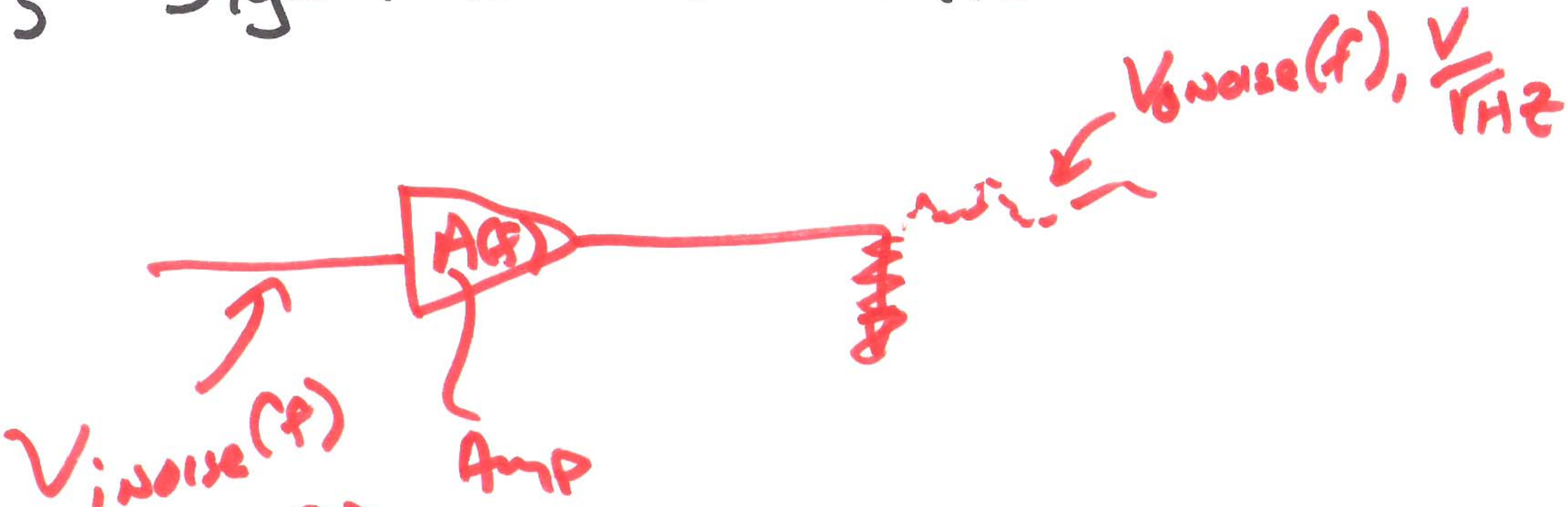
8.2.3 Signal-to-Noise Ratio



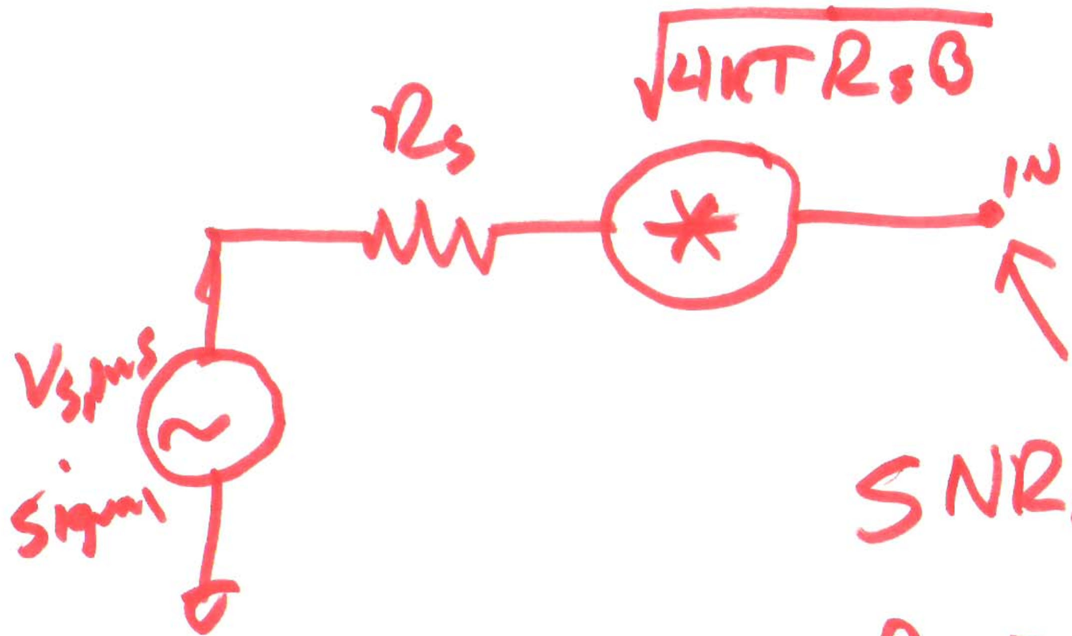
$$V_{inoise}(f) = \frac{V_{onoise}(f)}{A(f)}$$

