

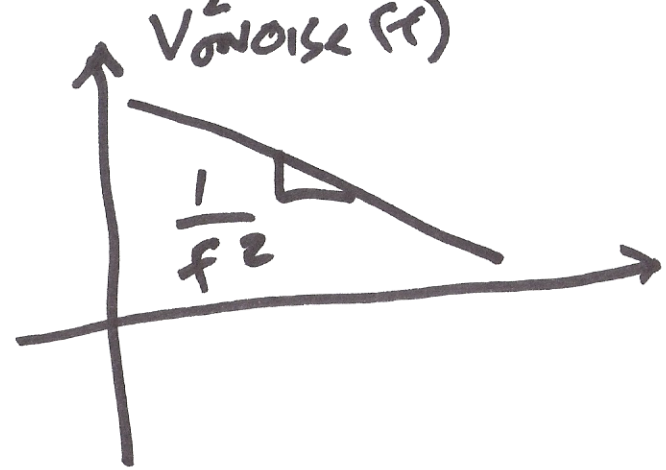
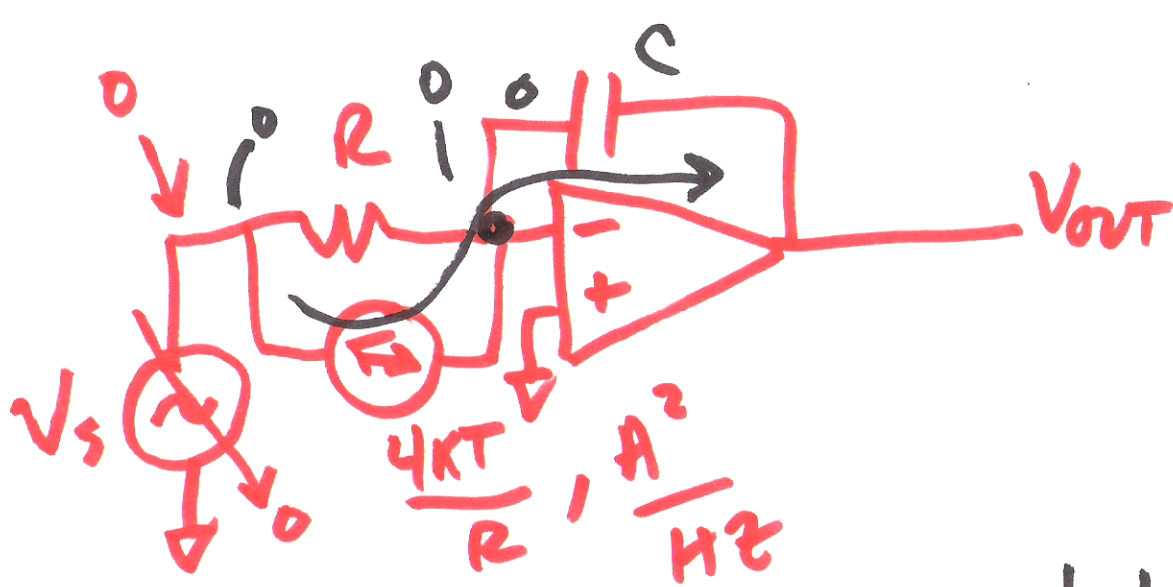
White noise
 $V_{\text{noise}}(f)$



Flicker (pink noise)

$1/f$ Spectral shape

Flicker noise = $1/f$ noise



$$V_{noise}^2(f) = \left| \frac{1}{j\omega C} \right|^2 \cdot \frac{4kT}{R}$$

$$= \frac{4kT}{(2\pi f)^2 R} \cdot \frac{1}{f^2}$$

$\frac{1}{f^2} \rightarrow$ Red noise

$$\begin{aligned}
 V_{\text{rms}}^2 &= \int_{f_L}^{f_H} \frac{4KT}{(2\pi C)^2 R} \cdot \frac{1}{f^2} \cdot df \\
 &= \frac{4KT}{(2\pi C)^2 R} \int_{f_L}^{f_H} f^{-2} \cdot df \\
 &= \frac{4KT}{(2\pi C)^2 \cdot R} (-1) \cdot \frac{1}{f} \Big|_{f_L}^{f_H}
 \end{aligned}$$

3)

