University of Glasgow

Electronic System Design 3

Lecture 10.1: Amplifier Noise analysis

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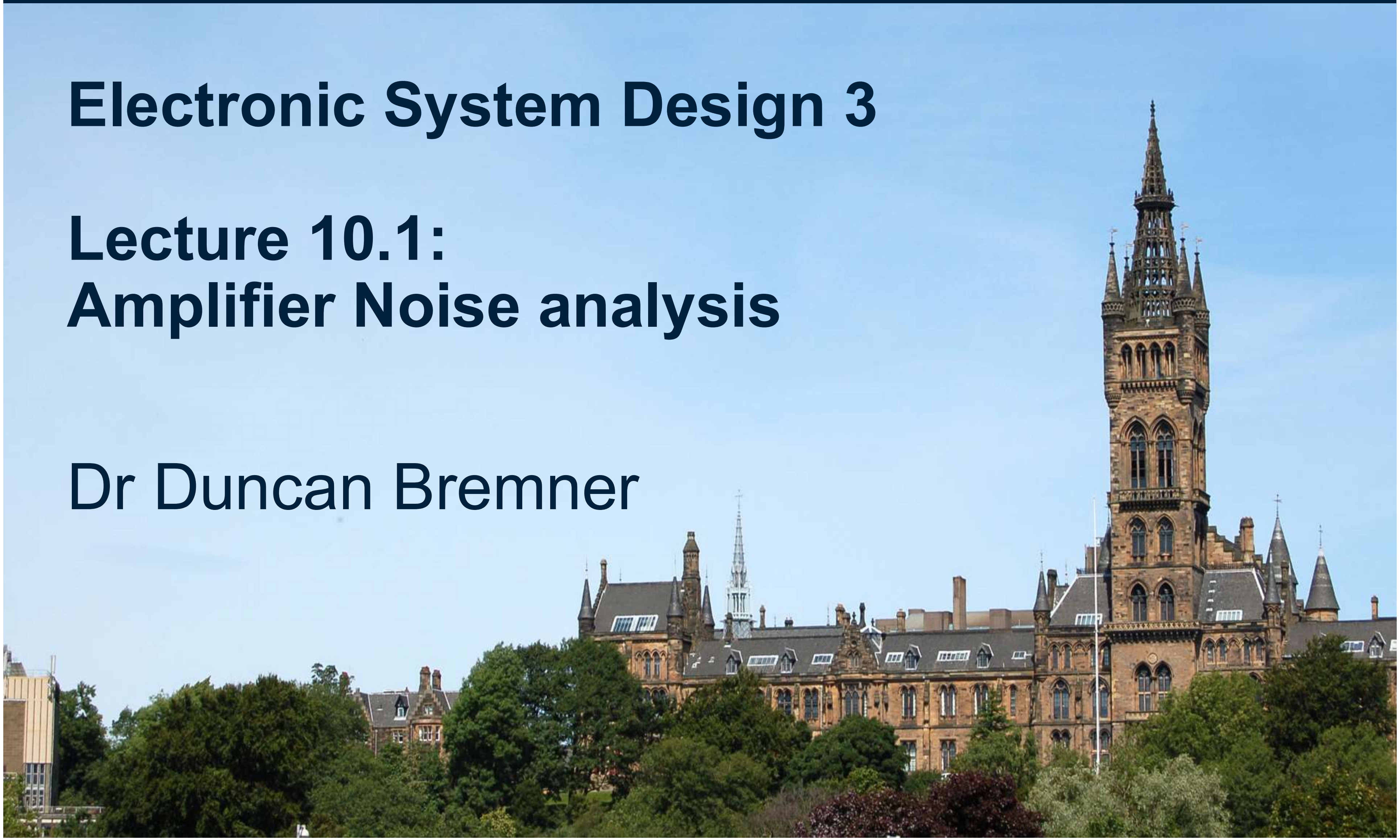


