SAFARI

Development of the

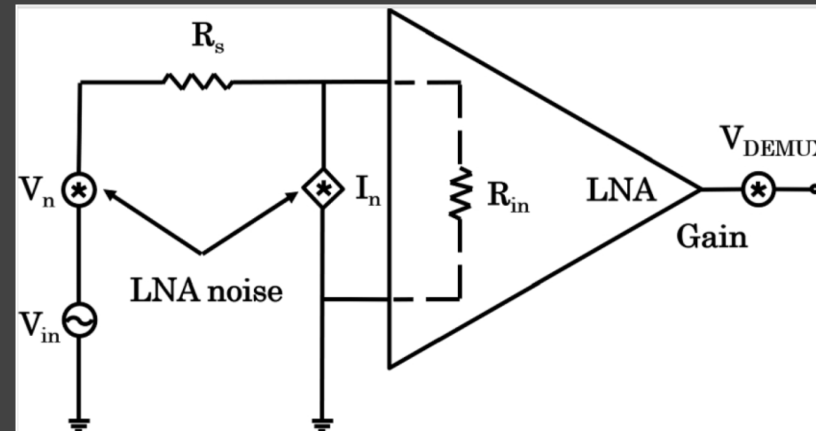
FDM Baseband Feedback

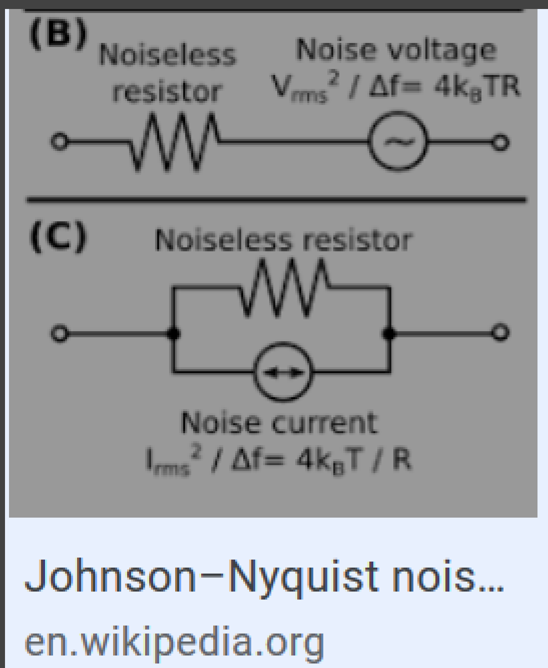
I. FEE Noise Model

SRON

Amin Aminaei, 28 September 2020

FEE Model



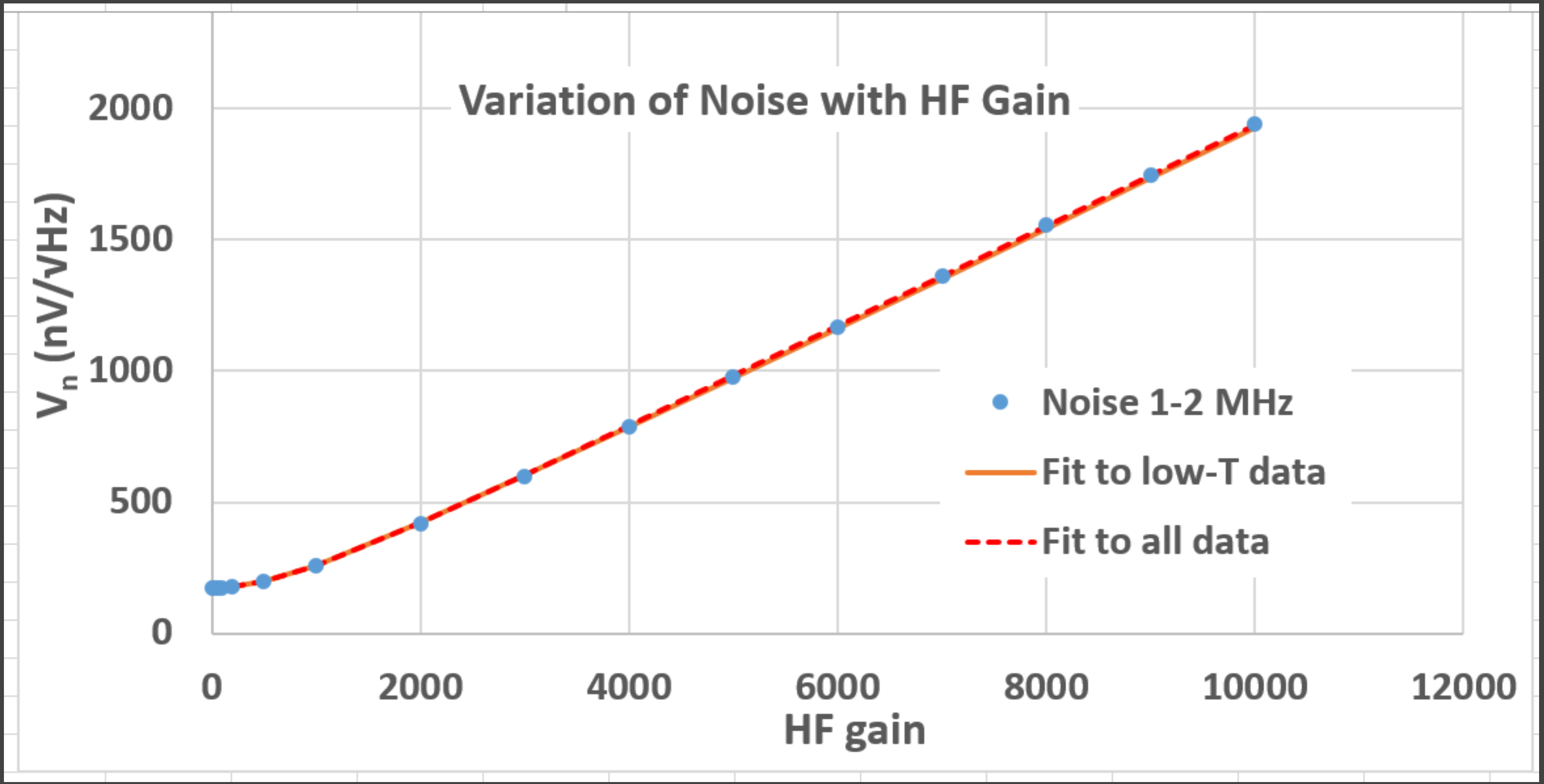


LNA: Vn=315pV/(Hz)^0.5
In=5.4pA/(Hz)^0.5
DEMUX Vn=173nV/(Hz)^0.5

Wang et al., 2020

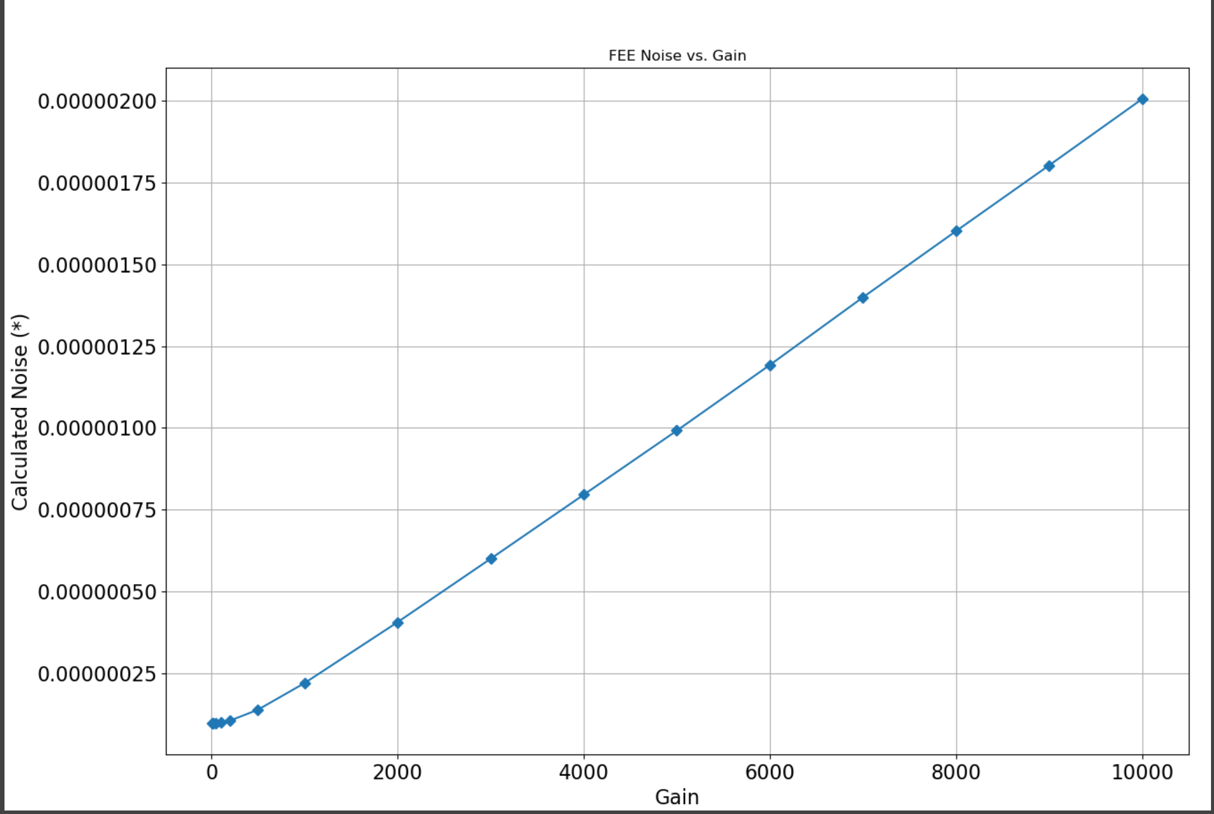
