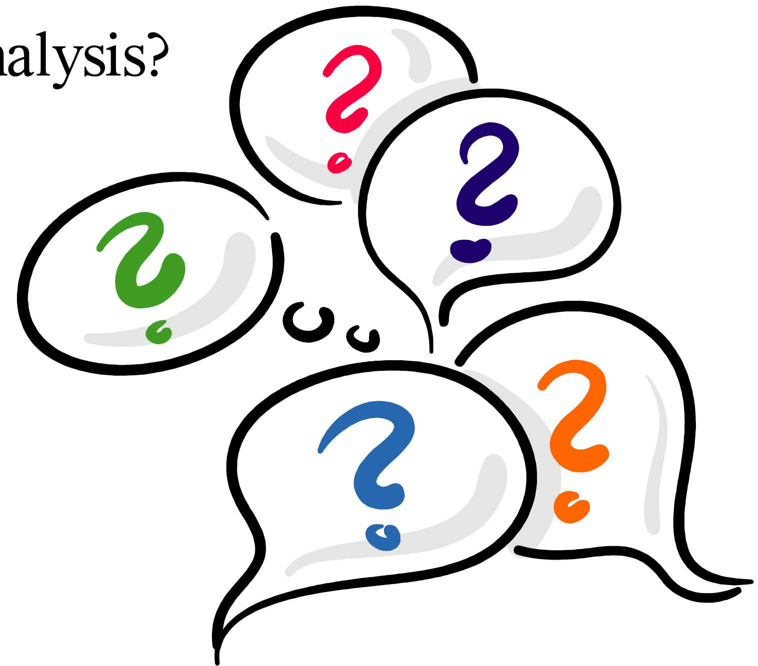
NOISE MODELING & SIMULATION

Flicker Noise in Deep Sub-micron MOSFETs

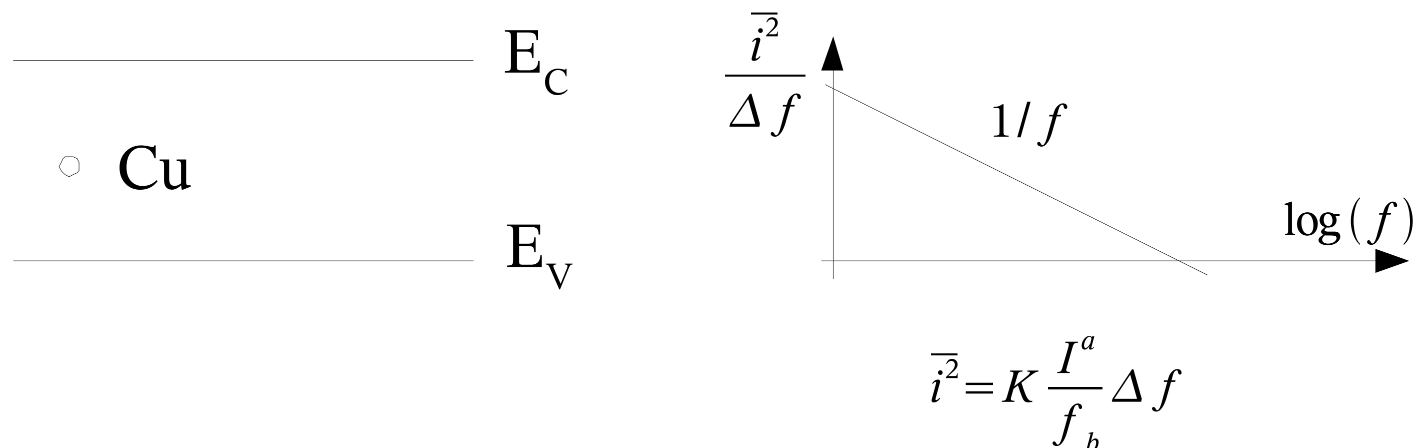
CIRCUIT DESIGNERS: WHAT DO WE NEED TO KNOW?

- Three key questions:
  - What exactly IS (flicker) noise?
  - How does it affect circuit operation (noise analysis)?
  - What are the pitfalls with noise analysis?