Amplifier Noise

All resistors have the same thermal noise

Amplifiers have different noise levels

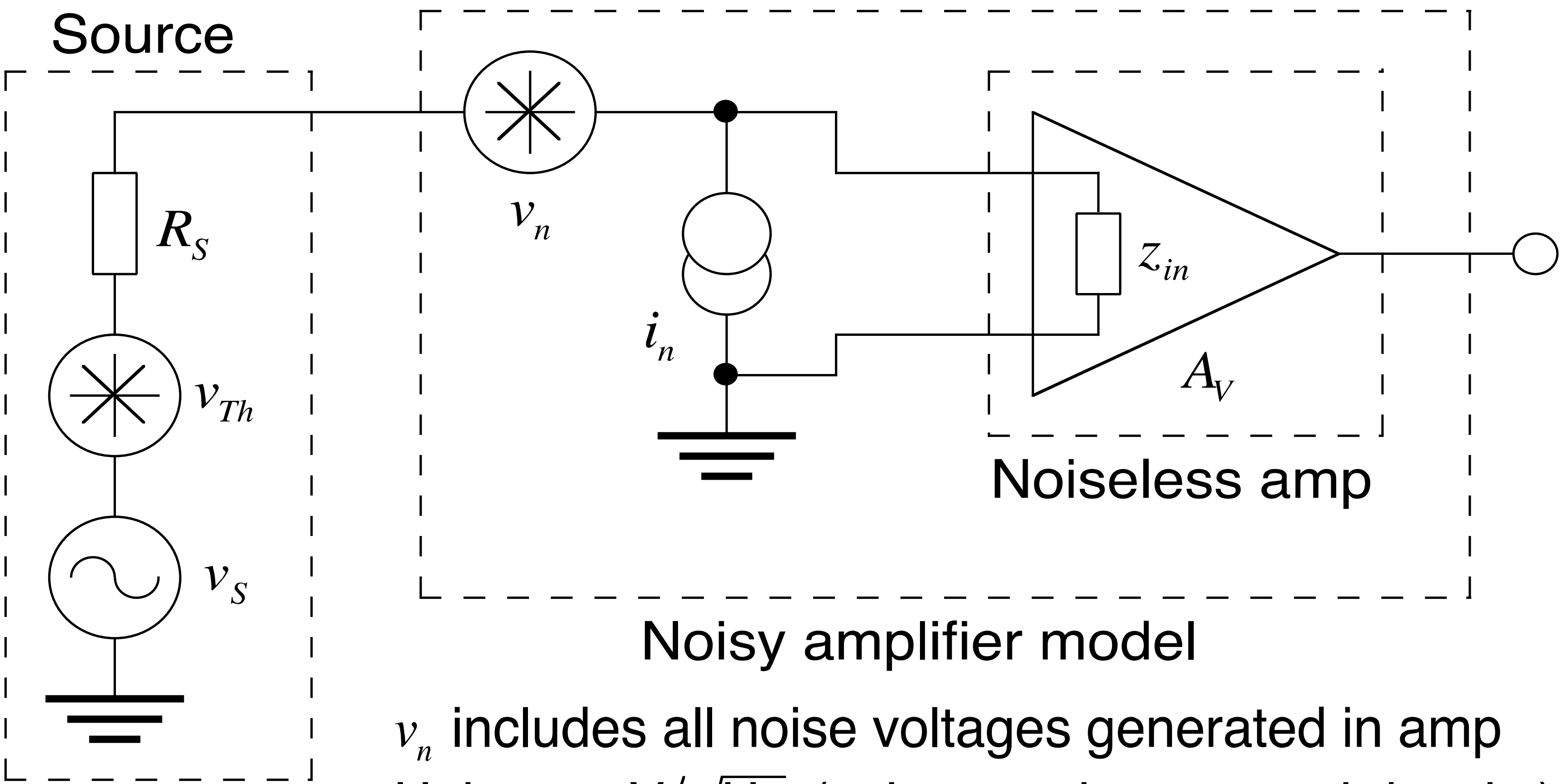
Noise depends on details of amplifier design

- Shot noise of input bias current
- Use of bias current cancellation
- Size of input transistor (flicker noise)
- Type of input transistor
  - Bipolar (low e_n)
  - MOS (low i_n)
  - JFET (lowish e_n, i_n)
- Input stage quiescent current / Resistor values

Input current noise and Input voltage noise. (Can't fix both!)

