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Electronic System Design 3

Lecture 11.2:
Low noise Amplifier Optimisation

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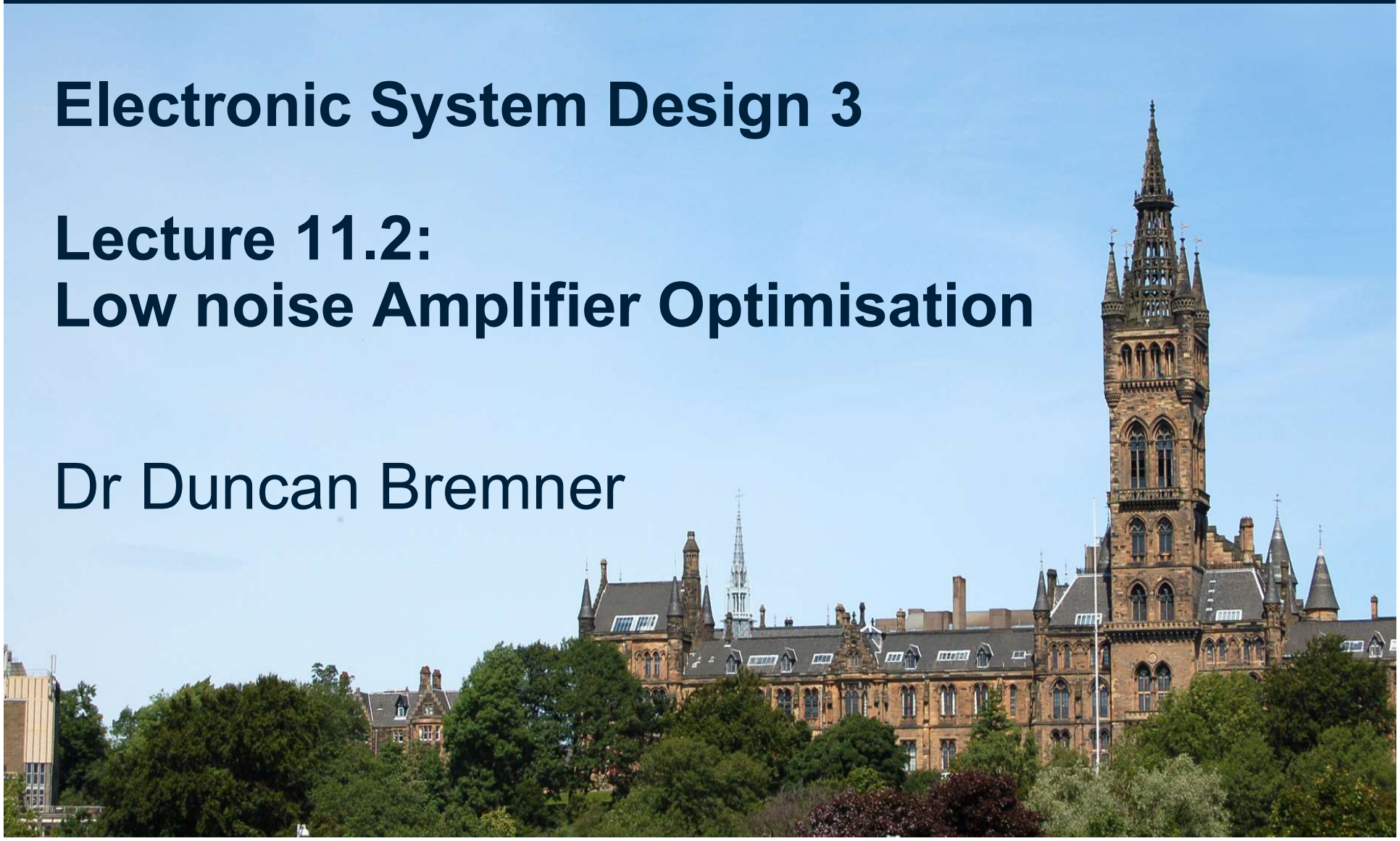
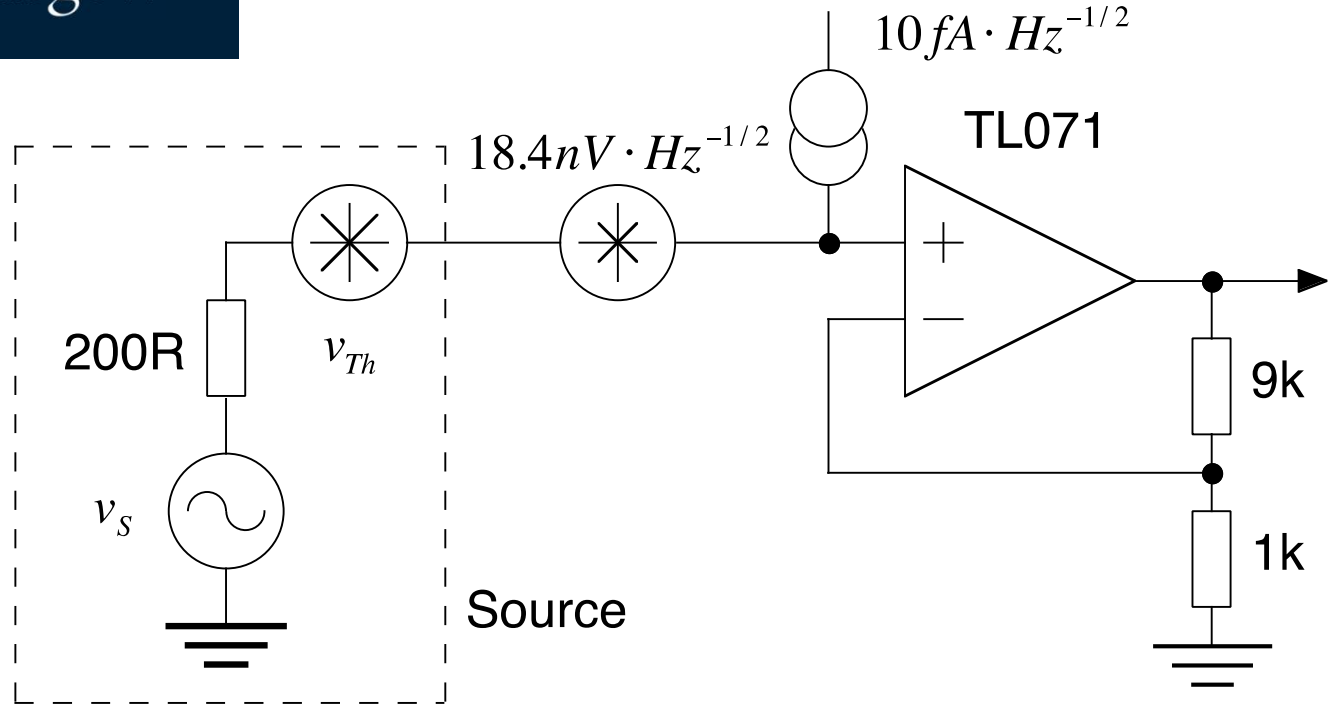


