Low-Frequency Contact Noise mitigation in graphene-FETs

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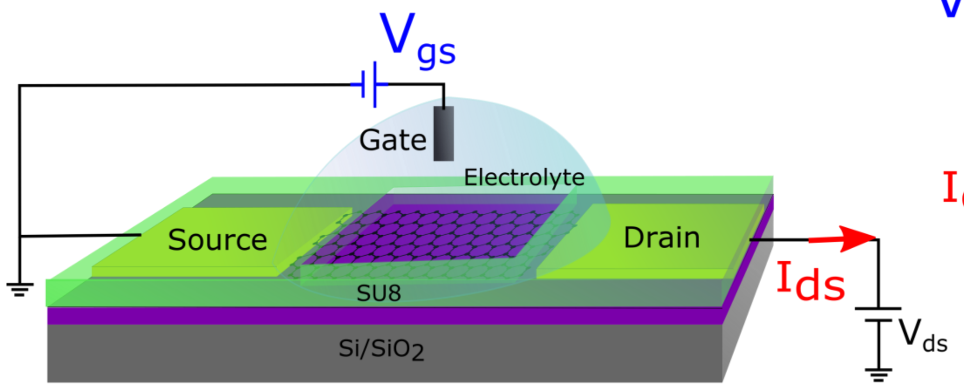
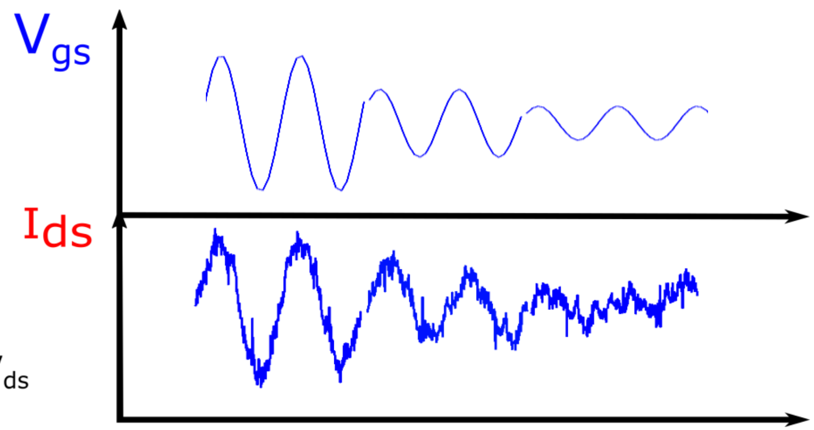
Patrons:

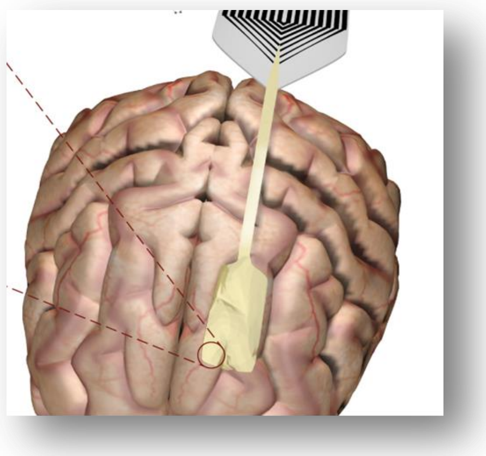
Low-frequency noise (LFN) limits sensing applications of graphene





