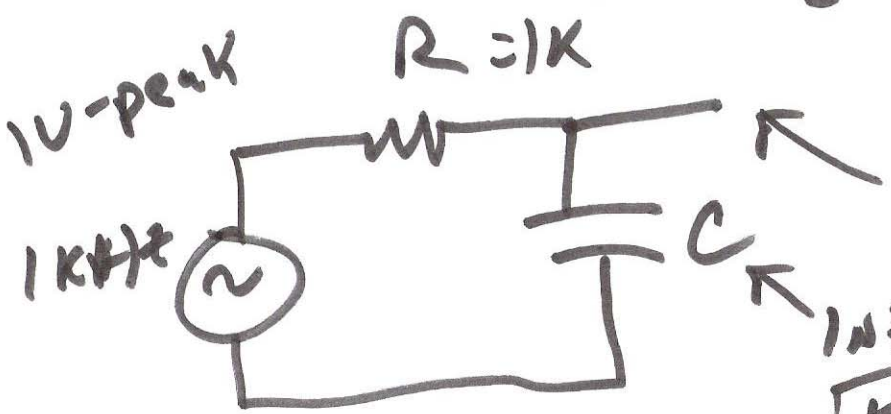
6)

$$SNR = \frac{\text{desired signal power, } P_s}{\text{undesired NOISE, } P_{NOISE}}$$

$$= 10 \cdot \log \frac{P_s}{P_{NOISE}}, \text{ dB}$$

$$SNR = 20 \cdot \log \frac{V_{s,rms}}{V_{NOISE}}$$

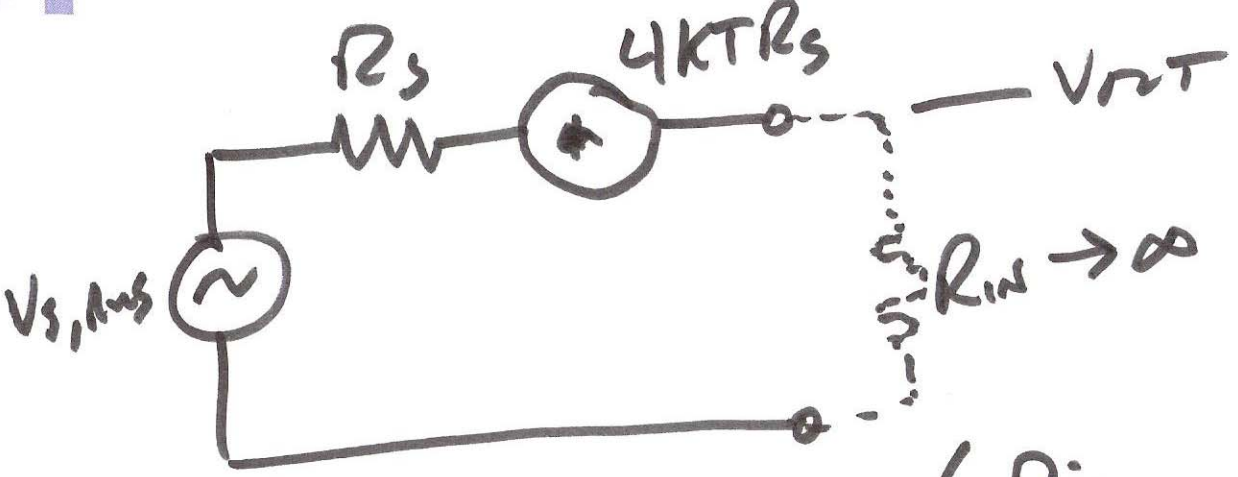
$$= 10 \log \frac{V_{s\,rms}^2 / R}{V_{NOISE}^2 / R}$$



$$SNR = 20 \log \frac{1/\sqrt{2}}{20\,\mu V}$$

$$\sqrt{\frac{KT}{C}} = 20\,\mu V \text{ rms}$$

7)

