ECE 614 Advance Analog IC Design

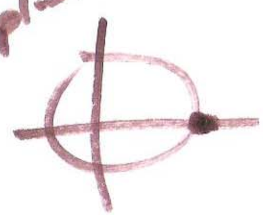
BOISE STATE UNIVERSITY

Sept. 22, 2011

Lecture 10

$$y[NT_s] = \frac{1}{K}\left(x[NT_s] + x[(N-1)T_s) + x[(N-2)T_s \cdots \quad x[(N-K)T_s)\right.$$

z-plane



$$z^{-1} \rightarrow e^{-j2\pi \frac{f}{f_s}}$$

$$Y(z) = \frac{1}{K}\left[X(z) + X(z)\cdot z^{-1} + X(z)z^{-2} + \cdots \quad X(z)z^{-K}\right]$$

1) $$H(z) = \frac{Y(z)}{X(z)} = 1 + z^{-1} + z^{-2} + \cdots z^{-K}$$

BOISE STATE UNIVERSITY

$$H(z) = \frac{1}{K}\left(1 + z^{-1} + z^{-2} + \cdots z^{-K}\right)\frac{(1-z^{-1})}{(1-z^{-1})}$$

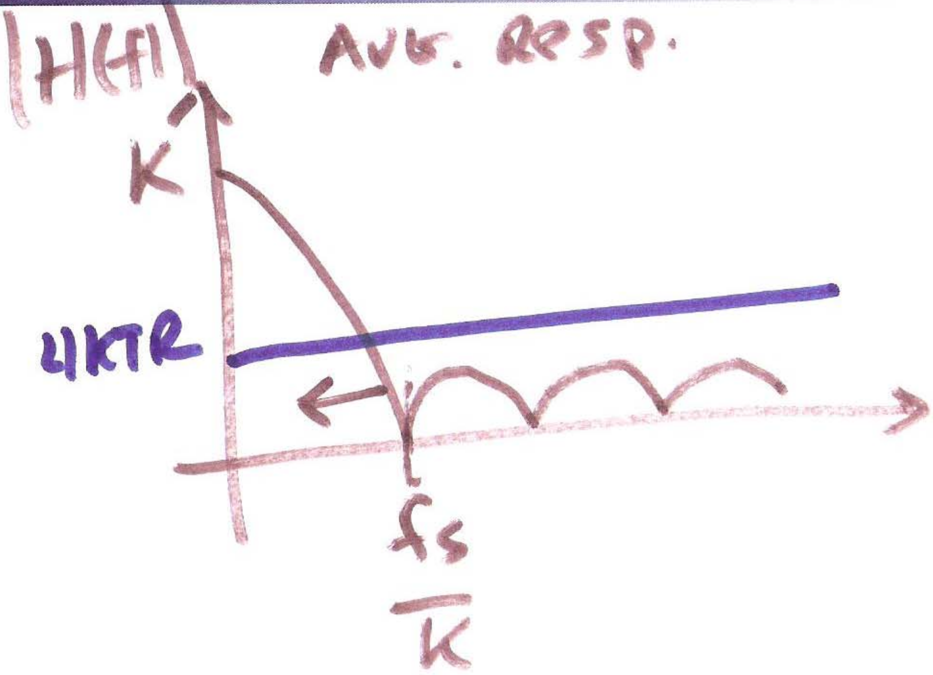
$$= \frac{1}{K}\left(1 - z^{-1} + z^{-1} - z^{-2} + z^{-2} - z^{-3} \cdots + z^{-(K-1)} - z^{-K}\right)$$

$$H(z) = \frac{1}{K}\frac{1 - z^{-K}}{1 - z^{-1}}$$ ← Averaging filter

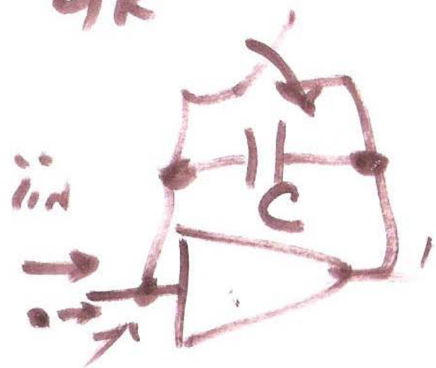
$$z^{-1} = e^{-j2\pi f \cdot T_s} = e^{-j2\pi \frac{f}{f_s}}$$

$$H(f) = K \frac{\sin 2\pi \frac{Kf}{f_s}}{2\pi \frac{Kf}{f_s}} \; ?$$

2)