$$SNR = \frac{\text{desired signal power}, P_{signal}}{\text{undesired signal (noise)}, P_{noise}}$$

$$= 10 \log \frac{P_{signal}}{P_{noise}} \rightarrow P_{signal} = V_{s,rms}^2 / 1\Omega$$

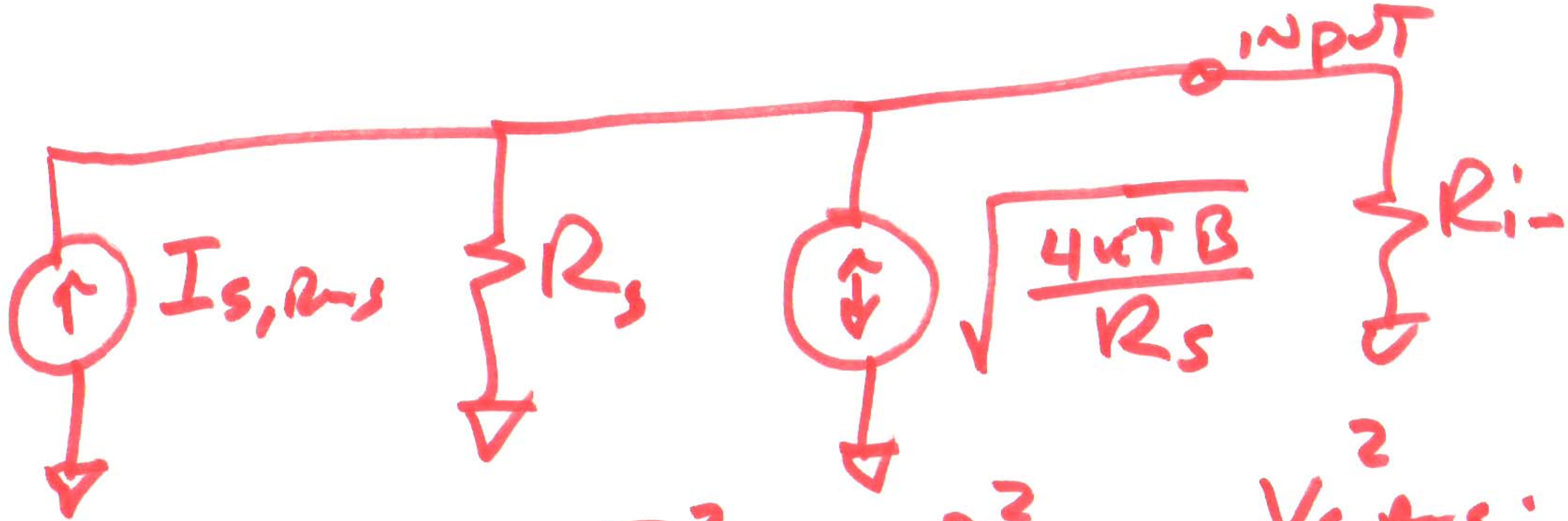
$$SNR = 10 \log \frac{P_s}{P_{noise}} = 20 \log \frac{\sqrt{P_s}}{\sqrt{P_{noise}}}$$