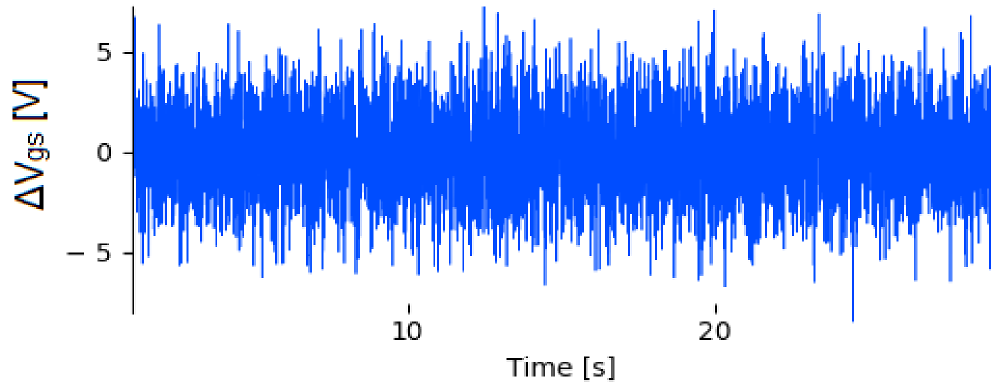
$$I_{ds} = G_m \Delta V_{gs}$$

$$\Delta V_{gs} = \Delta V_{gs-signal} + \Delta V_{gs-noise}$$

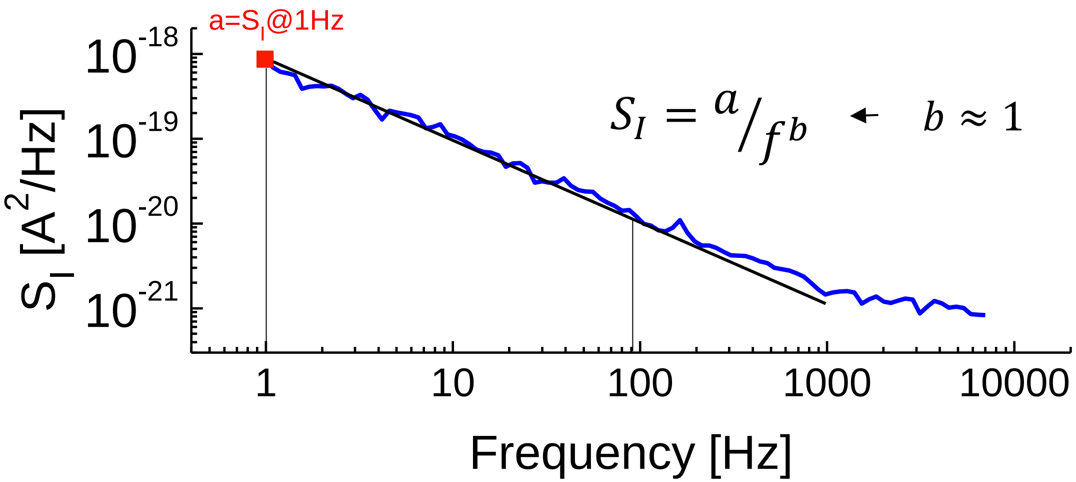


- Minimizing the noise level is crucial to maximize the sensitivity of the device

How is noise power measured?



FFT



$$S_I = {}^{a}/_{f^b} \quad \leftarrow \quad b \approx 1$$

$$I_{ds-rms} = \sqrt{\int S_I \, df} \propto \sqrt{a}$$

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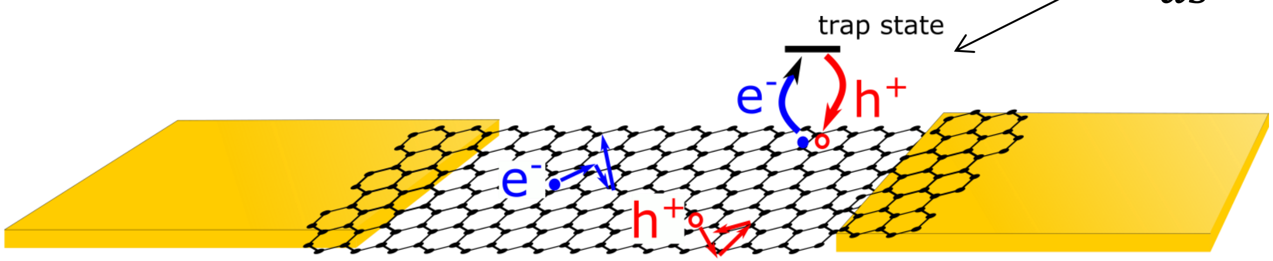
What is the origin of noise?