Voltage Amplifier Noise Model

Need to compare amplifiers: Use a simplified model



Noisy amplifier model

v_n includes all noise voltages generated in amp

Units are $V/\sqrt{Hz}$ (voltage noise spectral density)

v_n is a function of frequency

i_n is the same for noise current, $A/\sqrt{Hz}$

Amplifier Noise Model (2)

Equivalent input noise:

- Combine **all** noise sources into a single source at input (Add squares)
- Calculate output noise due to noise source
- Divide by system gain from source to O/P

System gain $K = A_V \dfrac{z_{in}}{R_S + z_{in}}$ (Just like 1st year)

From v_{Th} : $$V^2_{OUT(Th)} = |A_V|^2 \left| \frac{z_{in}}{R_S + z_{in}} \right|^2 v^2_{Th}$$

From v_n : $$V^2_{OUT(n)} = |A_V|^2 \left| \frac{z_{in}}{R_S + z_{in}} \right|^2 v^2_n$$

From i_n : $$V^2_{OUT(i_n)} = |A_V|^2 |z_{in} // R_S|^2 i^2_n$$

Amplifier Noise Model (3)

$$V_{OUT}^2(Total) = |A_V|^2 \left| \frac{z_{in}}{R_S + z_{in}} \right|^2 \left(v_{Th}^2 + v_n^2 \right) + |A_V|^2 |z_{in} \,//\, R_S|^2 \, i_n^2$$

Divide by system gain

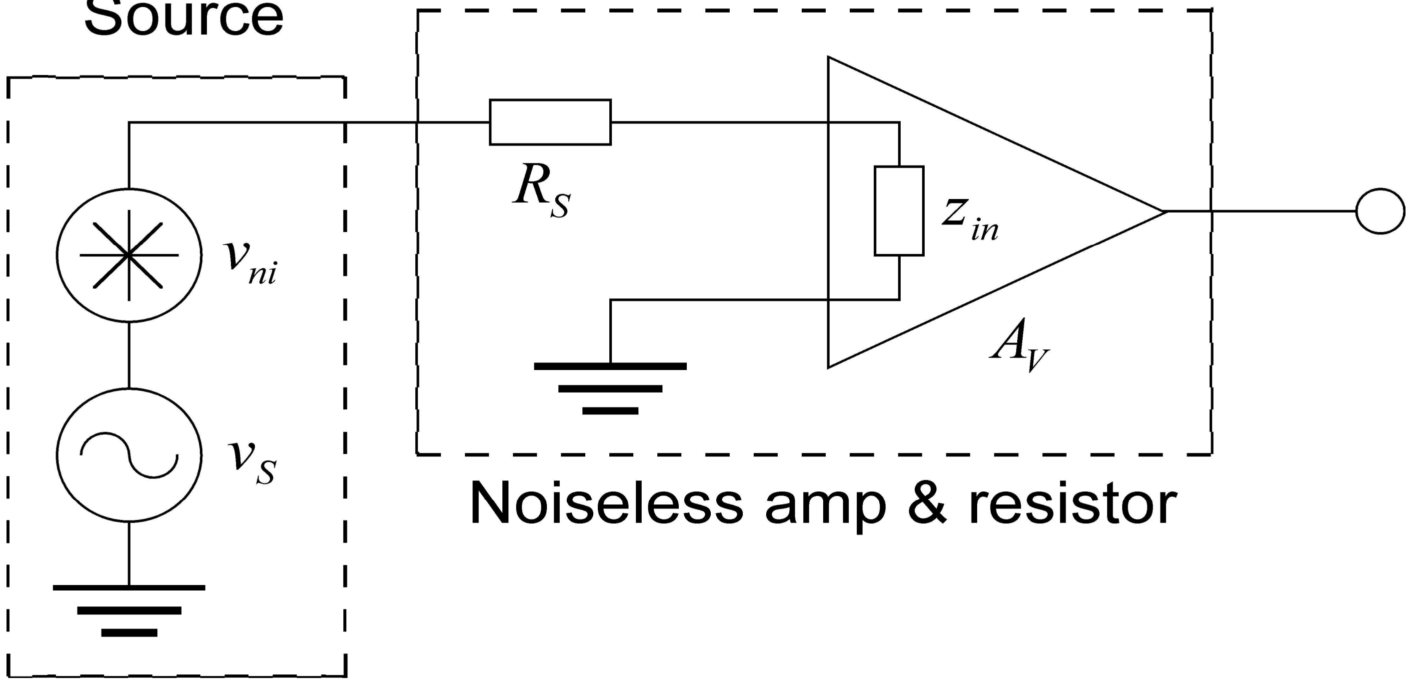
$$\frac{V_{OUT}^2(Total)}{K^2} = v_{Th}^2 + v_n^2 + \frac{|A_V|^2 \dfrac{|z_{in}|^2 |R_S|^2}{|z_{in} + R_S|^2}}{|A_V|^2 \dfrac{|z_{in}|^2}{|z_{in} + R_S|^2}} i_n^2 = v_{ni}^2$$

$$\Rightarrow v_{ni}^2 = v_{Th}^2 + v_n^2 + i_n^2 |R_S|^2$$

Interesting observation: Independent of z_{in}

Amplifier Noise Model (4)