$$= 20 \log \frac{V_{s,rms}}{V_{noise,rms}}$$

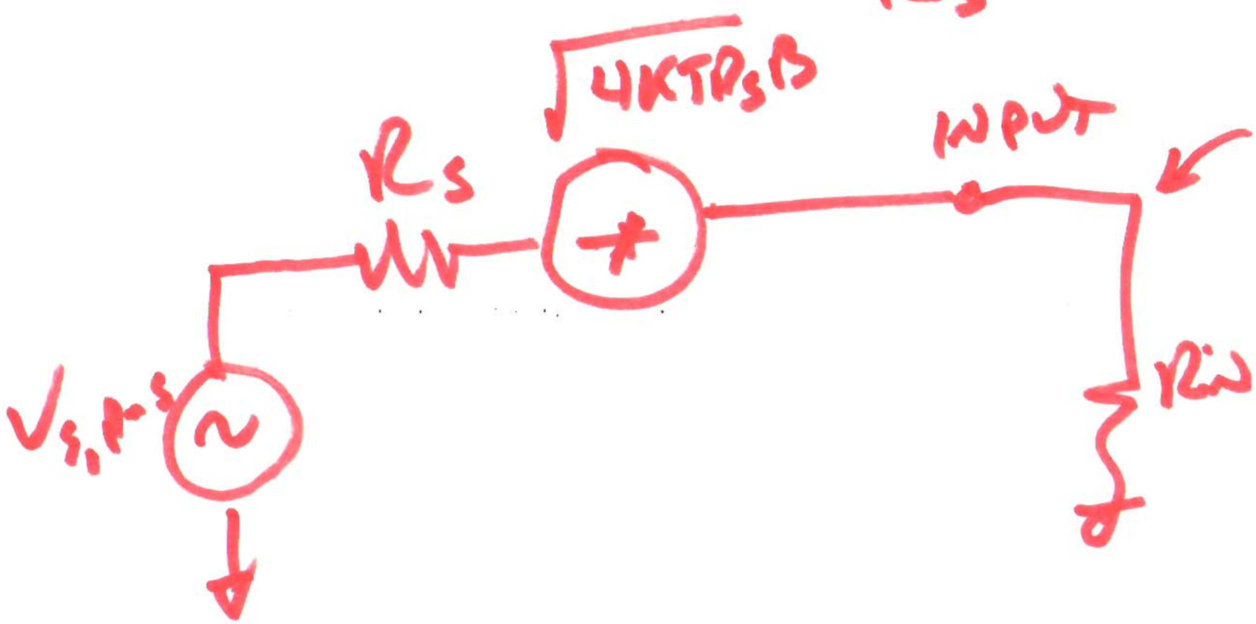


$$SNR_{in} = \frac{V_{s,rms}^2}{4kTR_s B}$$

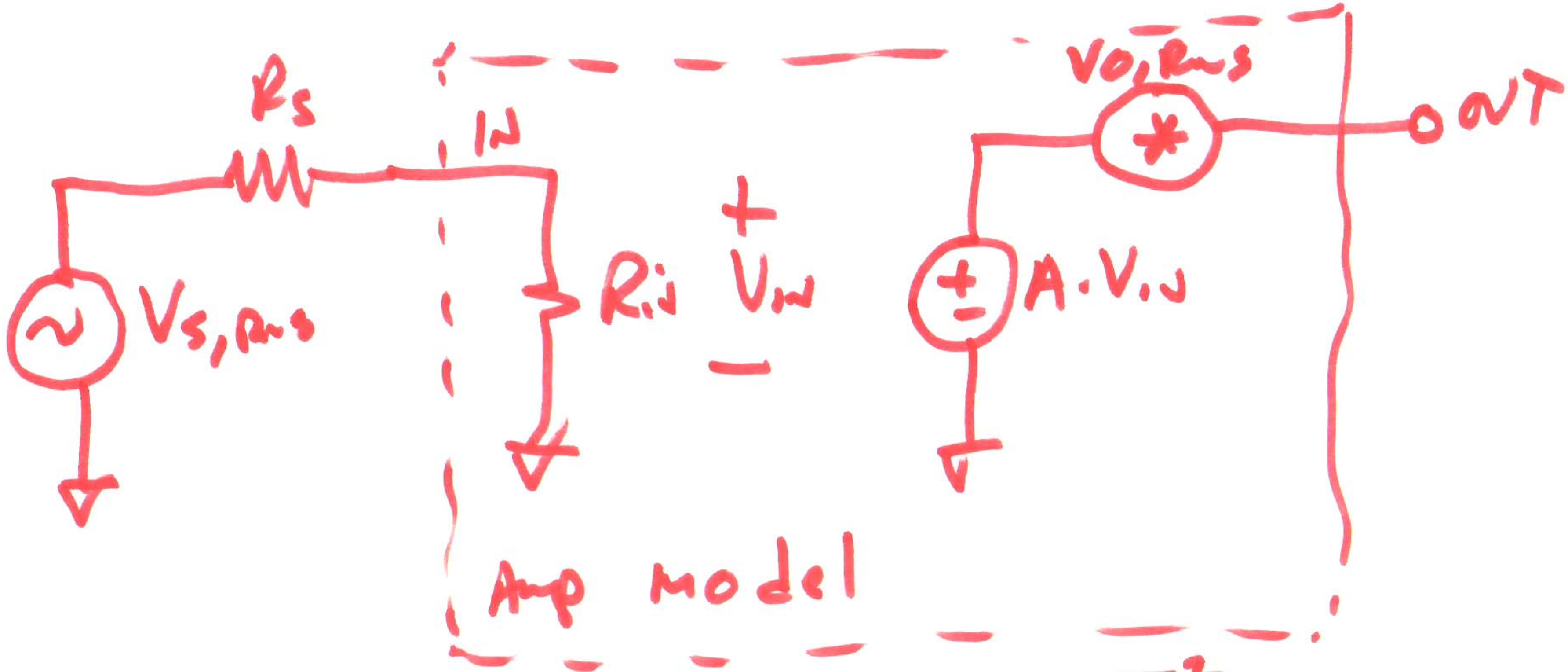