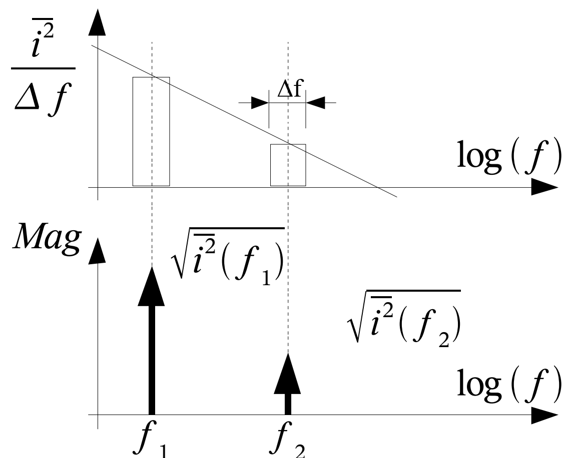
WHAT IS FLICKER NOISE?

- Caused by traps in semiconductor material
  - Due to contamination or crystal defects
- Has a 1/f power spectral density

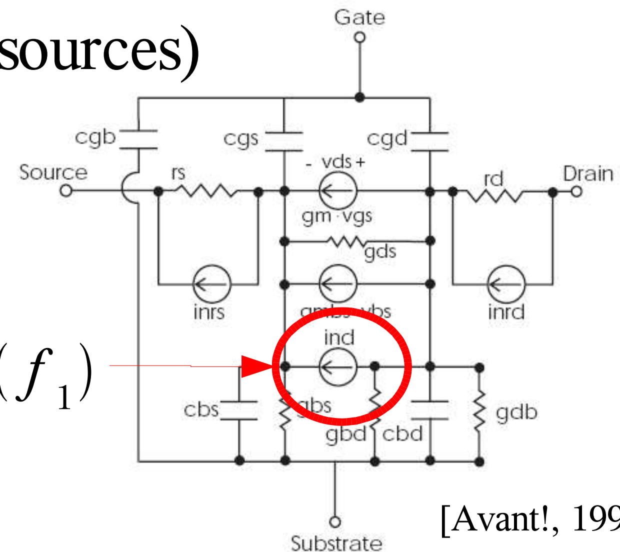


NOISE ANALYSIS

- Done with conventional (AC) circuit analysis techniques
  - Superposition principle
  - POWER is summed (non-correlated sources)

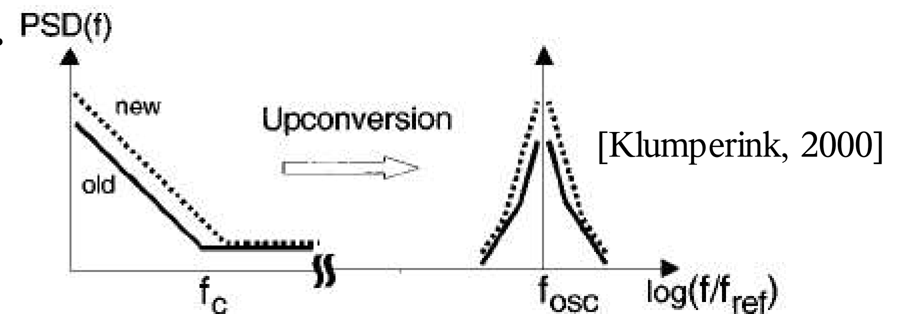


$$\sqrt{\overline{i^2}_{fl} + \overline{i^2}_{th}}(f_1)$$



[Avant!, 1999]

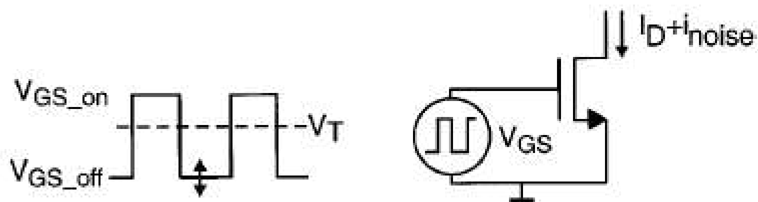
- Easily predict noise behaviour
  - Ex: upconversion