- Charge trapping-detrapping noise
- Mobility fluctuation noise

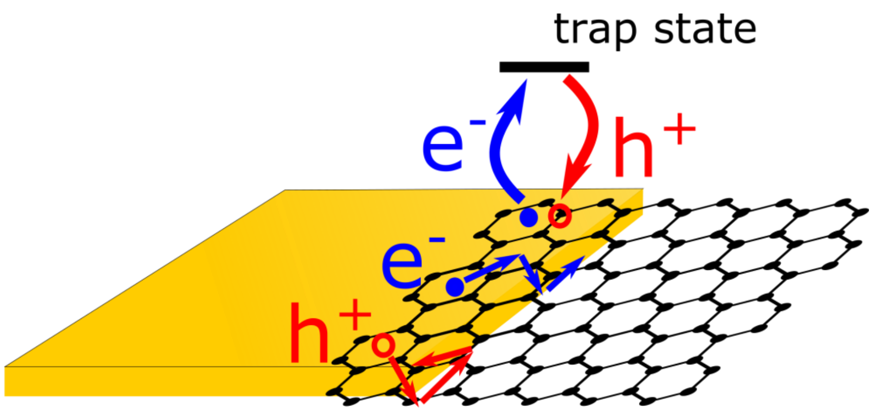
$$\frac{S_I|_{\Delta N}}{{I_{ds}}^2} \propto \frac{1}{n^2 A}$$



$$\frac{S_I|_{\Delta\mu}}{{I_{ds}}^2} \propto \frac{1}{A}$$

[Blandin. Nat. Nanotech. 2013 and Dmitriev et.al. J. Appl. Phys, 2009]

Is noise generated at the contacts?



$$\frac{S_{R_c}}{{R_c}^2} \overset{?}{\propto} \frac{1}{A_c n^2} \qquad \frac{S_{R_c}}{{R_c}^2} \overset{?}{\propto} \frac{1}{A_c}$$

If current was injected mainly through the edge of graphene it’d be one or another