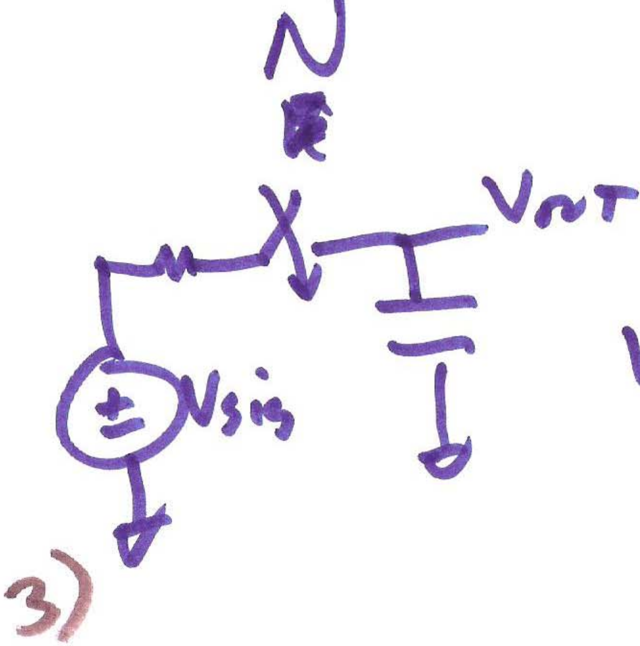
$$\frac{f_s}{4K}$$



$$V_{Rms}^2 = \frac{4KTBR}{K} \; V^2$$

$$\frac{1}{j\omega C} = \frac{v_o}{i_{in}}$$

$$V_{Rms} = \frac{4KTRB}{\sqrt{K}}$$

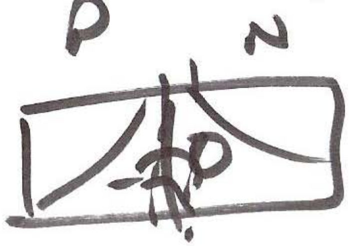


$$\sqrt{\frac{KT}{C}}$$

$$\frac{KT}{NC}$$

Shot Noise

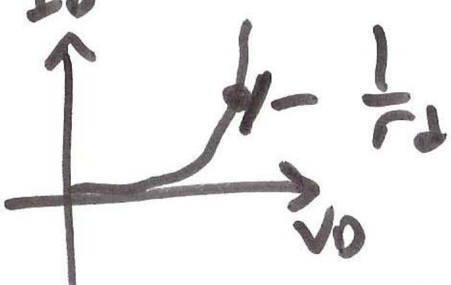
↓ potential barrier



