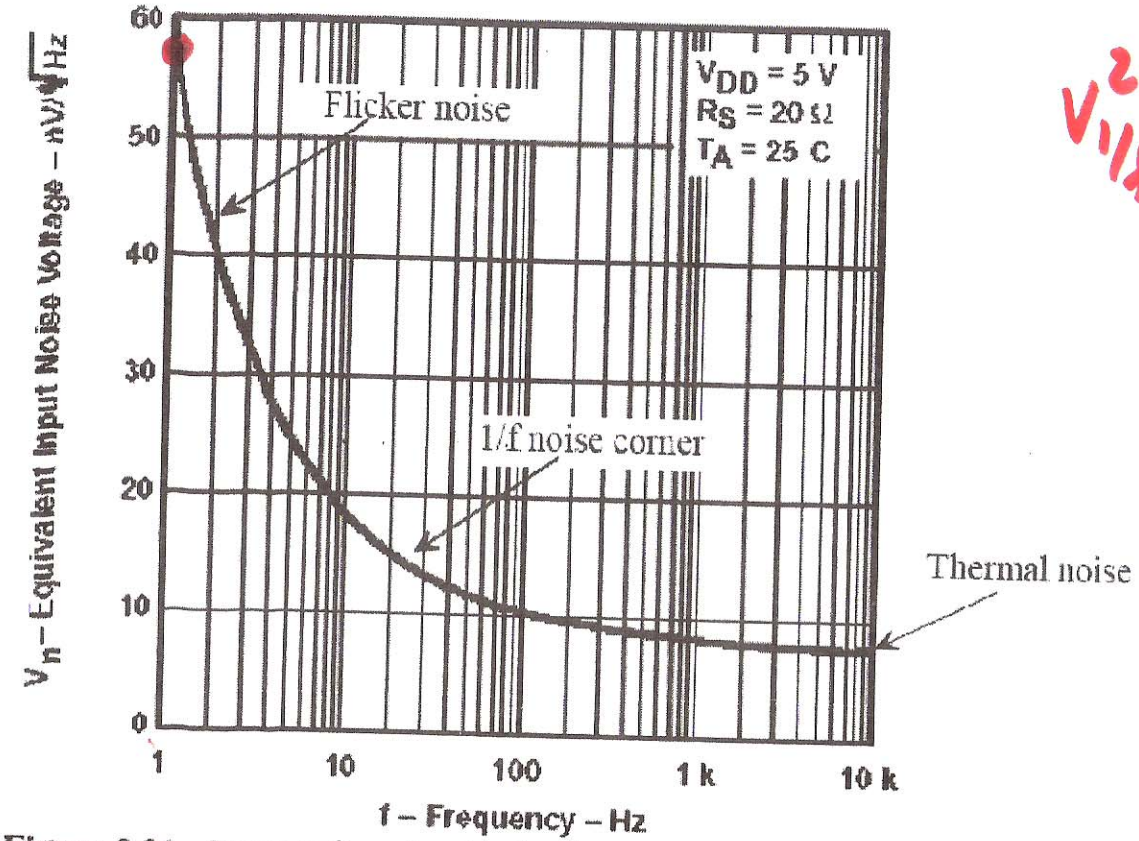


Figure 8.31 Input-referred noise for the TLC220x low-noise op-amp.

$$V_{1/f}^2(f) = \frac{F_{NN}}{f}, \frac{V^2}{Hz}$$

$$\frac{F_{NN}}{1} = \frac{(56nV)^2}{1}$$

$$F_{NN} = 3.14 \times 10^{-15} V^2$$

$$V_{noise,rms}^2 = \int_{f_L}^{f_H} \frac{F_{NN}}{f} \cdot df = F_{NN} \cdot \ln \frac{f_H}{f_L}$$