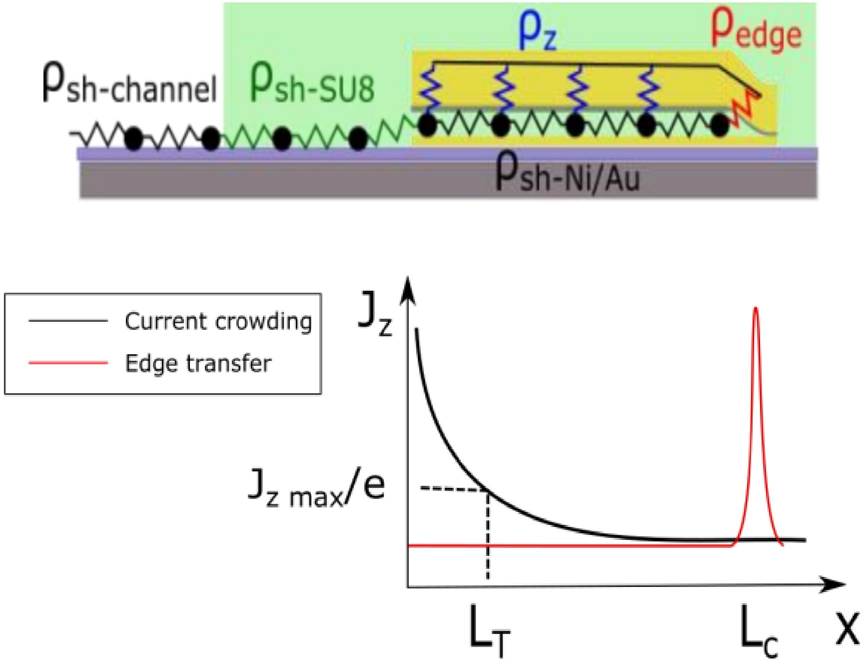
We want to **measure contact noise**

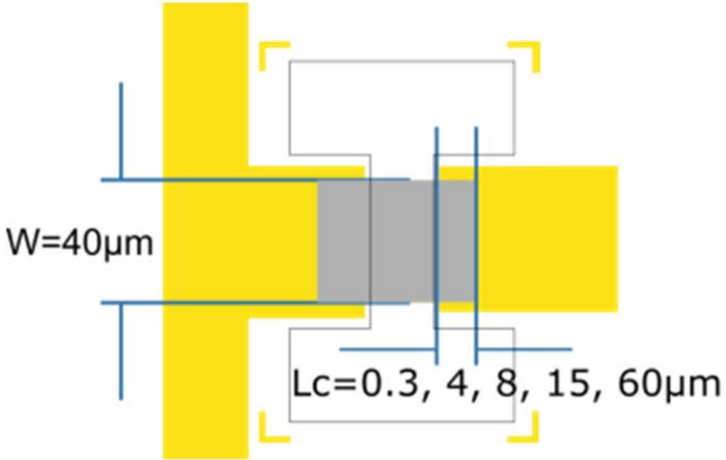
We want to **eliminate** it

What is the **geometric dependence** and **origin** of contact noise?

First, what is the **geometric dependence** of contact resistance?

- z-plane injection and edge injection have different geometry dependence





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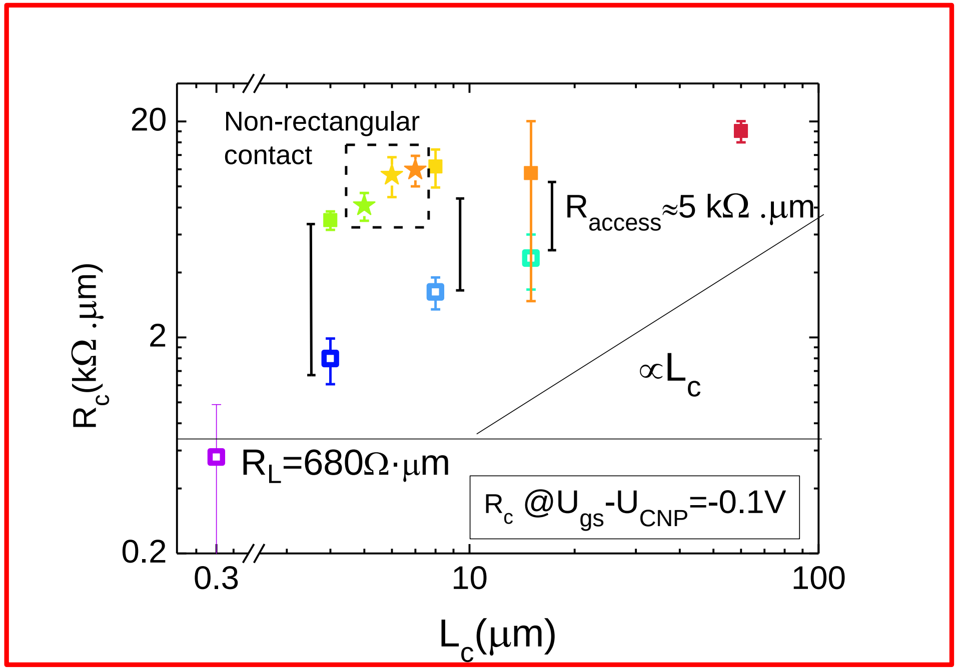
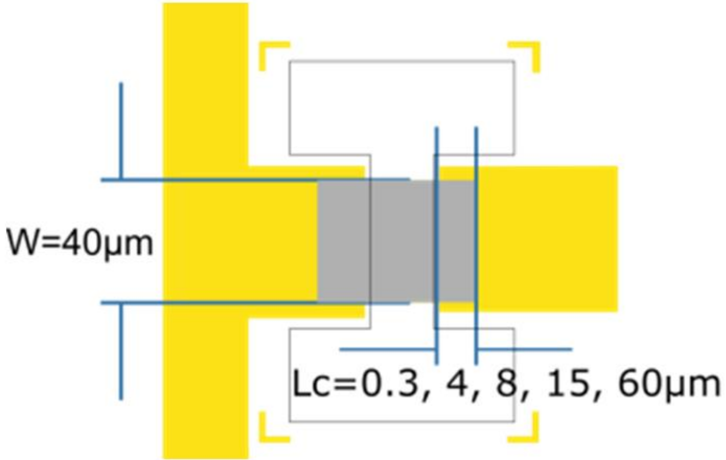


