Electronic System Design 3

Lecture 10.3:
Flicker (1/f) noise and amplifier performance

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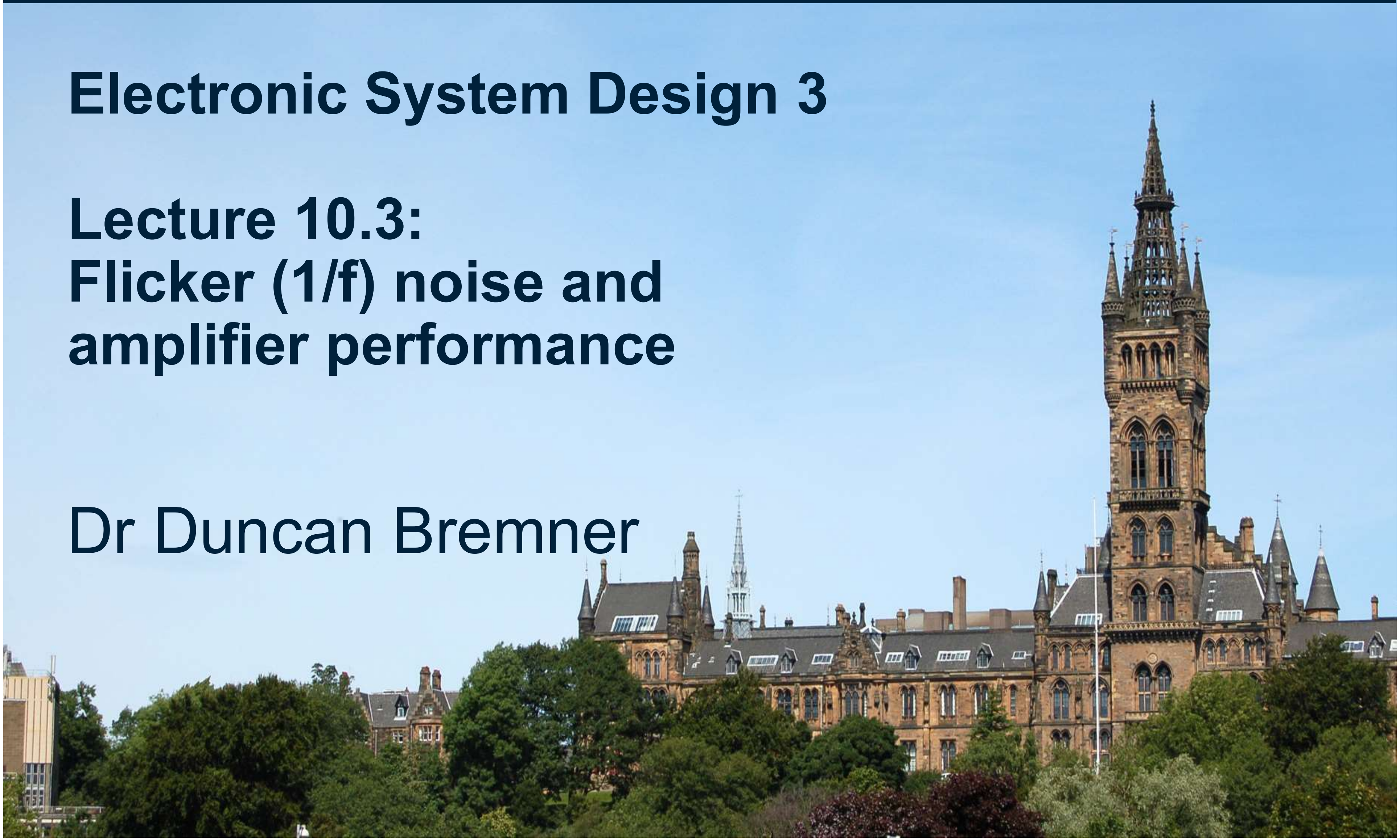
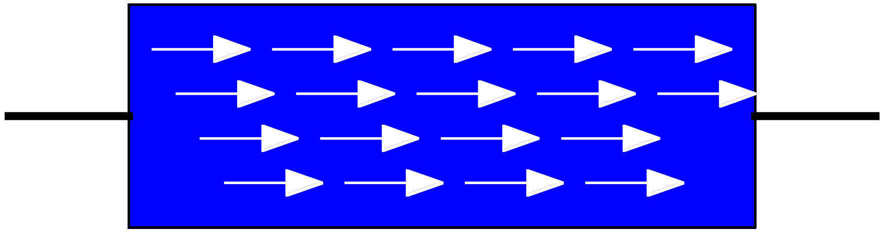