$f_H = 100\,GHz$

$f_L = 10^{-10}\,Hz$

once/320 years

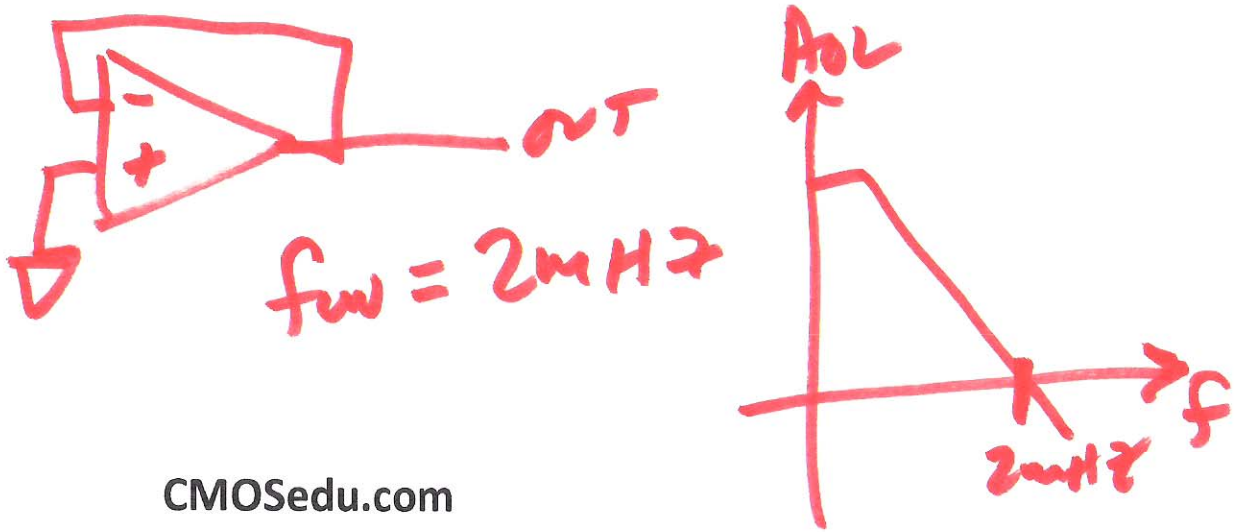
1)