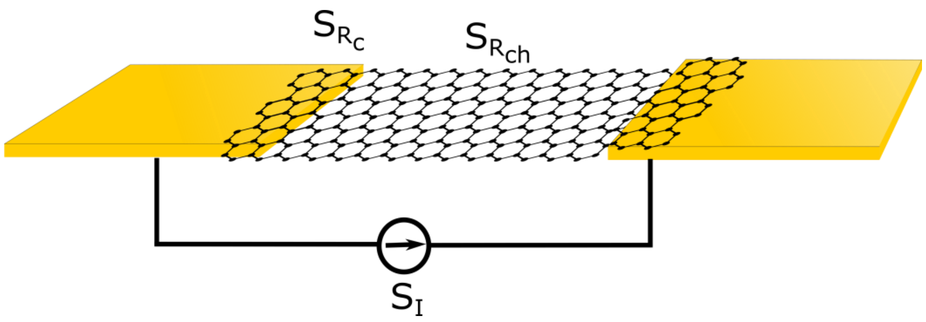


Injection through the edges dominates!

Then, what is the **geometric dependence** and **origin** of contact noise?

- Take the general equation:

$$\frac{S_I}{{I_{ds}}^2} = \frac{S_{R_c} + S_{R_{ch}}}{{R_T}^2}$$



- If charge trapping-detrapping dominates:

$$\frac{S_I}{{I_{ds}}^4} = \frac{k}{A_c {n_c}^2 {V_{ds}}^2} {R_c}^2 + \frac{k}{A_{ch} {n_{ch}}^2 {V_{ds}}^2} {R_{ch}}^2$$

- If contacts contribution dominates:

$$\frac{S_I}{{I_{ds}}^4} \propto L_c$$ **geometry**

$$\frac{S_I}{{I_{ds}}^4} \propto {R_c}^4$$ **origin**

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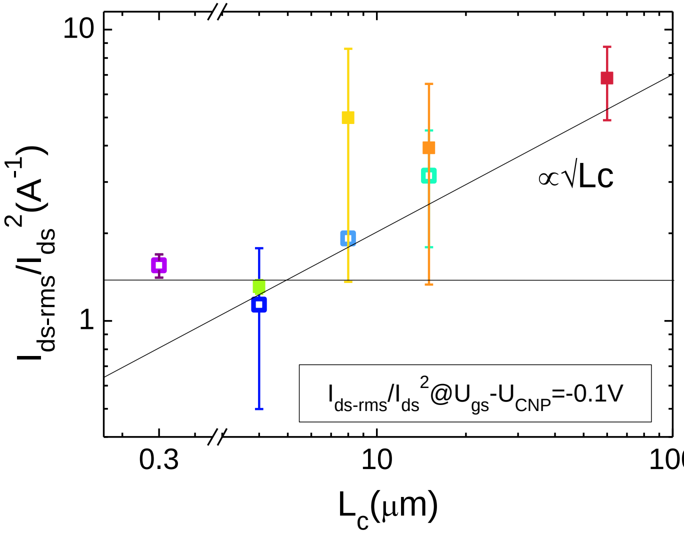
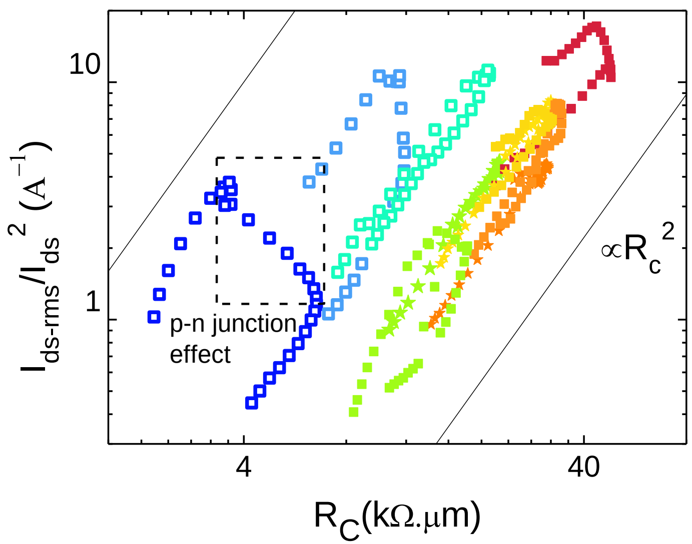
Geometry and origin of contact noise:

$$\frac{I_{rms}}{I_{ds}^{2}} \propto \sqrt{L_c}$$



Noise increases with Lc

$$\frac{I_{rms}}{I_{ds}^{2}} \propto R_c^{\,2}$$



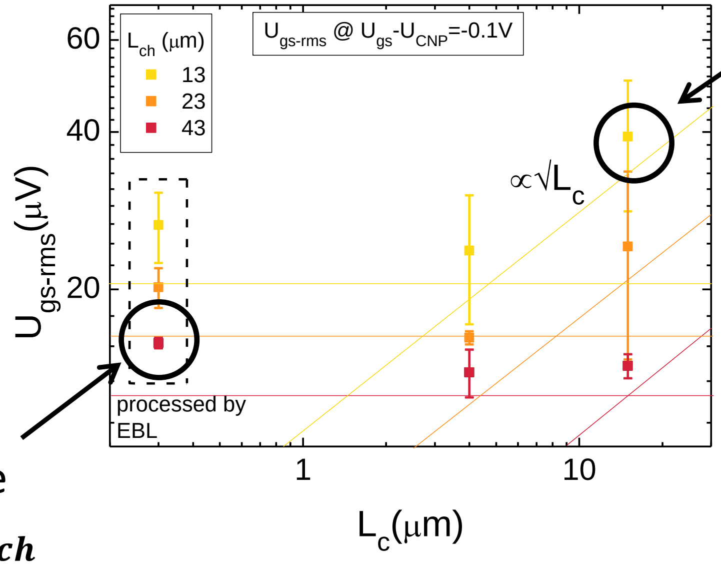
Charge trapping-detrapping noise

Can contact noise be **measured and reduced** by geometric design?

- From the general noise equation:

$$\frac{S_I}{{I_{ds}}^4} = \frac{kL_c}{{V_{ds}}^2 W^3} + \frac{kL_{ch}}{{V_{ds}}^2 W^3}$$

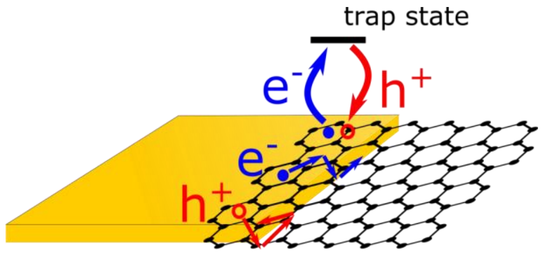
Contact noise can be measured if $\boldsymbol{L_c \gg L_{ch}}$



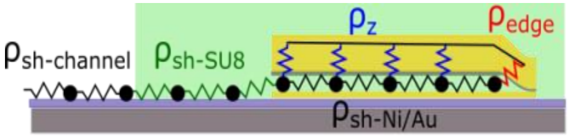
Contact noise can be minimized if $\boldsymbol{L_c \ll L_{ch}}$

To summarize

- There is a contribution from contacts to noise



- The geometric dependence of the contact resistance and noise can be determined by changing L_c



- The relative importance of the contacts contribution to noise can be changed by design