Source



Noiseless amp & resistor

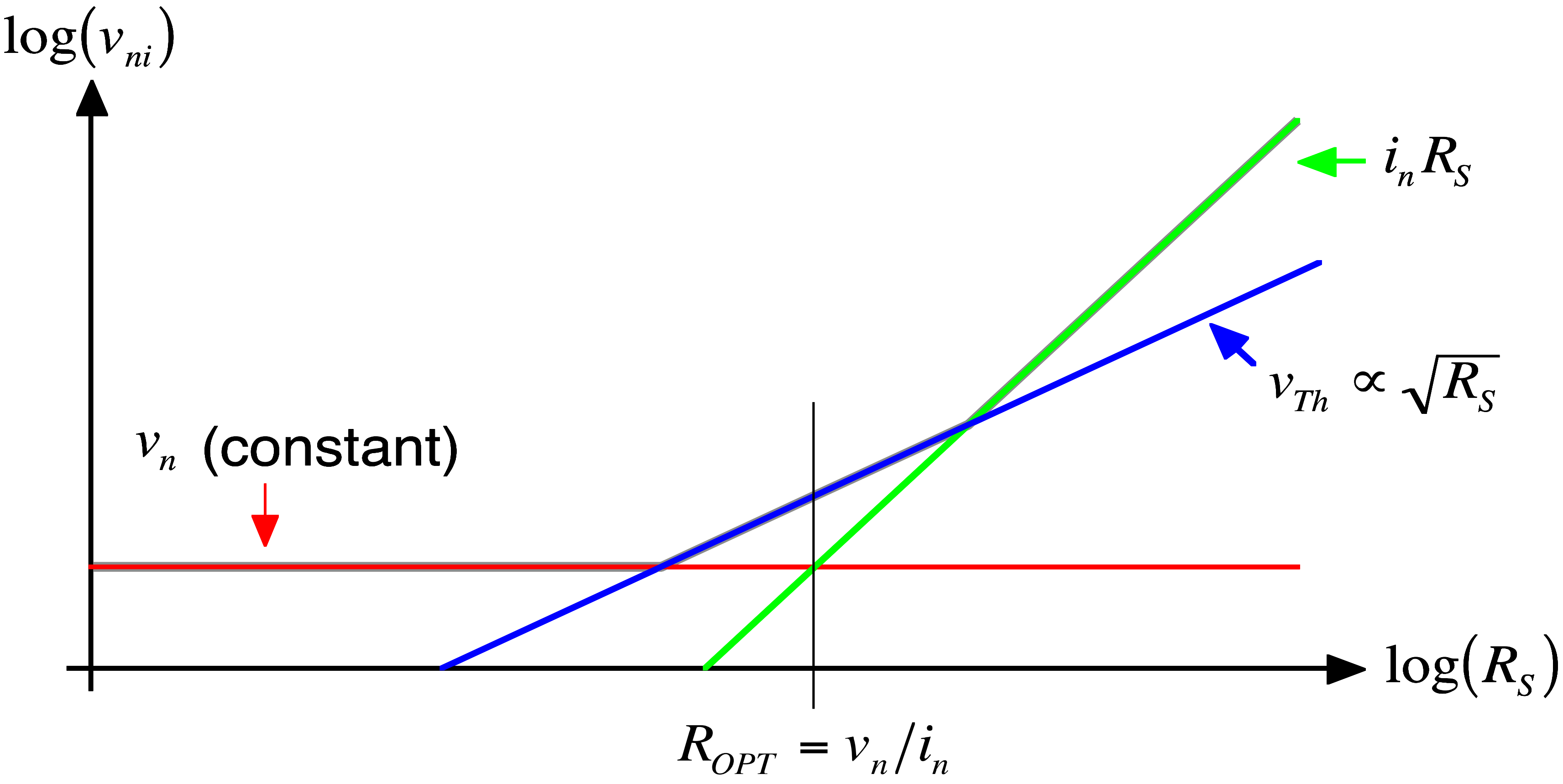
All noise sources replaced by single noise generator