$R_s \to 0$, $SNR \to \infty$ Academic (in SPICE)



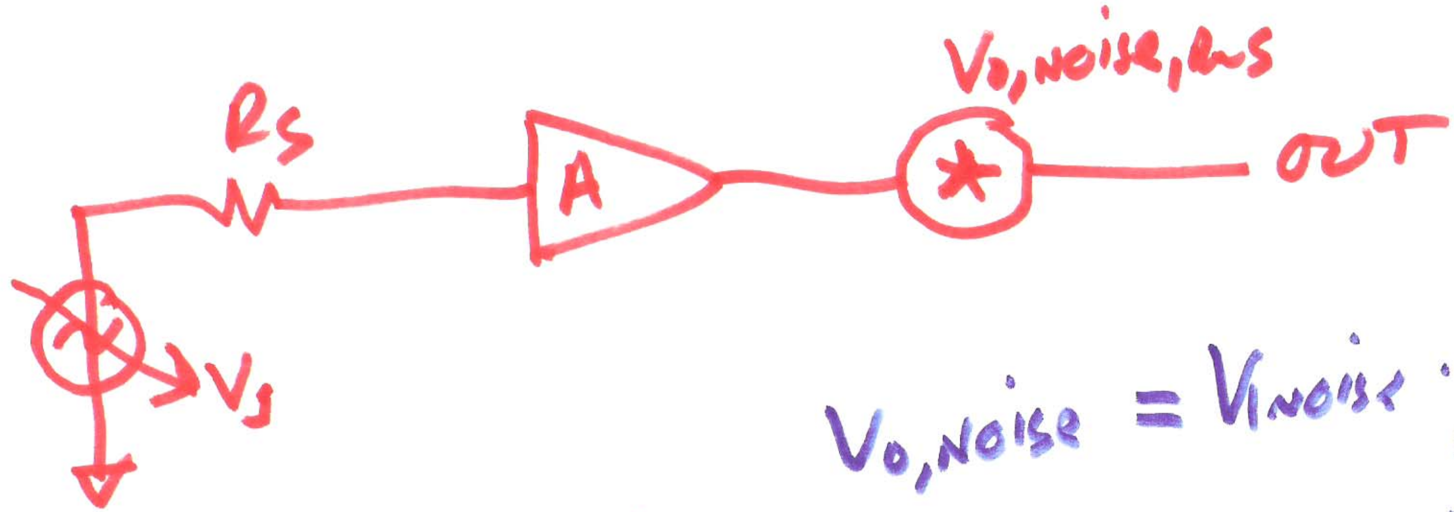
$$SNR_{in} = \frac{I_{s,rms}^2 \cdot R_s^2}{\frac{4kTB}{R_s} \cdot R_s^2} = \frac{V_{s,rms}^2}{4kTR_s \cdot B}$$