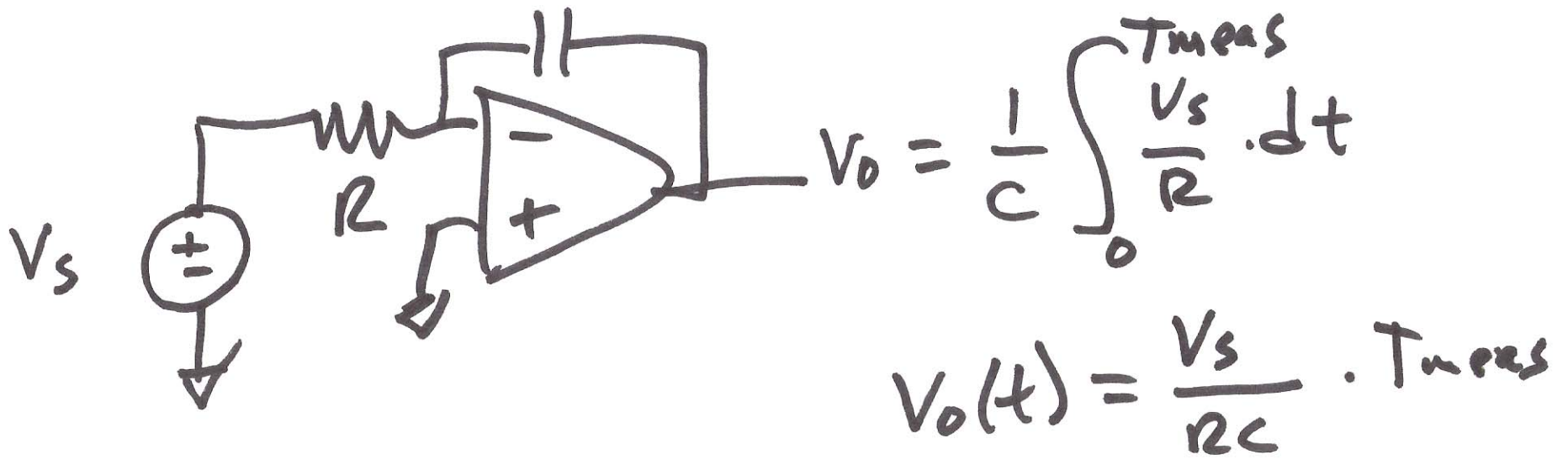
$$V_{O, rms}^2 = \frac{4kT}{(2\pi C)^2 R} \cdot \left(\frac{1}{f_L} - \frac{1}{f_H} \right)$$

$$f_H \rightarrow \infty$$

$$V_{O, rms}^2 = \frac{4kT}{(2\pi C)^2 R} \cdot \frac{1}{f_L} = \frac{4kT}{(2\pi C)^2 R} \cdot T_{meas}$$

$$T_{meas} \approx \frac{1}{f_L}$$

$$V_{O, rms} = \frac{\sqrt{4kT}}{2\pi C \cdot \sqrt{R}} \cdot \sqrt{T_{meas}}$$



$$SNR = \frac{\frac{V_s}{RC} \cdot T_{meas}}{\sqrt{\frac{4kT}{R} \cdot \frac{1}{2\pi f} \sqrt{T_{meas}}}}$$