White noise

$$PSD = 2qI_{DC} \quad \frac{A^2}{Hz}$$

What other potential barriers



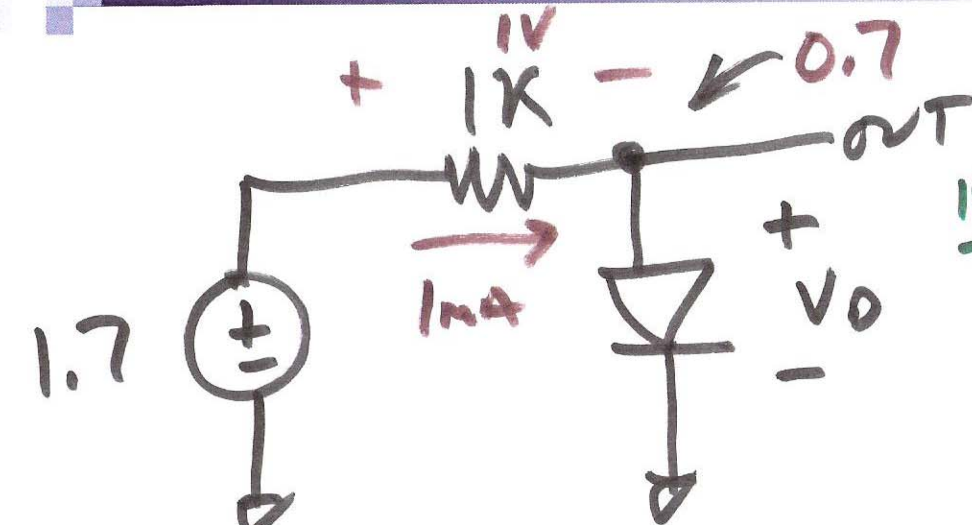
C-E BJT
B-E

Gate current → shot noise

1-NA — DC

$$r_d = \frac{V_T}{N \cdot I_{diode}}$$

4)



$\frac{1025}{25}$

41

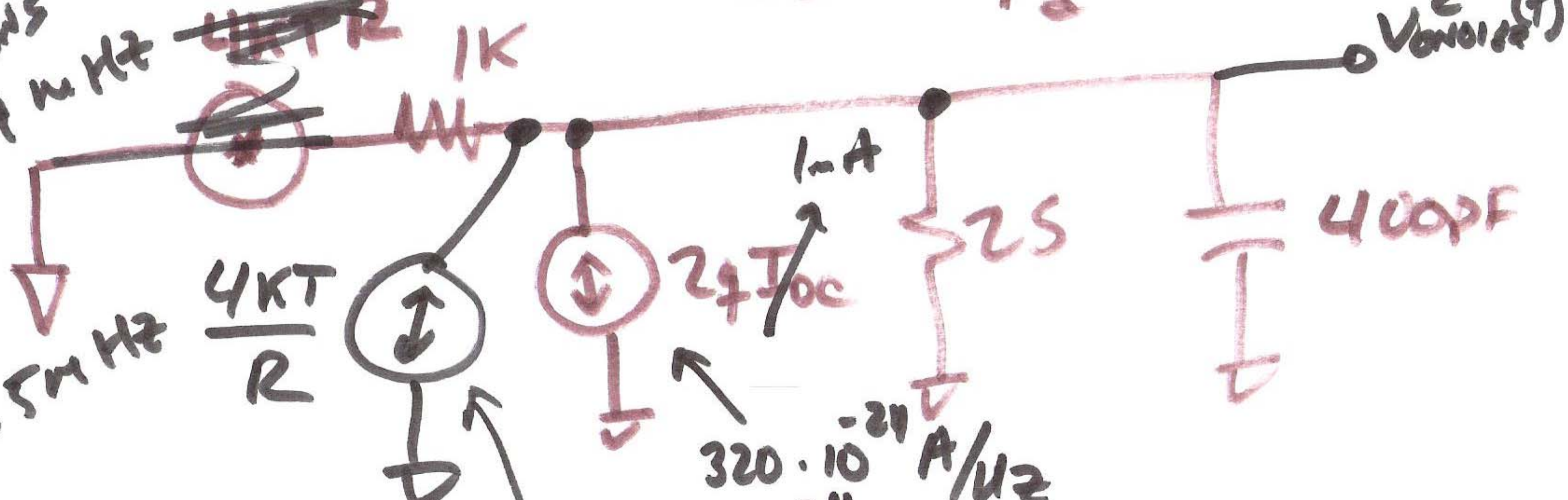
$r_d = \frac{25mV}{1mA} = \frac{V_T}{I_{Diode}}$