FEE7 Bandwidth is ~38.75 MHz, (Test Procedure FEE-7, SRON report, D. Boersma, 2014)
Analysis is initially done in FDM range

Measured Noise of FEE versus Gain.



Rin = 129 Ohm, Rs = 91.6 Ohm, T=1.3 K to 4K

T=1.3K-3.5K
Gain=10,100,1000,10000
(Test Points for LT-Spice)
R_{in}=129 Ohm
R_s=91.6 Ohm
In=5.4pA/rt.(Hz)
Vn=315pV/rt.(Hz)
$V_{n.Demux}$=173nV/rt.(Hz)
k_B=Boltzmann constant (1.38e-23)



If $R_{lead} \sim 0$

$$V^2_{Model} = V^2_{n.Demux} + Gain^2\,(I^2_n .\, R^2_s + V^2_n + 4.k_B\,.\,T.R_s).\,(R_{in}/(R_{in}+R_s))^2$$

$V^2_{Model} = V^2_{n.Demux}$ (Noise DEMUX) +

$Gain^2\,(I^2_n .\, R^2_s).\,(R_{in}/(R_{in}+R_s))^2)$ (FEE Current Noise) +

$Gain^2\,(V^2_n).\,(R_{in}/(R_{in}+R_s))^2)$ (FEE Voltage Noise) +

$Gain^2\,(4.k_B\,.\,T.R_s).\,(R_{in}/(R_{in}+R_s))^2$ (Rs Noise)