- Independent of amplifier gain
- Independent of amplifier input resistance

Makes comparison of amplifiers easier

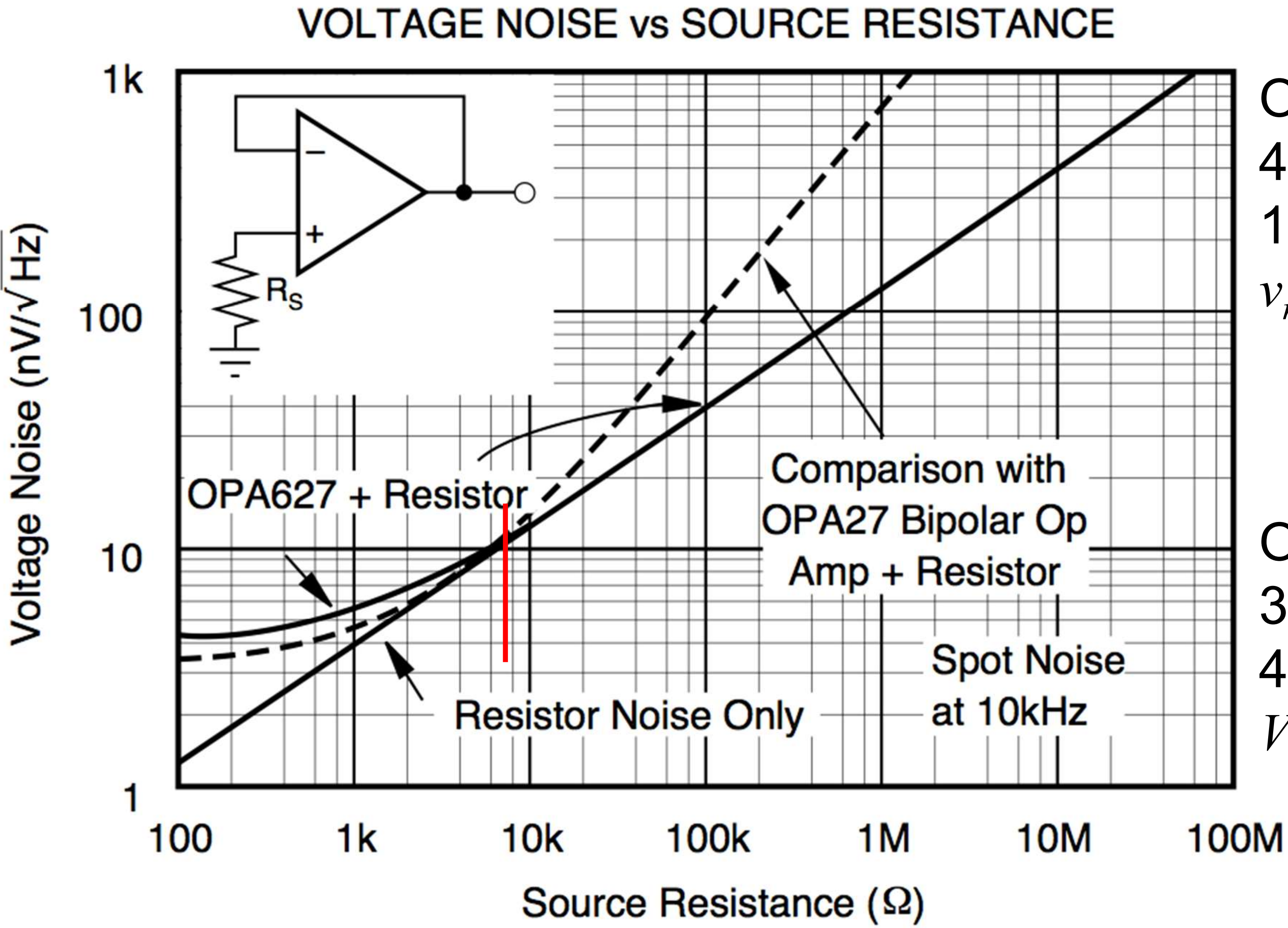
Graphical Noise Calculations

Effect of source resistance on noise



At R_S=R_{OPT} amplifier adds minimum noise to (irreducible) thermal noise

Let's look at a real amplifier…



OPA627:

4.5nV $Hz^{-1/2}$

1.6fA $Hz^{-1/2}$

$v_n/i_n = 2.8M\Omega$

OPA27:

3nV $Hz^{-1/2}$

400fA $Hz^{-1/2}$

$V_n/i_n = \mathbf{7.5k\Omega}$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Thank you
谢谢
INSPIRING PEOPLE