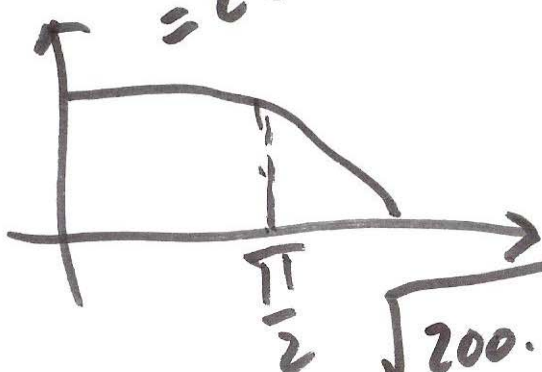
$= 25\Omega$

$C_d = \frac{\tau_T}{r_d} = \frac{10nS}{25\Omega}$

$f_{3dB} = \frac{1}{2\pi \cdot 10nS} = 15.9\ MHz$

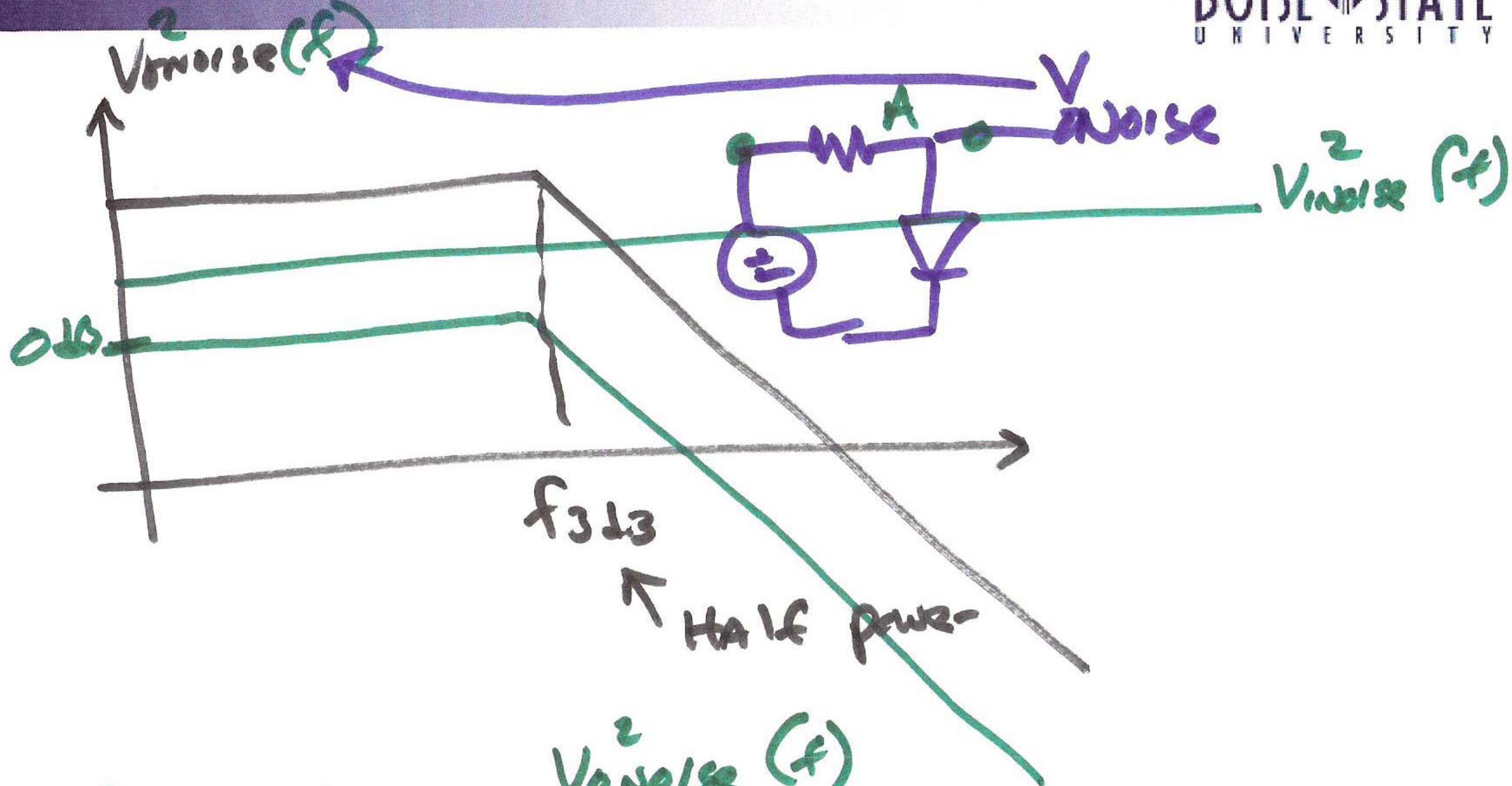
$NEB = \frac{\pi}{2} \cdot f_{3dB} = 25MHz$