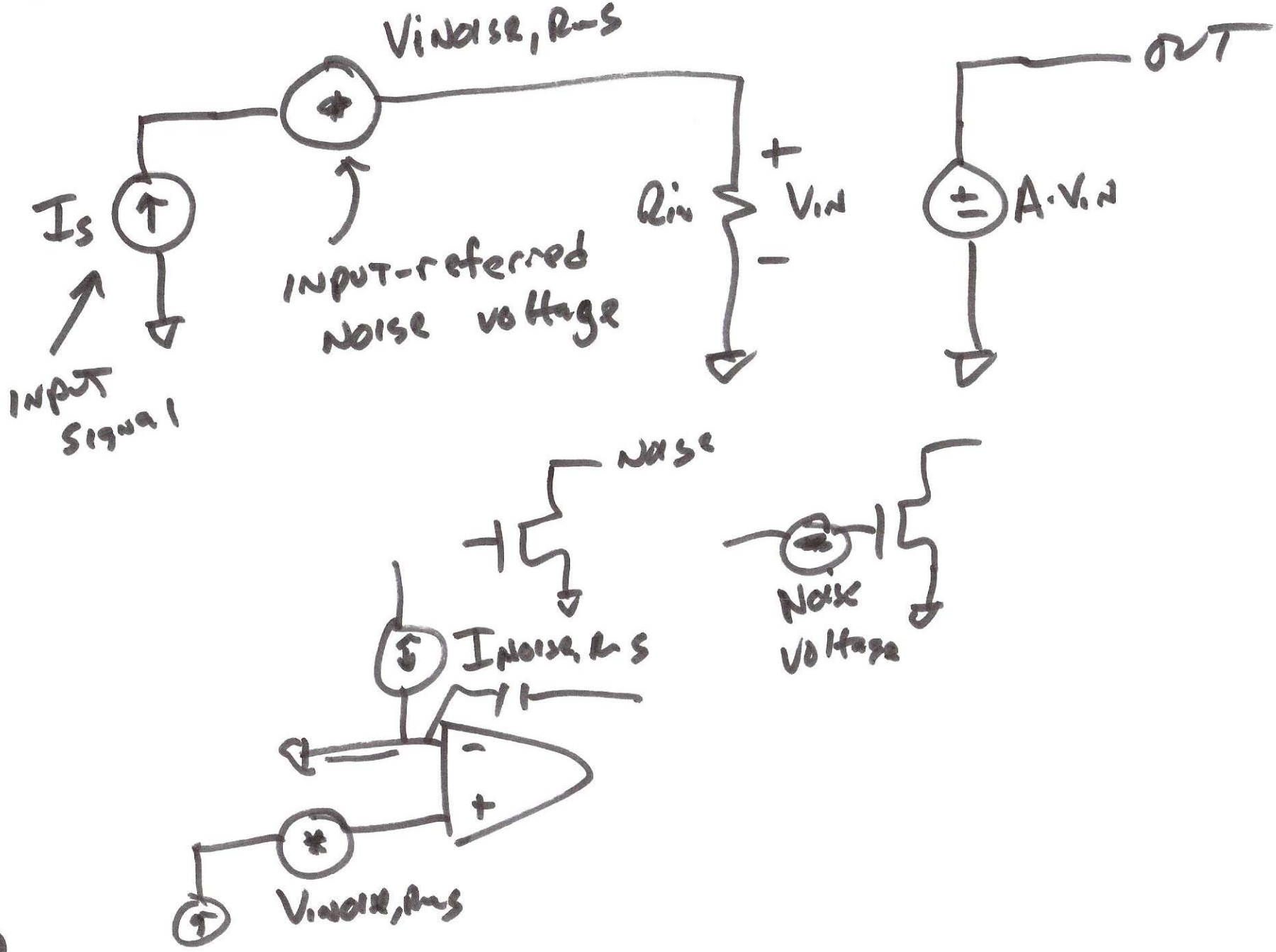


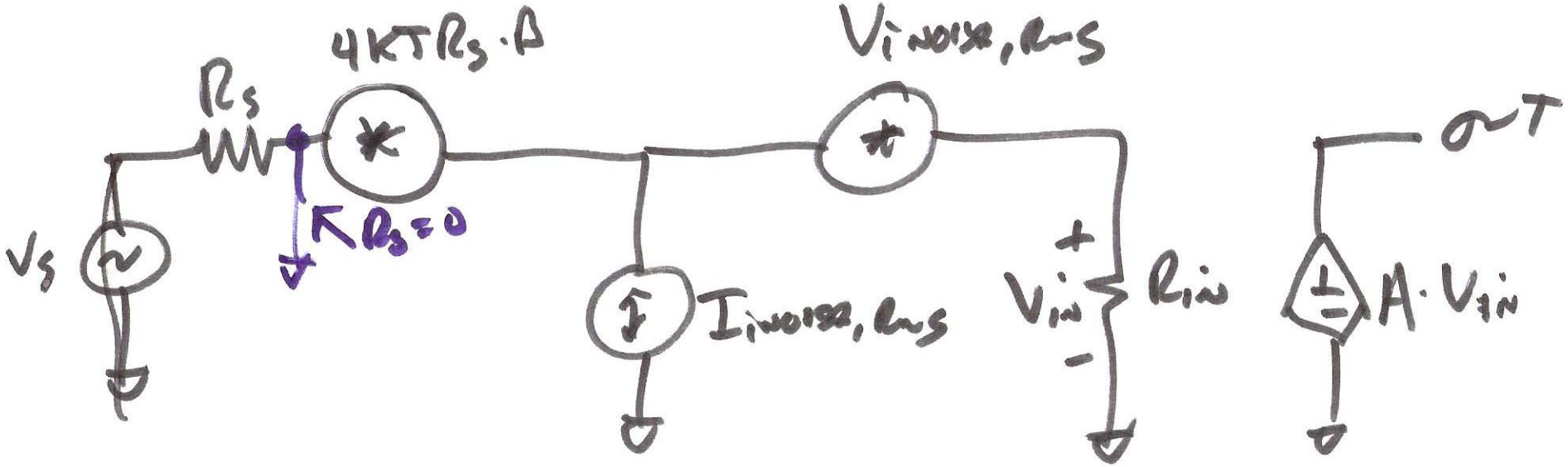
$$V_{OUT,rms}^2 = \left(\frac{R_{in}}{R_{in}+R_S}\right)^2 \cdot V_{S,Rms}^2$$

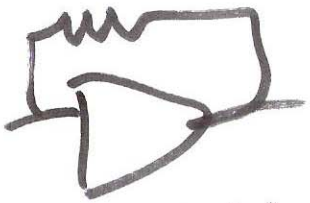
$$V_{o,noise}^2 = \left(\frac{R_{in}}{R_{in}+R_S}\right)^2 \cdot 4KTR_S \cdot B$$

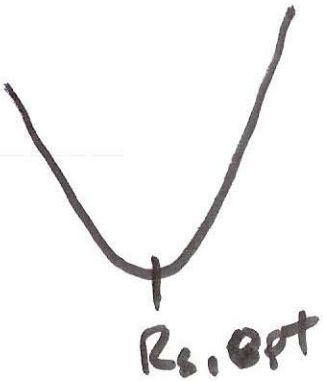
$$SNR = 10 \log \frac{V_{S,rms}^2}{4KTR_S \cdot B}$$

8)


VINOISE, RMS
OUT
IS
INPUT-referred
NOISE voltage
RIN
+
VIN
−
A·VIN
INPUT
Signal
NOISE
INOISE, RMS
NOISE
VOLTAGE
VINOISE, RMS







$$V^2_{Vo\,noise,rms} = 4KTR_s \cdot B \left(\frac{R_{in}}{R_{in}+R_s}\right)^2 \cdot A^2 +$$

$$\frac{\delta V^2_{Vo\,noise,rms}}{\delta R_s} = 0$$