$$SNR = \frac{V_{s,rms}^2 \cdot \left[\frac{R_{in}^2}{(R_{in}+R_s)^2}\right]}{4kTR_sB \cdot \left[\frac{R_{in}^2}{(R_{in}+R_s)^2}\right]}$$



$$SNR_{OUT} = \frac{V_{S,RMS}^2 \cdot \left[\frac{R_{in}}{R_S + R_{in}}\right]^2 A^2}{V_{O,RMS}^2}$$

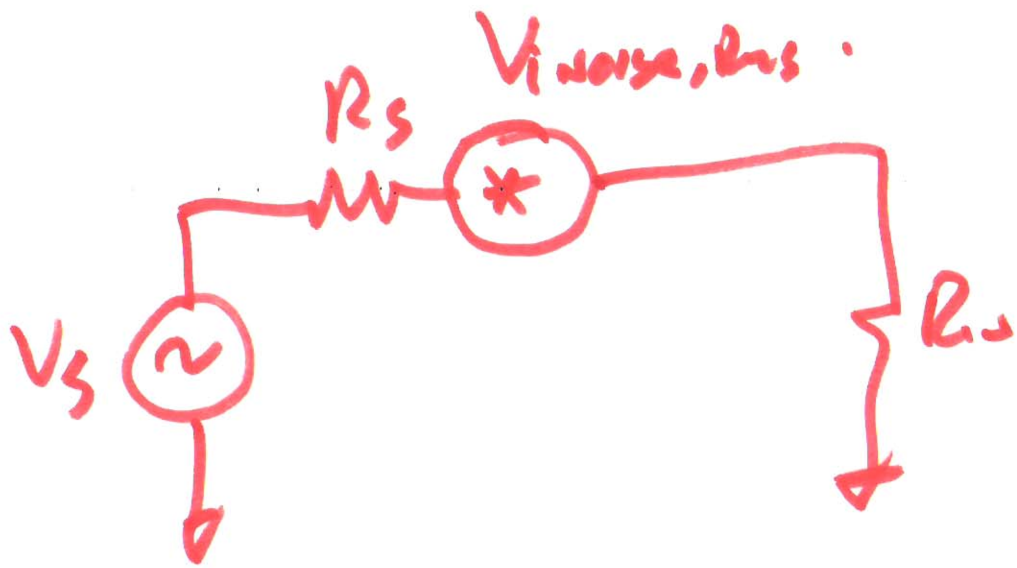


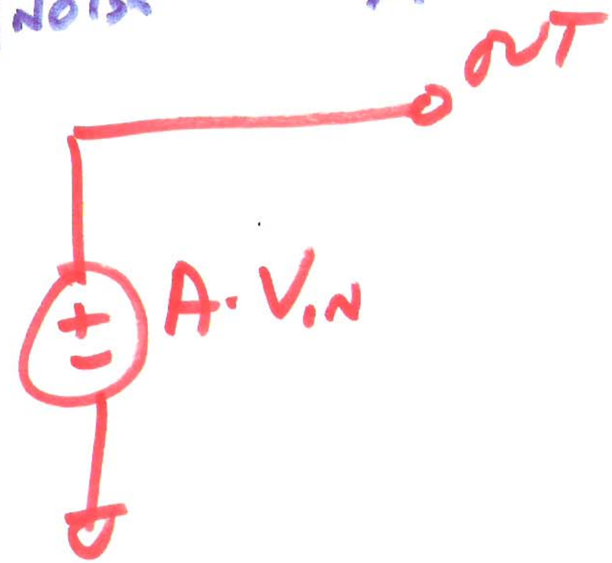
$$V_{o,noise} = V_{i,noise} \cdot \frac{R_{in}}{R_{in}+R_s} \cdot A$$