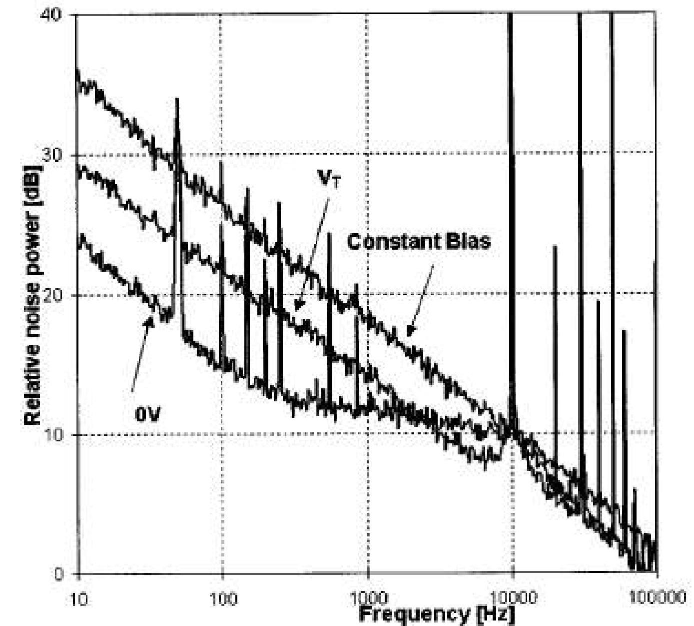


[Klumperink, 2000]

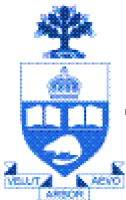
REDUCING 1/f NOISE

- Can we reduce 1/f noise?
  - Switched biasing reduces 1/f noise - reason is unknown
- New questions:
  - How do we simulate this effect?
  - How do we invent new techniques?
- For answers:
  - What IS noise?



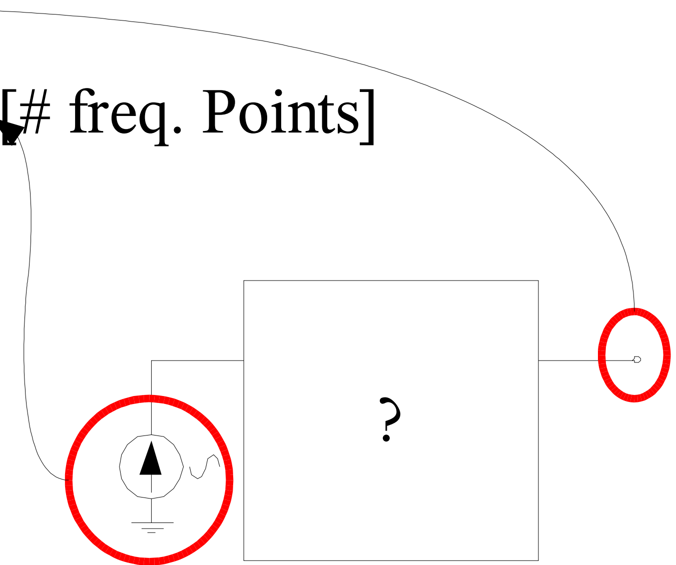


[Klumperink, 2000]



NOISE SIMULATIONS

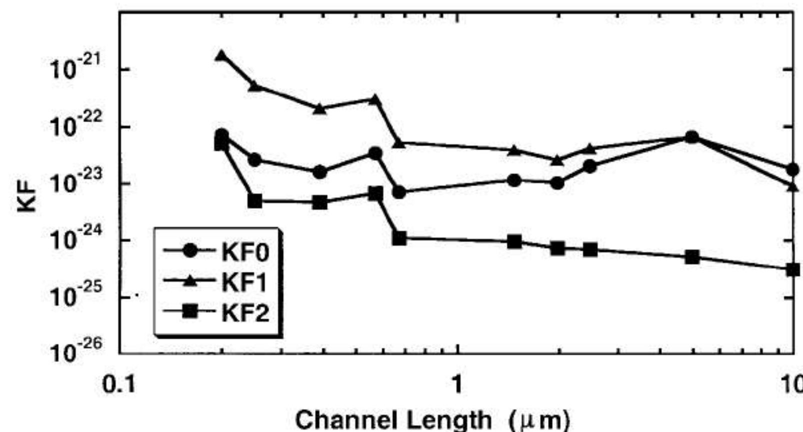
- HSPICE Analyses:
  - .NOISE [output node] [input I/V source] [# freq. Points]
  - .SAMPLE: for noise folding analysis
- HSPICE Outputs:
  - .PRINT NOISE [INOISE] [ONOISE]
  - .PLOT NOISE [INOISE] [ONOISE] [...]
  - .GRAPH: high resolution plots
  - .PROBE NOISE [INOISE] [ONOISE]