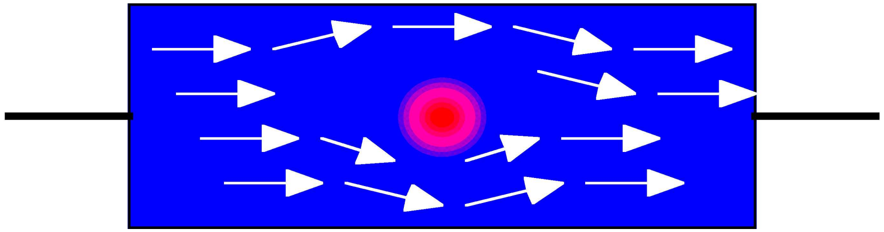
Flicker Noise ("1/f Noise")

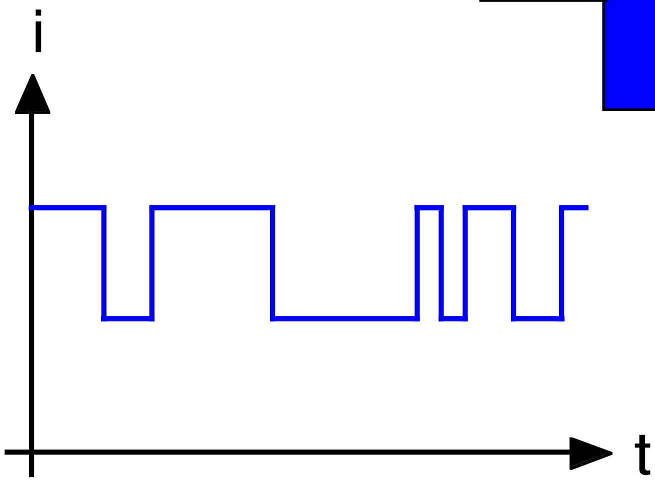
Current flows



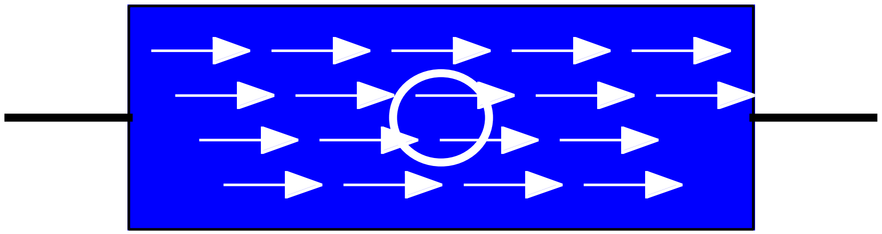
Defect in **active device** charges & discharges randomly