$R_{in} = \infty$

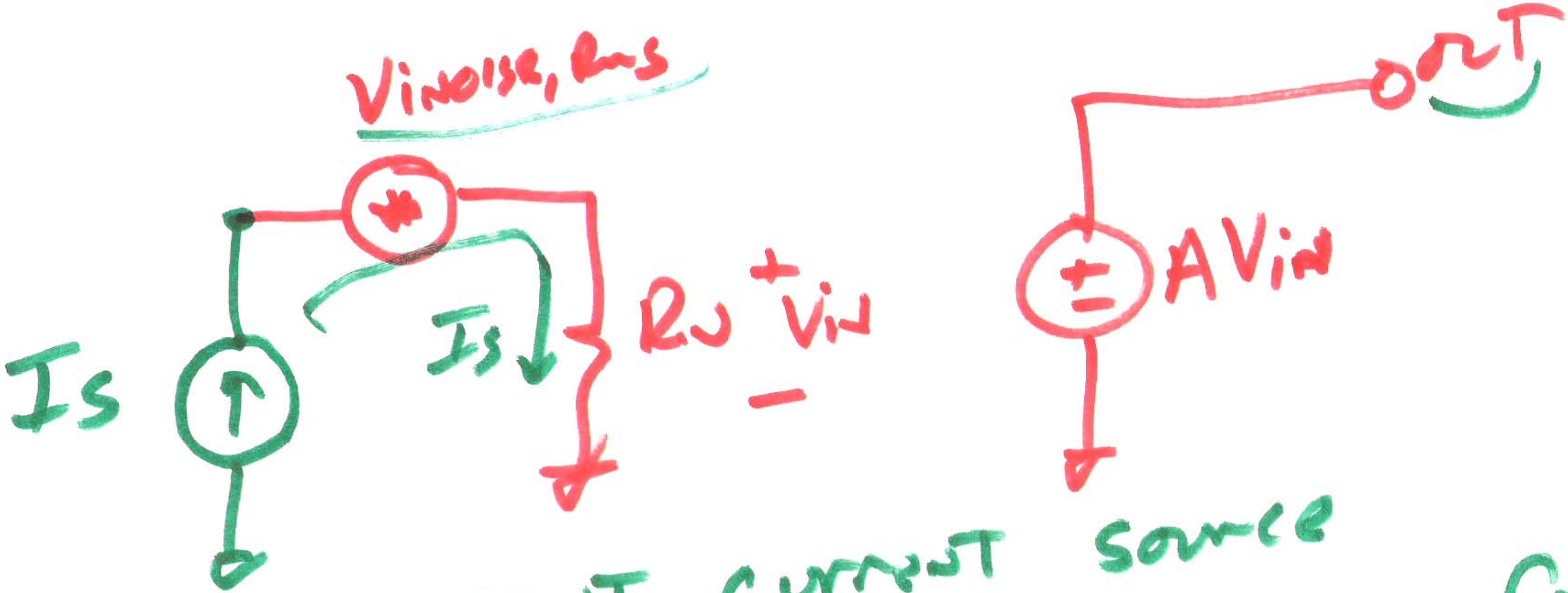
$$V_{i,noise} = \frac{V_{o,noise}}{A}$$

INPUT-referred





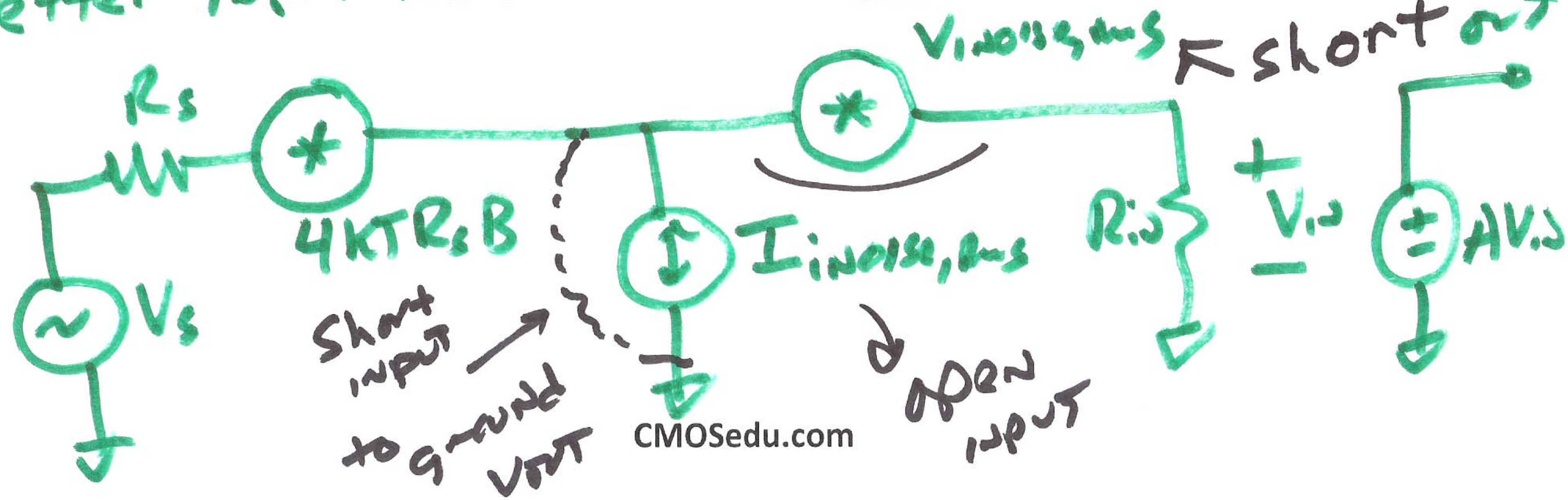
Example



Input current source

Output is noise free!

Better input noise model



b)

$$V^2_{o,NOISE} = 4KTR_S \cdot B \cdot \left[\frac{R_{IN}}{R_{IN}+R_S}\right]^2 A^2 +$$

$$I^2_{i\,NOISE,\,RMS} \cdot \left[\frac{R_S \cdot R_{IN}}{R_S + R_{IN}}\right]^2 \cdot A^2 +$$

$$V^2_{i\,NOISE,\,RMS} \cdot \left[\frac{R_{IN}}{R_{IN}+R_S}\right]^2 A^2$$

NOISE Figure

F = NOISE Factor

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

$NF = 3dB$ $\quad SNR_{IN} = 70\,dB$

$SNR_{OUT} = 67\,dB$

Optimum R_S

$$NF = 10 \log \frac{V_{o,noise,rms}}{4kTR_S \cdot B \left[\frac{R_{in}}{R_{in}+R_S}\right]^2 \cdot A^2}$$

$NF = 10 \log F$ ← Noise Factor

$R_S \rightarrow$ Big, $NF \rightarrow$ Big

$R_S \rightarrow 0$, $NF \rightarrow$ Big

So what is $R_{S,opt}$ ← optimum source resistance

to minimize NF?

$$F = \frac{4kTR_sB + I_{inoise,rms}^2 R_s^2 + V_{inoise,rms}^2}{4kTR_sB}$$

$$\frac{\delta F}{\delta R_s} = 0 \text{ , solve } R_{s,opt}$$

$$\frac{\delta F}{\delta R_s} = \frac{\delta}{\delta R_s}\left(1 + \frac{I_{inoise,rms}^2 \cdot R_s}{4kTB} + \frac{V_{inoise,rms}^2 R_s^{-1}}{4kTB}\right) = 0$$

$$0 = \frac{\delta}{\delta R_s}\left(I_{inoise,rms}^2 \cdot R_{s,opt} + V_{inoise,rms}^2 R_{s,opt}^{-1}\right)$$

$$I_{inoise,RMS}^2 + 2 I_{inoise,RMS} \cdot R_{s,opt} \cdot \frac{\delta I_{inoise}}{\delta R_s} \rightarrow 0$$