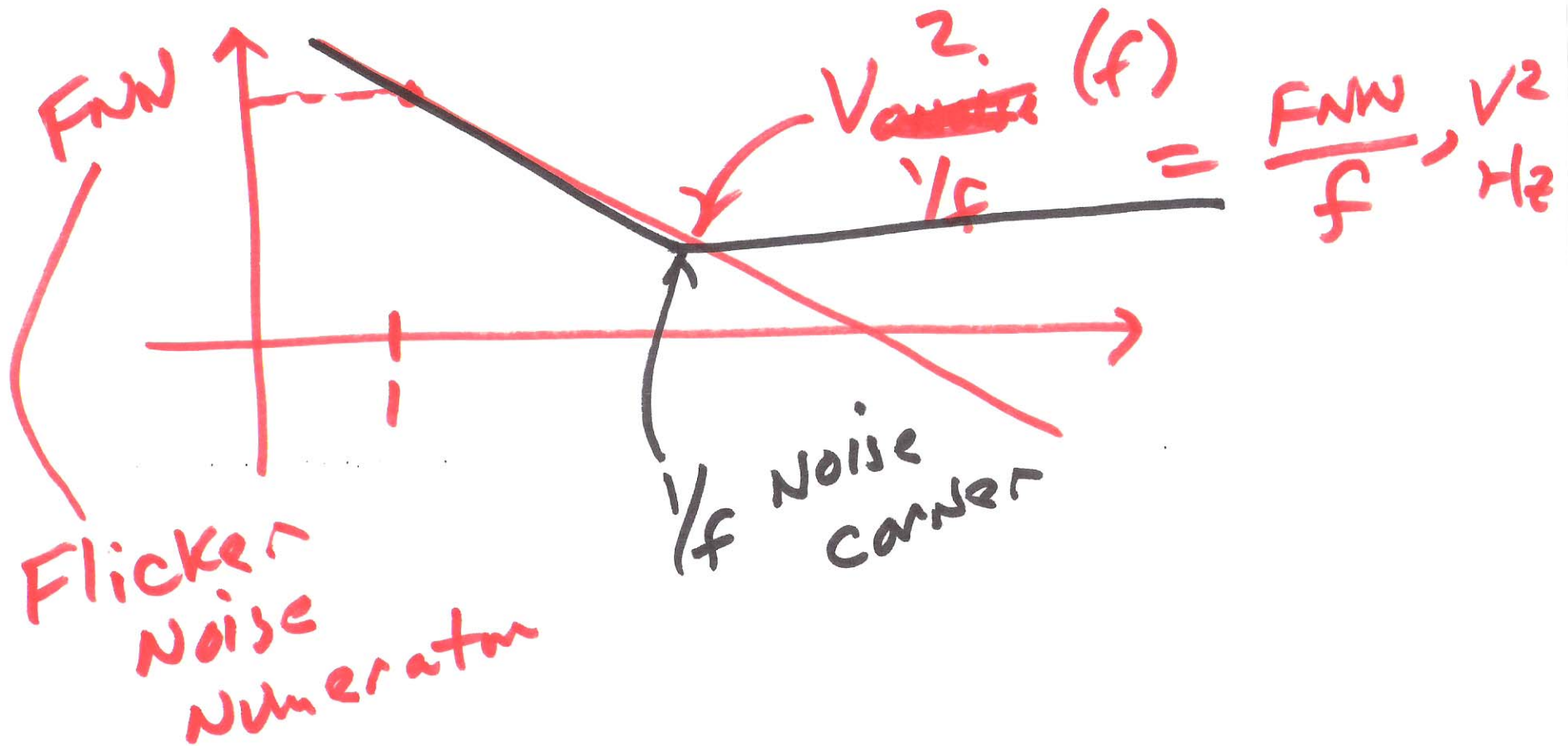
Key point (practically important)