Continuing with Design 2 (5)…



Now in the same form as the standard model

$$v_n = 18.4nV \cdot Hz^{-1/2} \quad i_n = 10\,fA \cdot Hz^{-1/2} \quad v_{Th} = \sqrt{4k_B TR} = 1.82nV \cdot Hz^{-1/2}$$

$$v_{ni} = \sqrt{v_{Th}^2 + v_n^2 + i_n^2 |R_S|^2} = \sqrt{3.3 \cdot 10^{-18} + 338 \cdot 10^{-16} + 4 \cdot 10^{-24}} = 18.5nV \cdot Hz^{-1/2}$$

What can we do to improve performance???

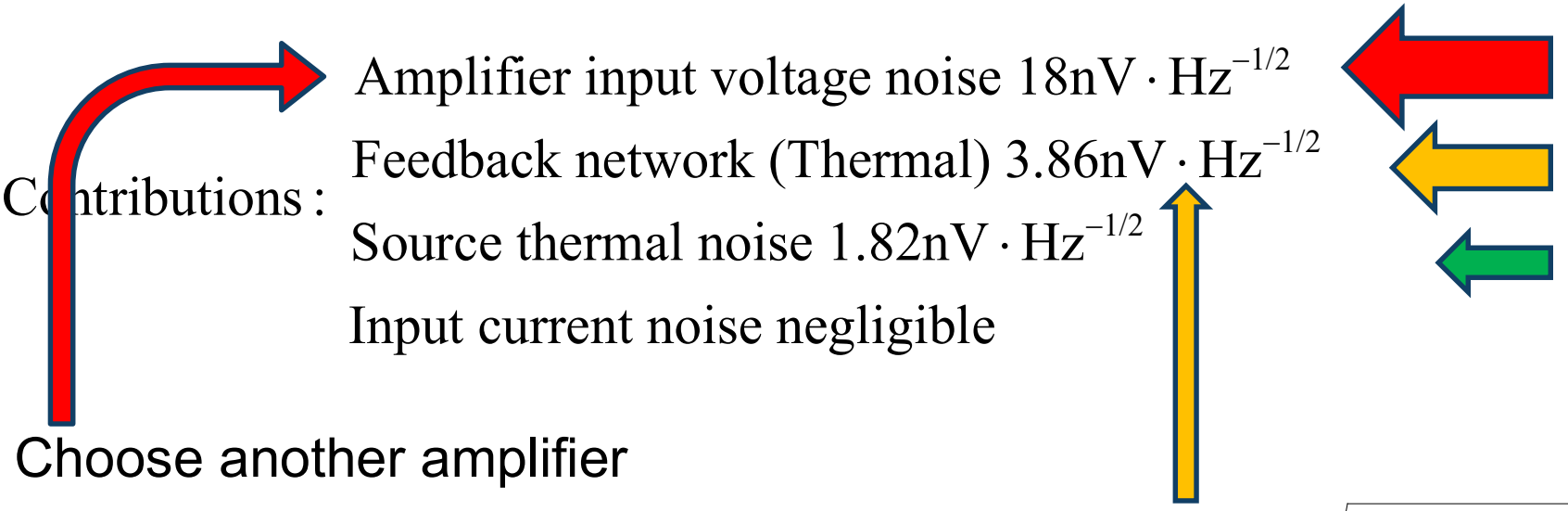
Design 2 (6)

Conclusion: Noise is dominated by input voltage noise of amp

$$\mathrm{NF} = 20 \cdot \log_{10} \frac{18.5 nV \cdot Hz^{-1/2}}{1.82 nV \cdot Hz^{-1/2}} = 20.1 dB \text{ (very bad)}$$

Contributions:

- Amplifier input voltage noise $18\mathrm{nV} \cdot \mathrm{Hz}^{-1/2}$
- Feedback network (Thermal) $3.86\mathrm{nV} \cdot \mathrm{Hz}^{-1/2}$
- Source thermal noise $1.82\mathrm{nV} \cdot \mathrm{Hz}^{-1/2}$
- Input current noise negligible



Choose another amplifier

Reduce impedance of feedback network to < 200Ω; $\sqrt{4k_B T \cdot 0.9k\Omega}$

Don't worry too much about noise current

(200Ω is small for an opamp)