Defect charges, current reduced



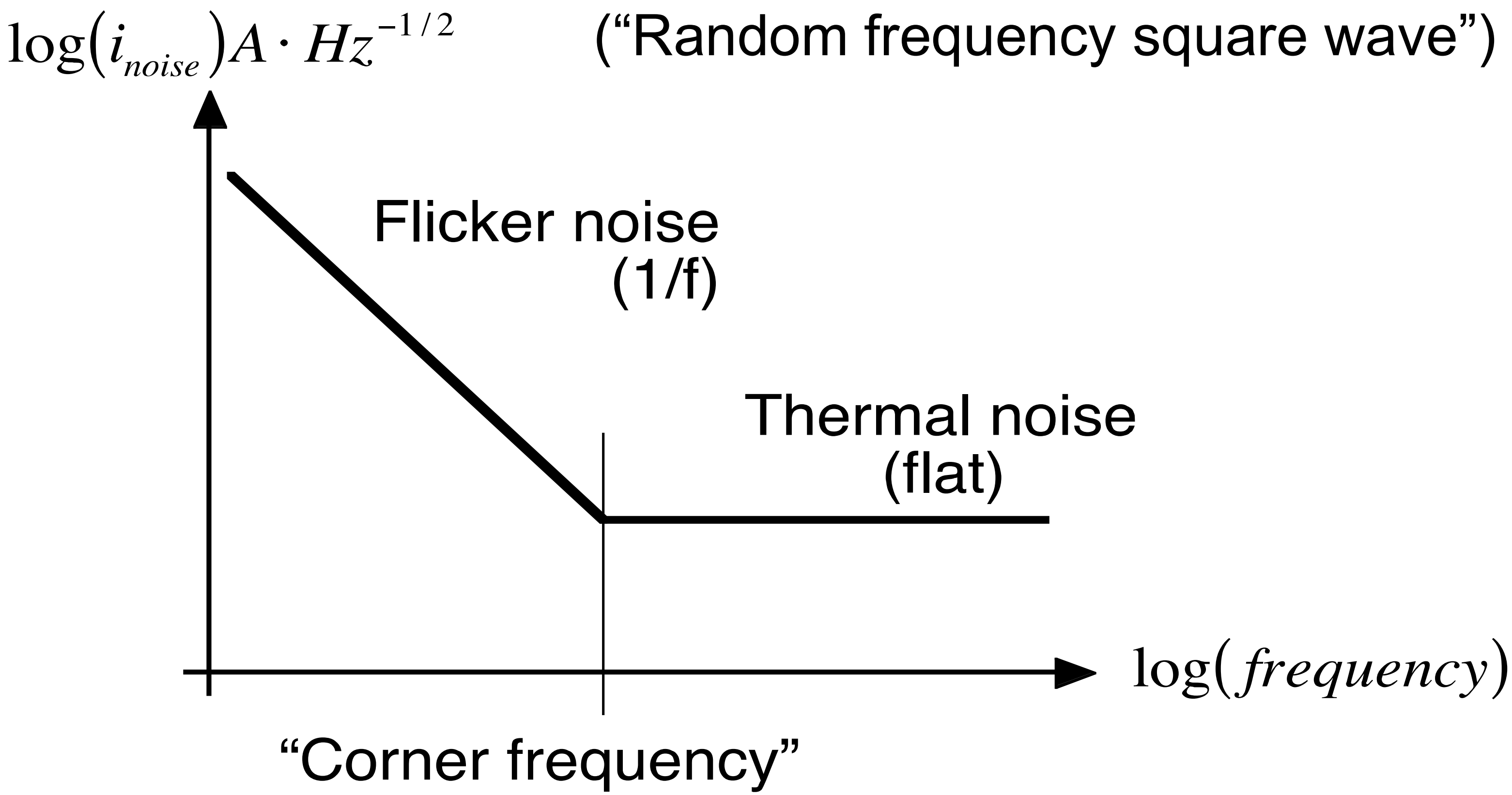


Uncharged defect: Current back



Flicker noise (2)

Noise flickers on and off randomly.
Has approximately 1/f frequency dependence
("Random frequency square wave")