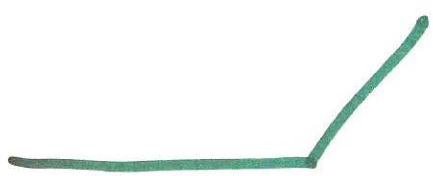


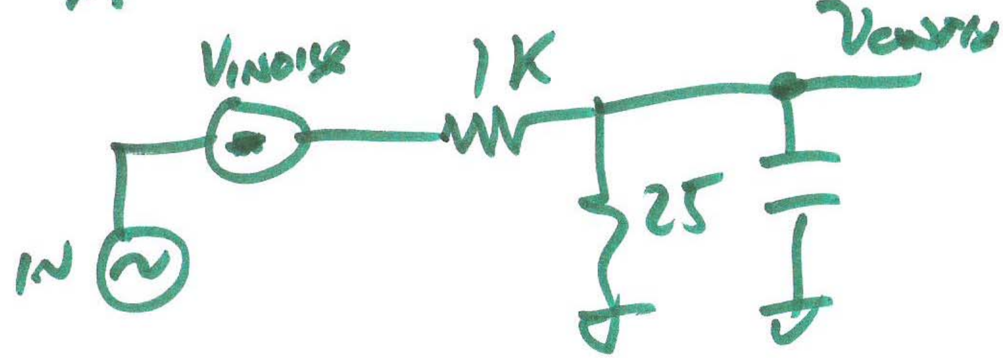
$V_{onoise}^2(f) = 200 \cdot 10^{-21}\ \frac{V^2}{Hz}$

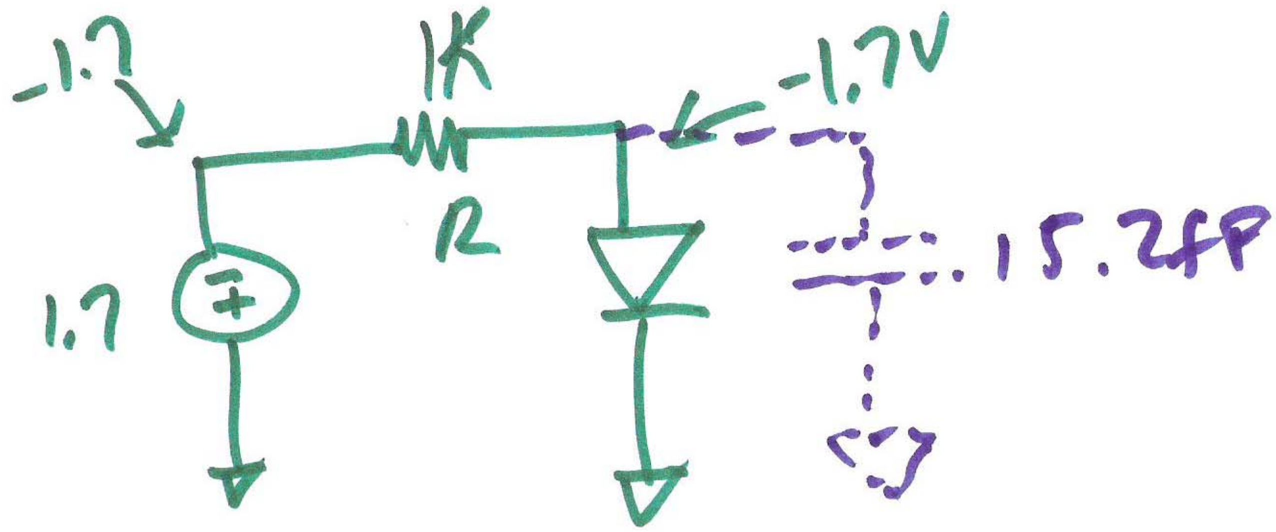
5) $\sqrt{200 \cdot 10^{-21} \cdot 25MHz} = 2.2mV$