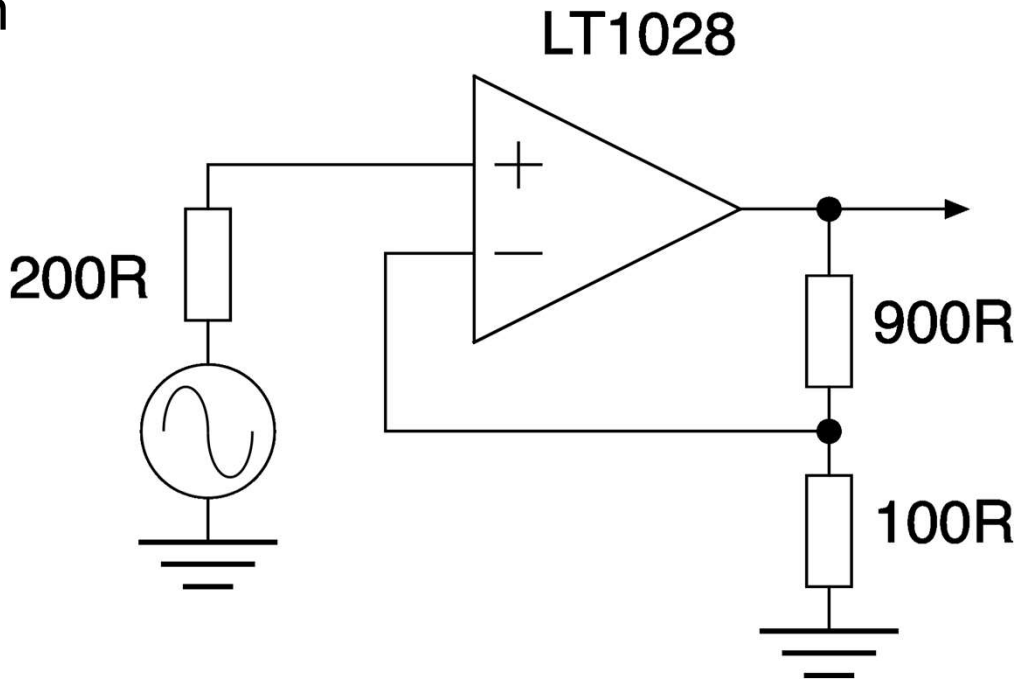
Design 2 (7)

Choice of amplifier: Lowest voltage noise amplifier you have been given: LT1028C

$$v_n = 0.85 nV \cdot Hz^{-1/2} \qquad i_n = 1000\, fA \cdot Hz^{-1/2}$$ [from datasheet]