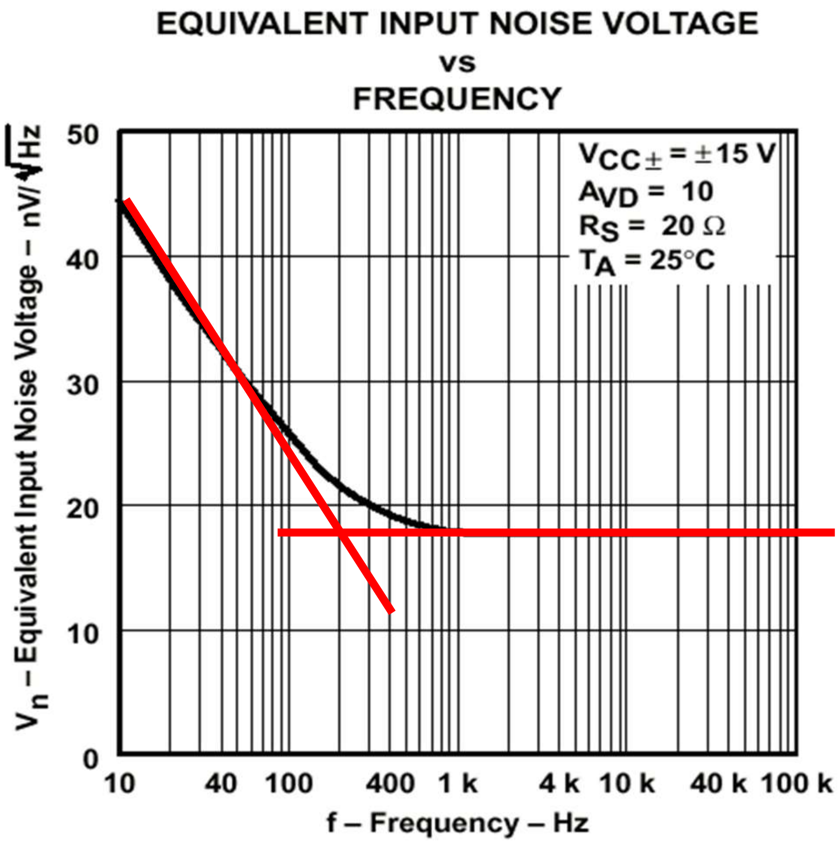
Varies between devices.
Also seen as voltage noise

Real Devices

TL071

$$v_n = 18nV \cdot Hz^{-1/2} \qquad i_n = 10\,fA \cdot Hz^{-1/2}$$

$$i_b = 65pA \qquad \sqrt{2qi_b} = 4.6\,fA \cdot Hz^{-1/2}$$



$$\frac{v_n}{i_n} = 1.8M\Omega$$

Noise corner frequency ~ 200Hz

More devices

NE5534 (Low noise cheap bipolar)

$$v_n = 3.5nV \cdot Hz^{-1/2}$$

$$i_n = 400\,fA \cdot Hz^{-1/2}$$

$$\frac{v_n}{i_n} = 5.8k\Omega$$

$$i_b = 500nA \qquad \sqrt{2qi_b} = 400\,fA \cdot Hz^{-1/2}$$

Corner freq. $\sim 60Hz$

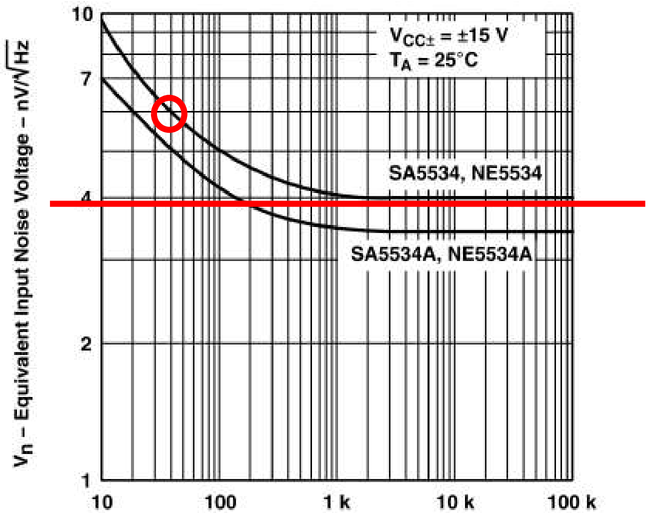


Figure 7. Equivalent Input Noise Voltage vs Frequency

OPA827 (Wonderful JFET)