$$V^2_{i\,noise,rms} \cdot \left(\frac{R_{in}}{R_{in}+R_s}\right)^2 \cdot A^2 +$$

$$I^2_{i\,noise} \cdot \left(\frac{R_s}{R_{in}+R_s}\right)^2 \cdot A^2$$

10)

$$\frac{\delta}{\delta R_S}\left[(R_{in}+R_S)^{-2}\cdot A^2\cdot\left[4KT R_S\cdot B R_n^2 + V_{noise,rms}^2\cdot R_n^2 + I_{noise,rms}^2\cdot R_S^2\right]\right]=0$$

~~$4KT B R_n^2$~~

$$\frac{\delta (R_{in}+R_S)^{-2}\cdot X}{\delta R_S} = -2(R_{in}+R_S)^{-3}\cdot\frac{\delta R_S}{\delta R_S}\cdot X + (R_{in}+R_S)^{-2}\cdot\frac{\delta X}{\delta R_S}$$

$$-2(R_{in}+R_S)^{-1}\cdot[\quad]+4KT B R_n^2 + 2R_S\cdot I_{noise,rms}^2$$

11)

Noise Figure, NF

$$NF = 10 \log \frac{SNR_{in}}{SNR_{OUT}}$$

$R_s = 0$

$SNR_{in} \to \infty$

F ← Noise Factor