$$\ln \frac{100\,GHz}{10^{-10}\,Hz} \approx 49$$

$$V_{NNSe,rms} = 7 \cdot \sqrt{FNW}$$

$$\frac{KT}{C} \qquad NEB = \frac{\pi}{2} f_{3dB}$$

Example 8.15



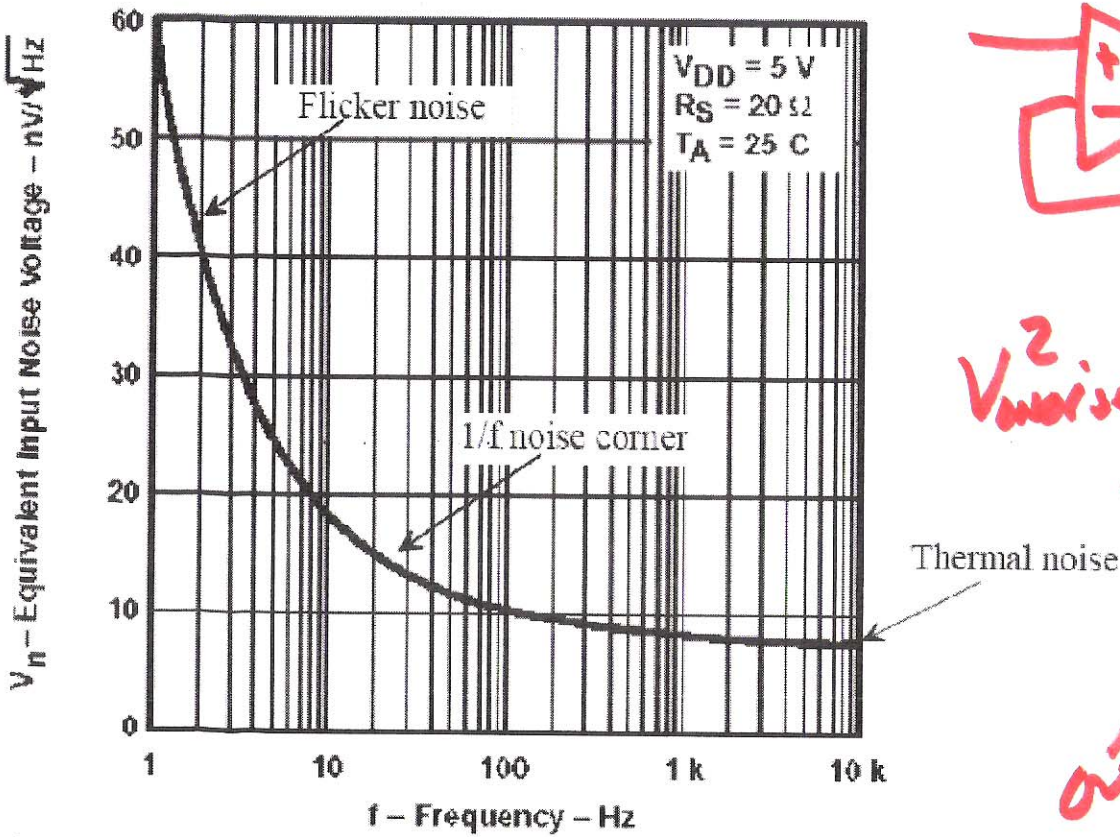


Figure 8.31 Input-referred noise for the TLC220x low-noise op-amp.

TLC220

V_{Onoise}

$$V^2_{Onoise}(f) = \frac{3.14\times10^{-15}\ V^2}{f}\frac{}{Hz} + 64\times10^{-18}\frac{V^2}{Hz}$$

OUTPUT NOISE PSD

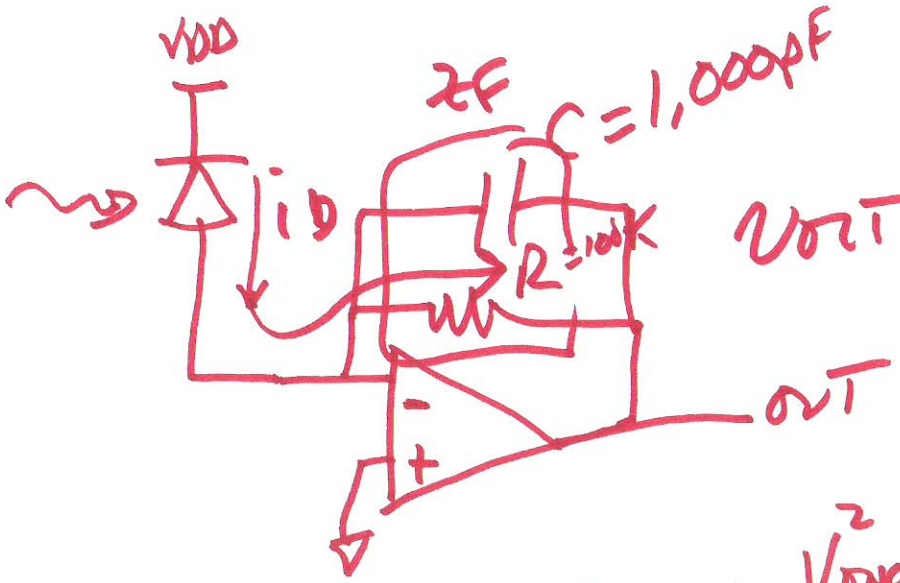
$$V^2_{Onoise,rms} = 49\cdot 3.14\times10^{-15} + 64\times10^{-18}\frac{V^2}{Hz}\cdot 2MHz\cdot\frac{\pi}{2}$$

$$Gain\cdot BW = f_{3dB}$$

$$V_{Onoise,rms} = 154\,V = V_{Onoise,R.S}$$

Thermal

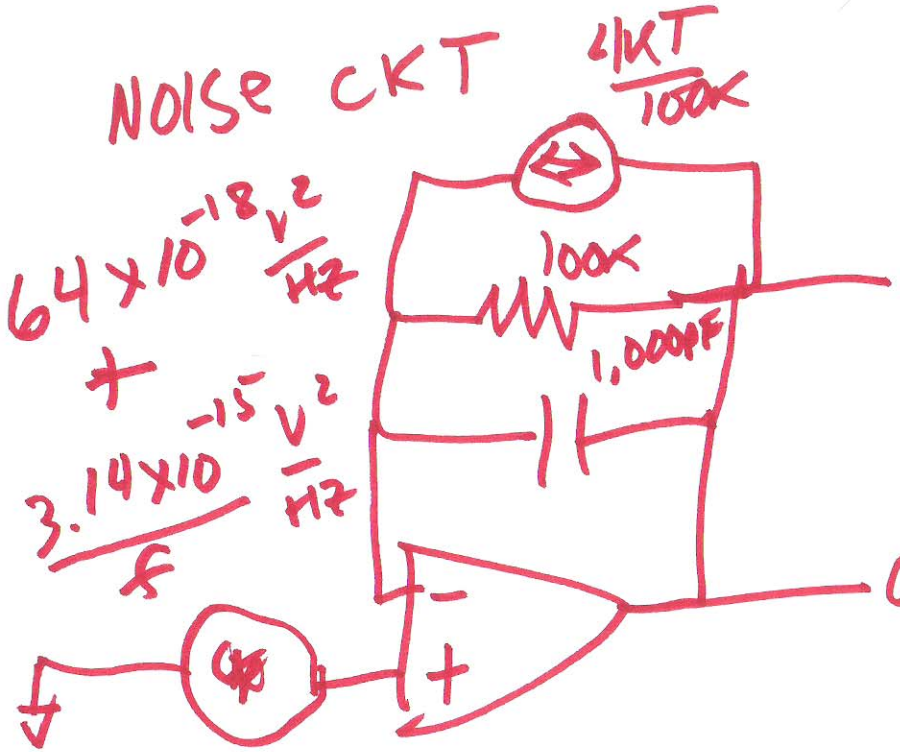
3)