BASIC SPICE FLICKER MODELS FOR MOSFET CHANNELS

- Want to ensure accurate L dependance of models
  - Benchmark: KF parameter

NLEV	0	1	2 & 3
PSD	$\frac{\overline{i^2_{fl}}}{\Delta f}=\frac{KF0\cdot I_D^{AF}}{C_{OX}L^2 f}$	$\frac{\overline{i^2_{fl}}}{\Delta f}=\frac{KF1\cdot I_D^{AF}}{C_{OX}LW\,f}$	$\frac{\overline{i^2_{fl}}}{\Delta f}=\frac{KF2\cdot g_m^2}{C_{OX}LW\,f^{AF}}$

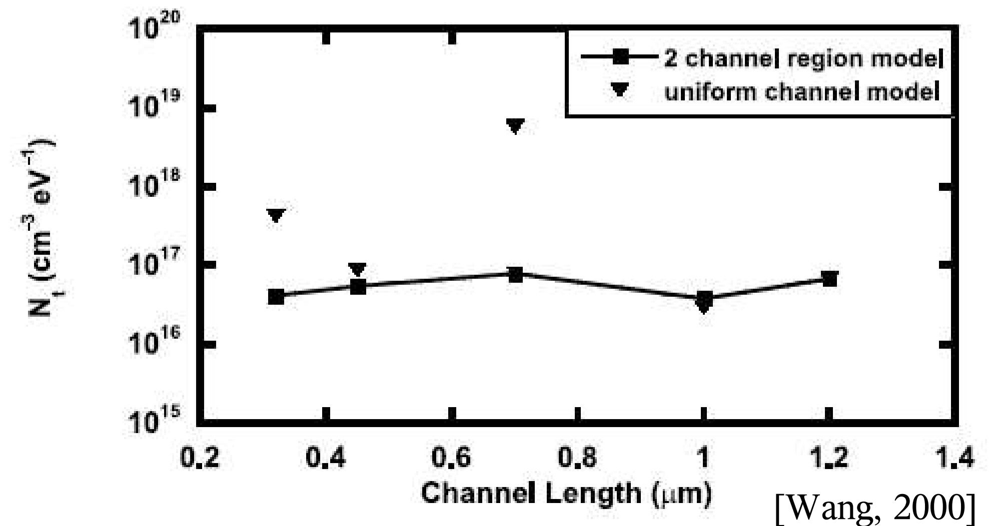


[Çelik-Butler, 1999]

- All bad models for deep sub-micron (No $1/L^3$ dependance)

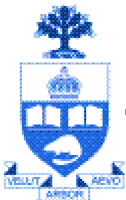
BSIM FLICKER MODEL FOR MOSFET CHANNELS

- Again, want to ensure accurate L dependance of models
  - New benchmark for BSIM3: trap density (N_t)
- Problem
  - Non-constant N_t
- Solution*
  - Dual V_T model (for MDD & channel regions)



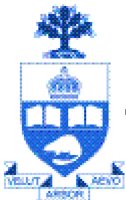
[Wang, 2000]

*Solution is not yet implemented (BSIM4 uses same model as BSIM3)



CONCLUSION: SHOULD WE EVEN TRY?

- Even with these problems, we can still use noise simulations as a guide. Simply be conscious:
  - For what devices are the models valid?
  - Noise simulations for small devices underestimate noise
  - Use larger devices with known characteristics if possible
- More effort should be put in understanding noise
  - Simulation results will be more accepted by designers
  - Might even find simple ways to reduce noise



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