SNR \uparrow as $\sqrt{T_{meas}}$

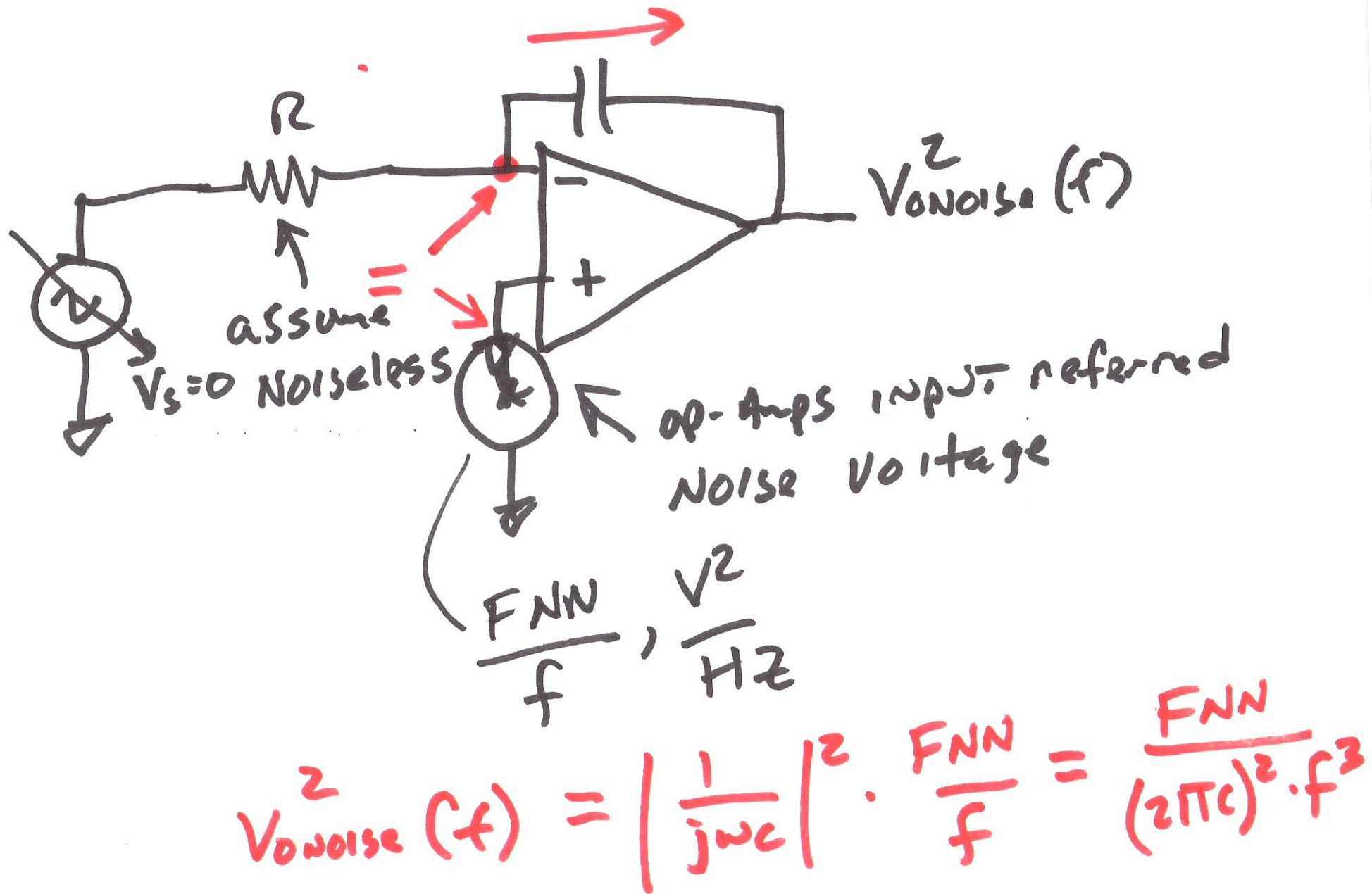
When integrating thermal noise

5)

Flicker noise



6)



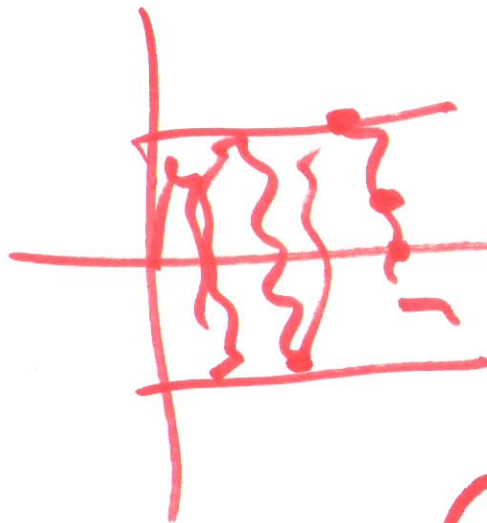
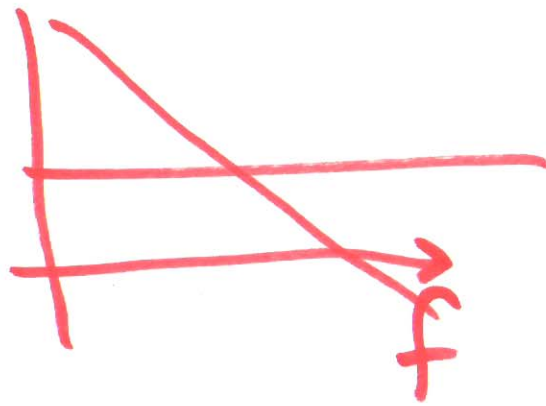
$$\begin{aligned}
 V_{0, \text{rms}}^2 &= \int_{f_L}^{f_H} \frac{F_{NN}}{(2\pi C)^2} \cdot f^{-3} df \\
 &= \frac{F_{NN}}{(2\pi C)^2} \int_{f_L}^{f_H} f^{-3} df \\
 &= \frac{F_{NN}}{(2\pi C)^2} (-2) \cdot \frac{1}{f^2} \Big|_{f_L}^{f_H} \\
 &= \frac{2F_{NN}}{(2\pi C)^2} \cdot \frac{1}{T_{\text{meas}}^2}
 \end{aligned}$$

$$V_{o, rms} = \frac{\sqrt{F_{NN}}}{\sqrt{2} \cdot TTC} \cdot T_{meas}$$

$$SNR = \frac{\frac{V_s}{RC} \cdot \cancel{T_{meas}}}{\frac{\sqrt{F_{NN}}}{\sqrt{2} \cdot TTC} \cdot \cancel{T_{meas}}}$$

Key point is NO INCREASE
IN SNR WITH T_{meas} !

Thermal Shot Flicker



PDF
 σ = standard deviation
 $\sigma = \text{RMS of NOISE}$
 $\sigma^2 = \text{MS of NOISE}$

$V_{0, \text{rms}} = 1 \mu\text{V}$
 peak-to-peak
 $6 \mu\text{V}$

6σ . VARIANCE
 is p-p noise