$$V_{OUT} = -i_d \cdot Z_F$$

$$V^2_{ONoise,(f)} = \frac{3.14\times10^{-15}\ V^2}{f,\ Hz} + 64\times10^{-18}\ \frac{V^2}{Hz}$$

NOISE CKT



$$+\frac{4KT}{100K}\cdot\frac{100K\cdot\frac{1}{j\omega 1000pF}}{100K+\frac{1}{j\omega 1000pF}}$$

$$|A(f)| = \left|\frac{V_{OUT}}{i_d}\right| = \frac{R_F}{1+j\omega R_F C}$$

$$V_{o,noise,rms}^2 = 49 \cdot 3.14 \times 10^{-15} + 64 \times 10^{-18} \cdot \frac{\pi}{2} \cdot 2\text{MHz} + \frac{KT}{CL} =$$

$$\boxed{V_{o,noise,rms} \approx 14.3\,\mu V}$$

$$\rightarrow 154 \times 10^{-15} + 200 \times 10^{-12} + 4 \times 10^{-12}$$

Noise free → Op-Amp

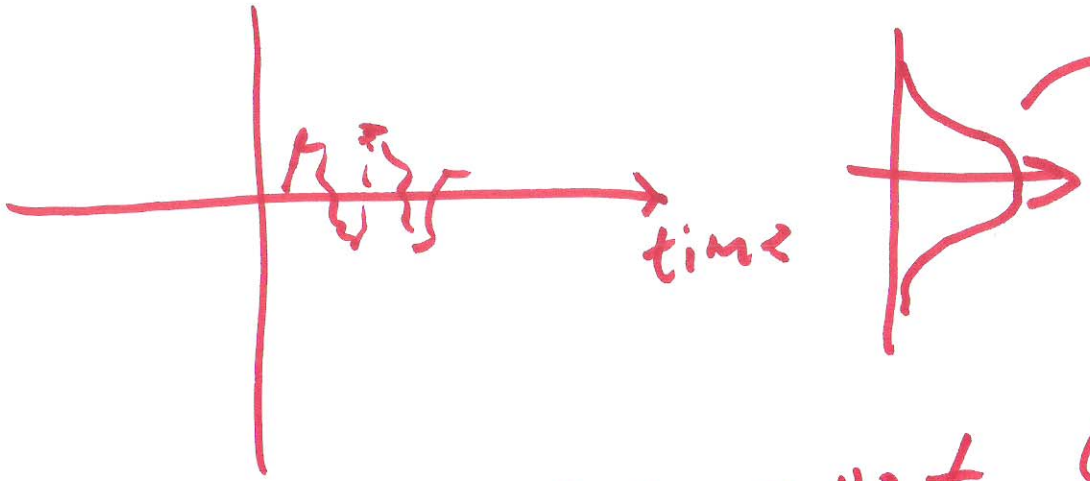
$$V_{o,noise,rms} = \sqrt{4 \times 10^{-12}}$$

$$= 2\,\mu V$$

5)