$$V^2_{inoise}(f) = \frac{V^2_{onoise}(f)}{A}$$

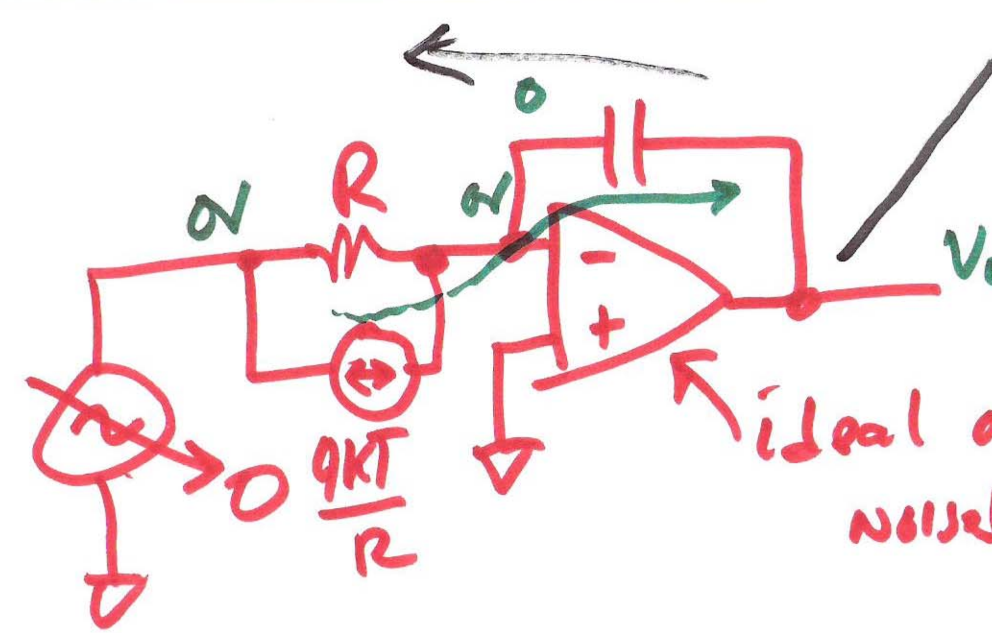






RMS OUTPUT NOISE?

$$\sqrt{\frac{kT}{C}} = 521\,\mu V$$



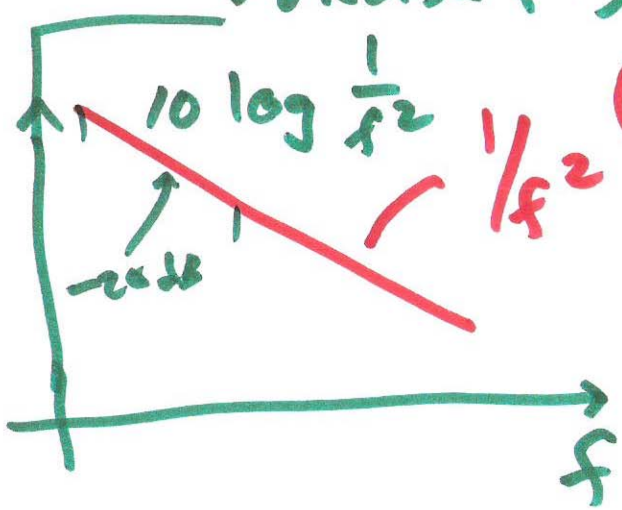
ideal op-amp
noiseless, infinite gain, etc.

PSD

fres → 0

$$V^2_{onoise}(f) = \frac{4KT}{R}\cdot\left|\frac{1}{j2\pi fC}\right|^2$$

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



$$V^2_{ONOISE,RMS} = \int_{f_L}^{f_H} \underbrace{\frac{4KT}{R} \cdot \frac{1}{(2\pi C)^2}}_{X} \cdot \frac{df}{f^2}$$

$$\int f^{-2} \cdot df$$

$$-f^{-1}$$

$$= X \int_{f_L}^{f_H \to \infty} \frac{df}{f^2} = \frac{X}{-} \cdot \frac{1}{f} \Big|_{f_L}^{f_H}$$

$$f_L = \frac{1}{T_{meas}}. \qquad X \left(\frac{1}{f_L} - \frac{1}{f_H} \to 0 \right)$$

$X \cdot T$

$$V^2_{ONOISE,RMS} = X \cdot T_{meas}$$

$$V_{ONOISE} = \sqrt{X} \cdot \sqrt{T_{meas}}$$