$$v_n = 4nV \cdot Hz^{-1/2}$$

$$i_n = 2.2\,fA \cdot Hz^{-1/2}$$

$$\frac{v_n}{i_n} = 1.82M\Omega$$

$$i_b = 10\,pA \qquad \sqrt{2qi_b} = 1.8\,fA \cdot Hz^{-1/2}$$

Corner freq. $\sim 20Hz$

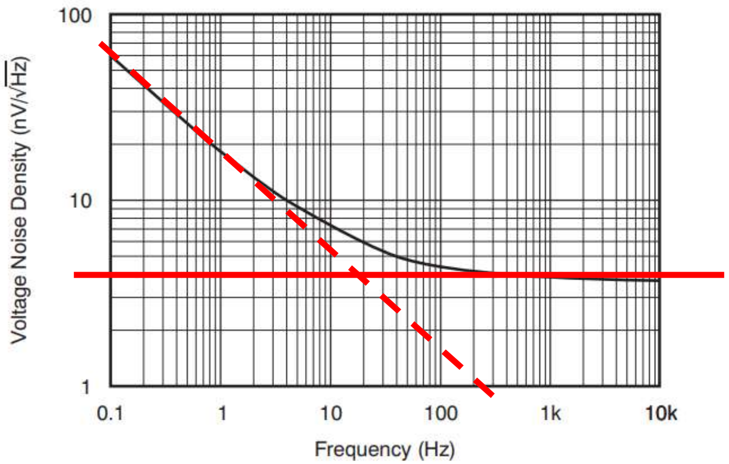


Figure 1. Input Voltage Noise Density vs Frequency

Even more devices

OPA277 (Low noise OPA177)

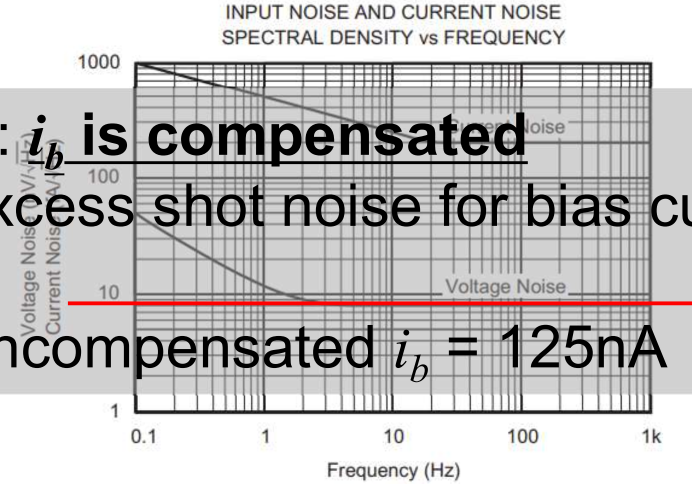
$v_n = 8nV \cdot Hz^{-1/2}$

$i_n = 200\,fA \cdot Hz^{-1/2}$

$\frac{v_n}{i_n} = 40k\Omega$

$i_b = 500\,pA \qquad \sqrt{2qi_b} = 13\,fA \cdot Hz^{-1/2}$

Corner freq. $\sim 15\,Hz$



Note: **i_b is compensated**

$\Rightarrow$ Excess shot noise for bias current

$\Rightarrow$ Uncompensated i_b = 125nA

AD8429 (Low noise bipolar instrument amp.)

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

$i_n = 1500\,fA \cdot Hz^{-1/2}$

$\frac{v_n}{i_n} = 667\Omega$

$i_b = 150nA \qquad \sqrt{2qi_b} = 220\,fA \cdot Hz^{-1/2}$

Corner freq. $\sim 10\,Hz$

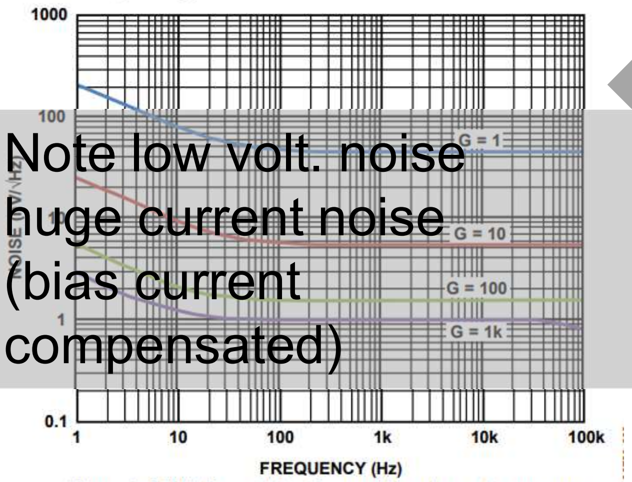


Figure 2. RTI Voltage Noise Spectral Density vs. Frequency

Note low volt. noise huge current noise (bias current compensated)

Another device….