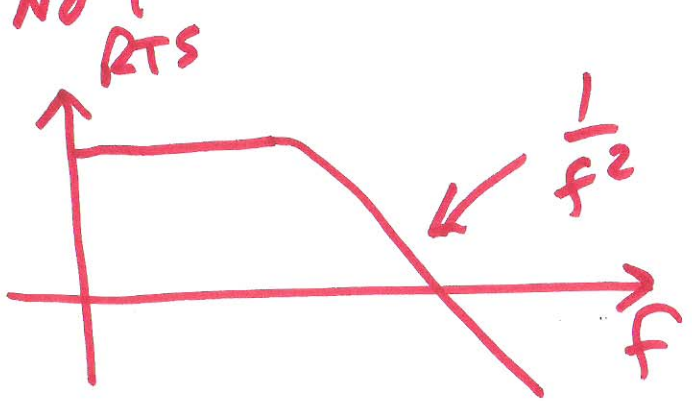
Random Telegraph Signal Noise (RTS)

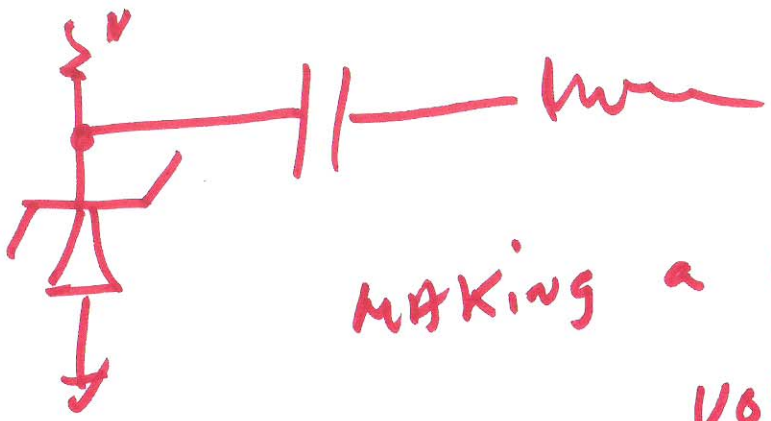
Popcorn, Burst Noise



Gaussian, Flicker, shot, thermal noise

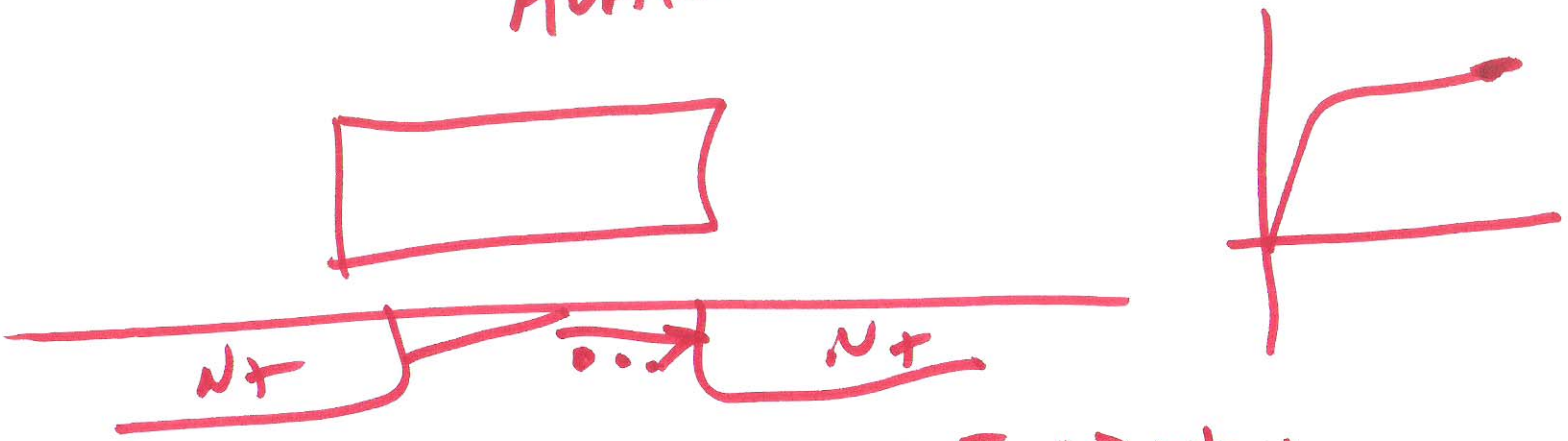
RTS → Not Gaussian





Making a Low-noise
voltage reference
using Zener

Avalanche



Impact Ionization

Higher V_{DS}

24:52