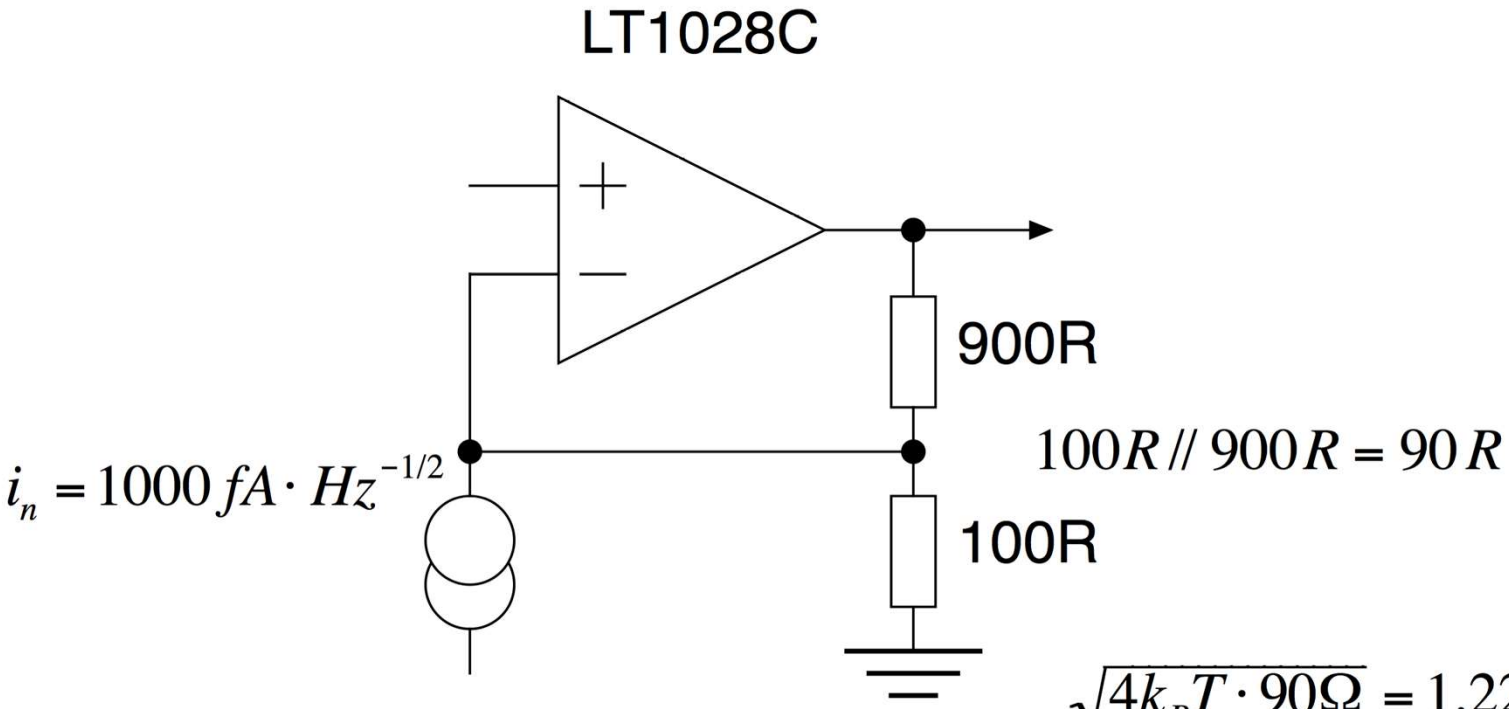
Reduce feedback impedance to less than source resistance:

Revised design



Design 2 (8)

Change Amplifier: … now Repeat analysis:



$i_n = 1000\,fA \cdot Hz^{-1/2}$

$100R \,//\, 900R = 90R$

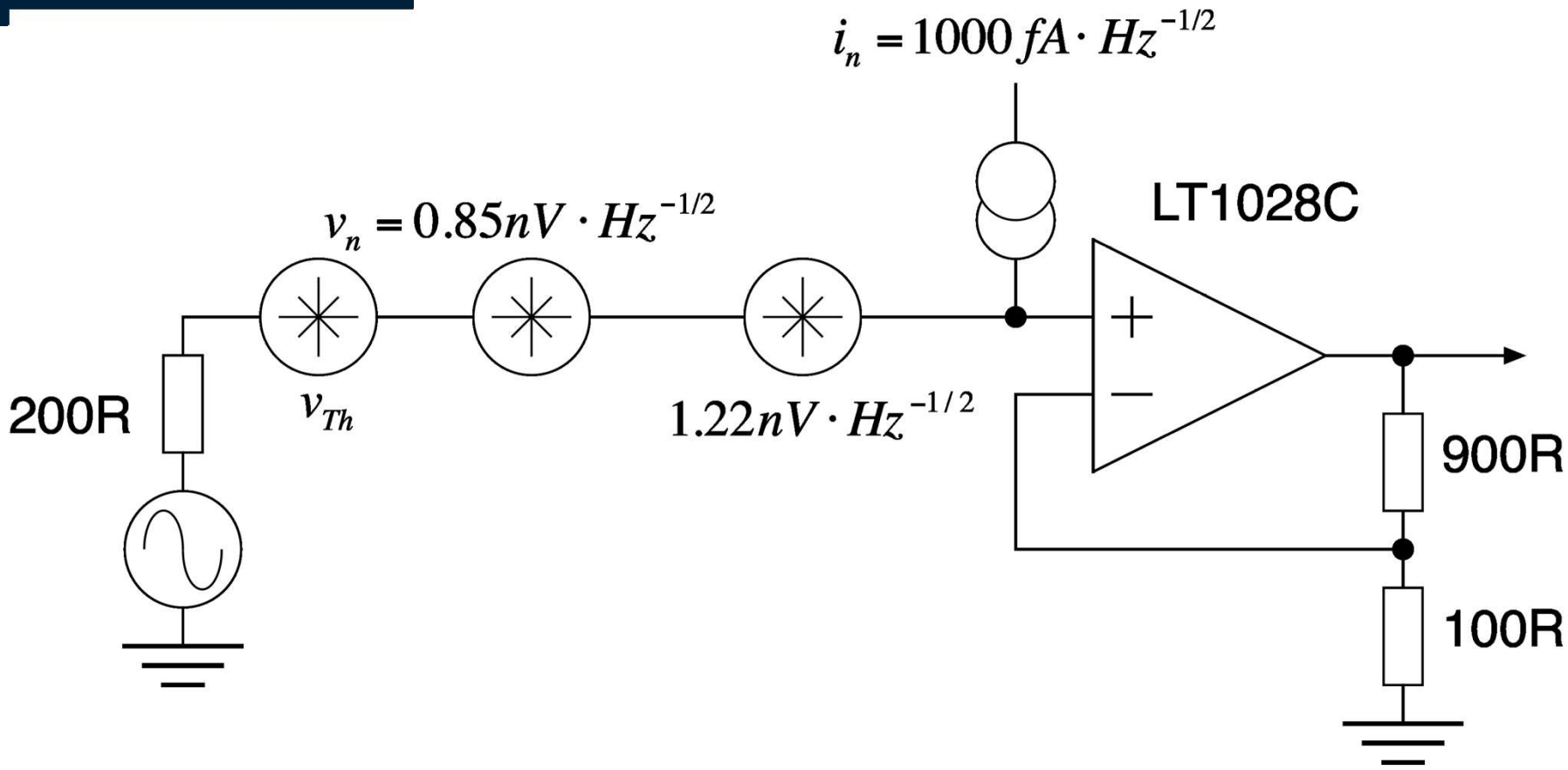
$\sqrt{4k_B T \cdot 90\Omega} = 1.22nV \cdot Hz^{-1/2}$

$1000\,fA \cdot Hz^{-1/2} \cdot 90\Omega$

$= 0.09nV \cdot Hz^{-1/2}$

$$\sqrt{\left(1.22nV \cdot Hz^{-1/2}\right)^2 + \left(0.09nV \cdot Hz^{-1/2}\right)^2} = 1.22nV \cdot Hz^{-1/2}$$

Design 2 (9)



$$\sqrt{\left(1.22nV \cdot Hz^{-1/2}\right)^2 + \left(0.85nV \cdot Hz^{-1/2}\right)^2} = 1.49nV \cdot Hz^{-1/2} = v_n$$

$$v_{Th} = \sqrt{4k_B T \cdot 200\Omega} = 1.82nV \cdot Hz^{-1/2}$$

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Design 2 (10)

$$v_{ni} = \sqrt{v_{Th}^2 + v_n^2 + i_n^2 |R_S|^2} = \sqrt{(1.82nV)^2 + (1.49nV)^2 + (0.2nV)^2} = 2.36nV \cdot Hz^{-1/2}$$

$$\text{NF} = 20 \cdot \log_{10} \frac{2.36nV \cdot Hz^{-1/2}}{1.82nV \cdot Hz^{-1/2}} = 2.25dB$$

17.8dB improvement: …A radio antenna has 8x smaller diameter

Total noise in 20kHz bandwidth is $\sqrt{20000Hz} \cdot 2.36nV \cdot Hz^{-1/2} = 0.33\mu V$


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Thank you
谢谢
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