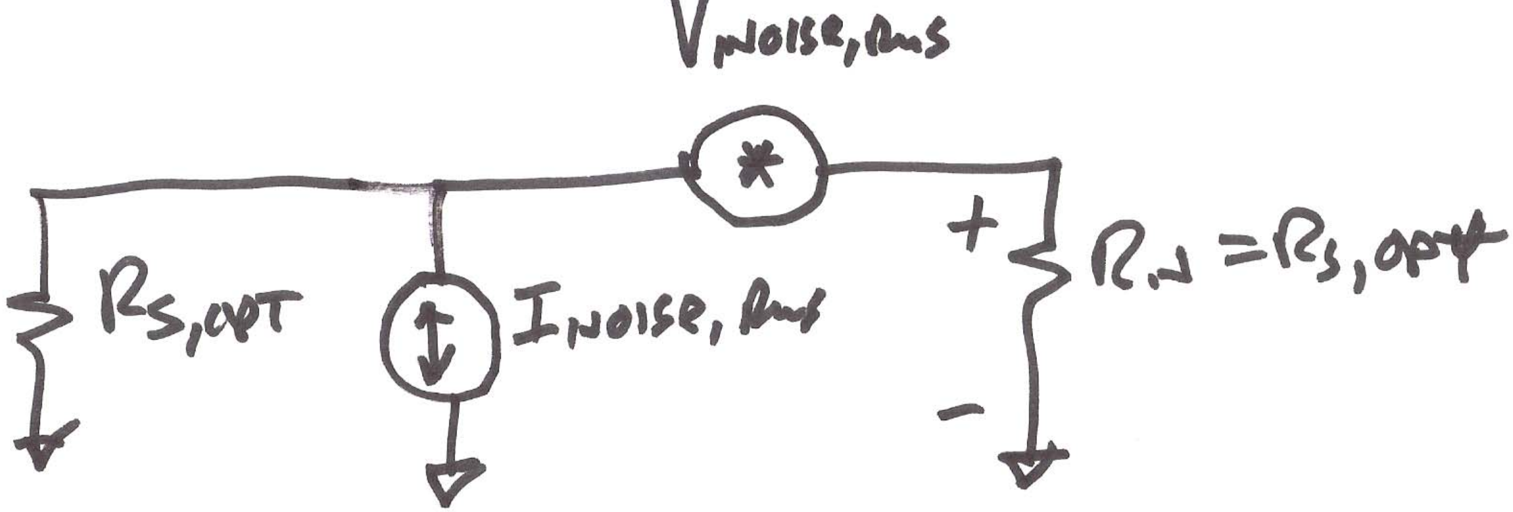
$$- V_{inoise,RMS}^2 R_{s,opt}^{-2} + R_s^{-1} 2 V_{inoise,RMS} \cdot \frac{\delta V_{inoise}}{\delta R_s} \rightarrow 0$$

$$= 0$$

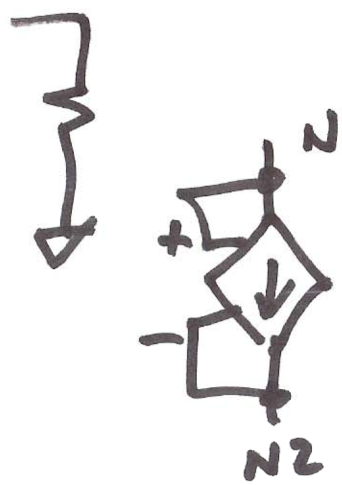
$$I_{inoise,RMS}^2 = \frac{V_{inoise,RMS}^2}{R_{s,opt}^2}$$

$$\boxed{R_{s,opt} = \frac{V_{inoise,RMS}}{I_{inoise,RMS}}}$$

$$F_{opt} = 1 + \frac{(V_{inoise,rms} \cdot I_{inoise})/2}{KTB}$$



$$\frac{V_{noise} \cdot I_{inoise}}{2}$$



$10^{-3} = 1K$

noiseless