LT1028 (Low noise bipolar)

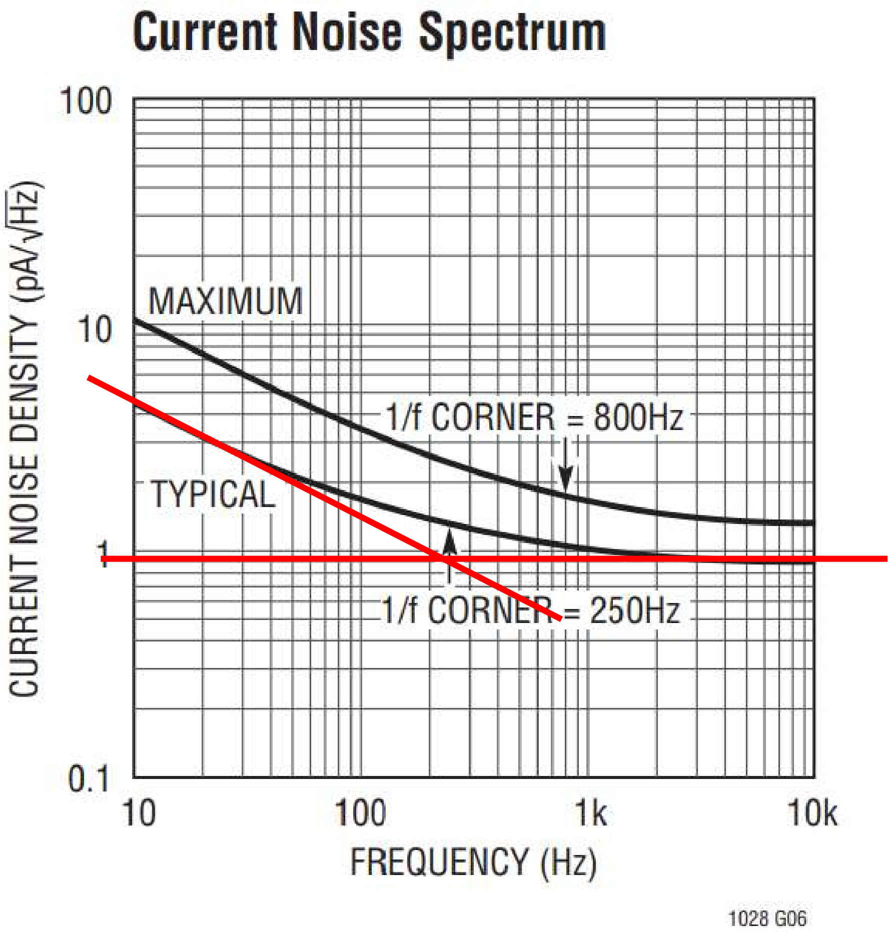
$$v_n = 0.85nV \cdot Hz^{-1/2}$$

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

$$\frac{v_n}{i_n} = 850\Omega$$

$$i_b = 25nA \qquad \sqrt{2qi_b} = 90\,fA \cdot Hz^{-1/2}$$

Corner freq. $\sim 250\,Hz$



Summary

Thermal noise

- Increases with temperature
- Uniform with frequency
- Power spectral density is independent of R
- Present in all resistors

Shot noise

- Increases with current
- Uniform with frequency
- Only present for some device types / if current flowing

Flicker (1/f) noise

- Increases with current
- Only present for some device types
- Increases at low frequencies

- Design for source impedance / Choose devices
- Limit bandwidth to minimum required
- Control circuit impedances so as not to add excess noise


University of Glasgow
Thank you
谢谢
INSPIRING PEOPLE