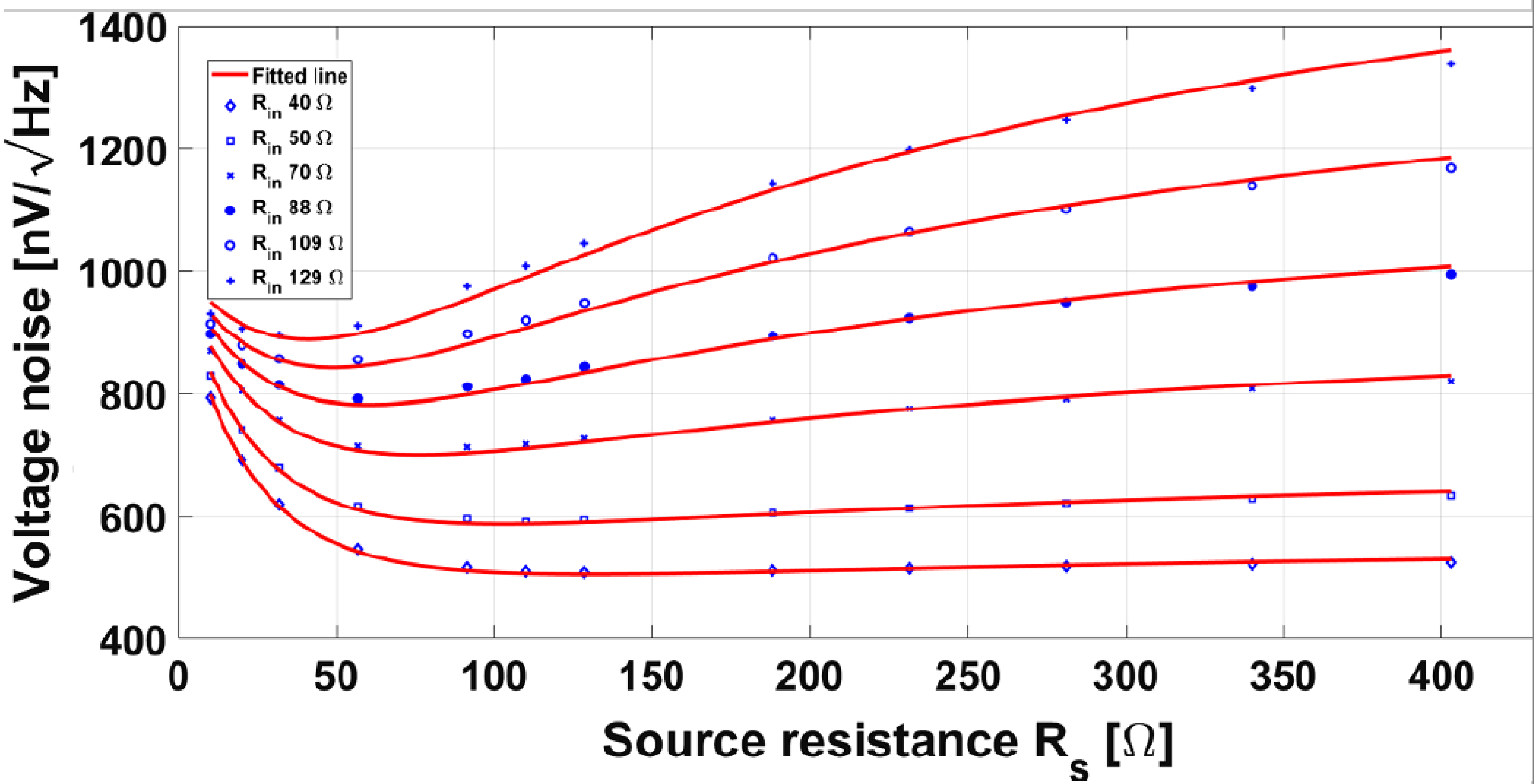
SRON

* 0.57 to match with the real data to be investigated

Noise vs. Rin, Rs

FEE which has 74-dB gain (5000) in the range 1–5 MHz and active input impedance

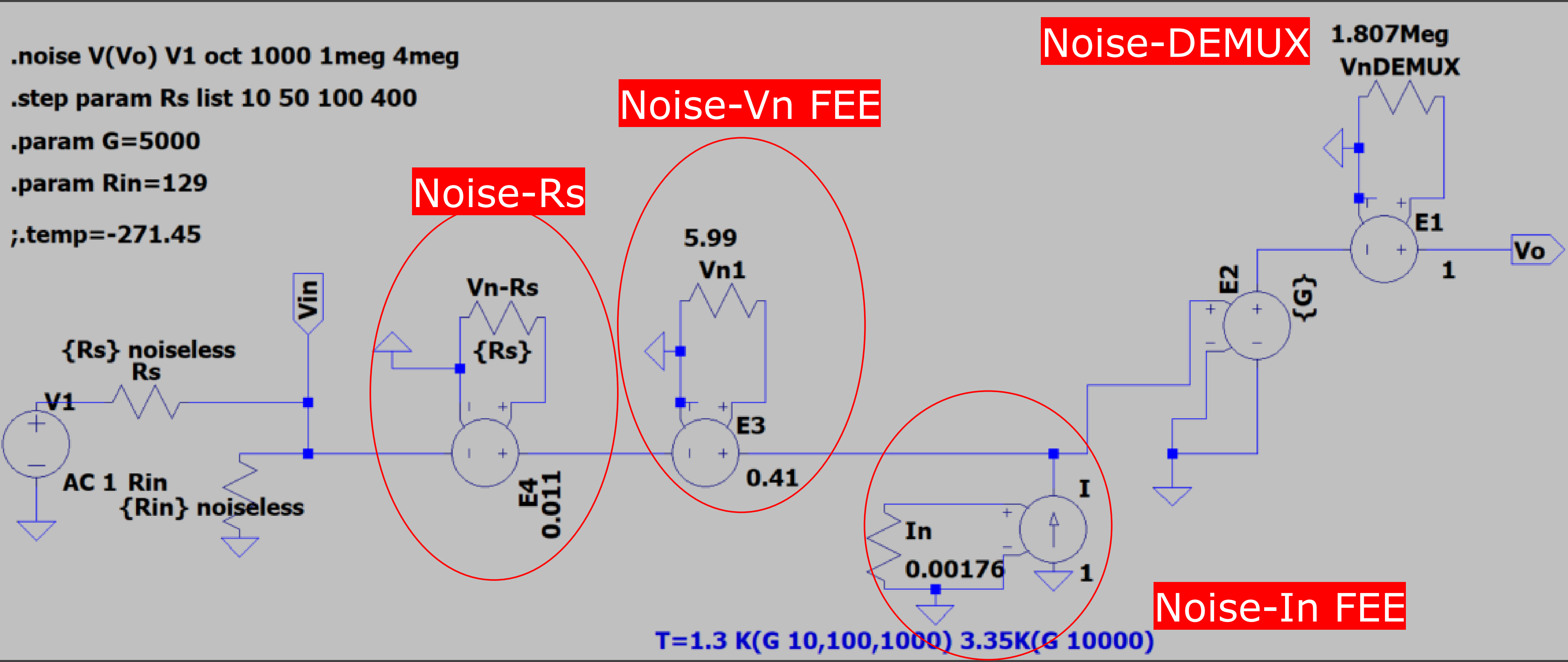
At 1.3 K, the output noise as a function of R_s with different R_{in}. The fitted current noise is $5.4 \pm 0.1\ \mathrm{pA}/\sqrt{\mathrm{Hz}}$, while the fitted voltage noise $315 \pm 10\ \mathrm{pV}/\sqrt{\mathrm{Hz}}$, both identical to the fitted parameters at 50 mK. (Color figure online)

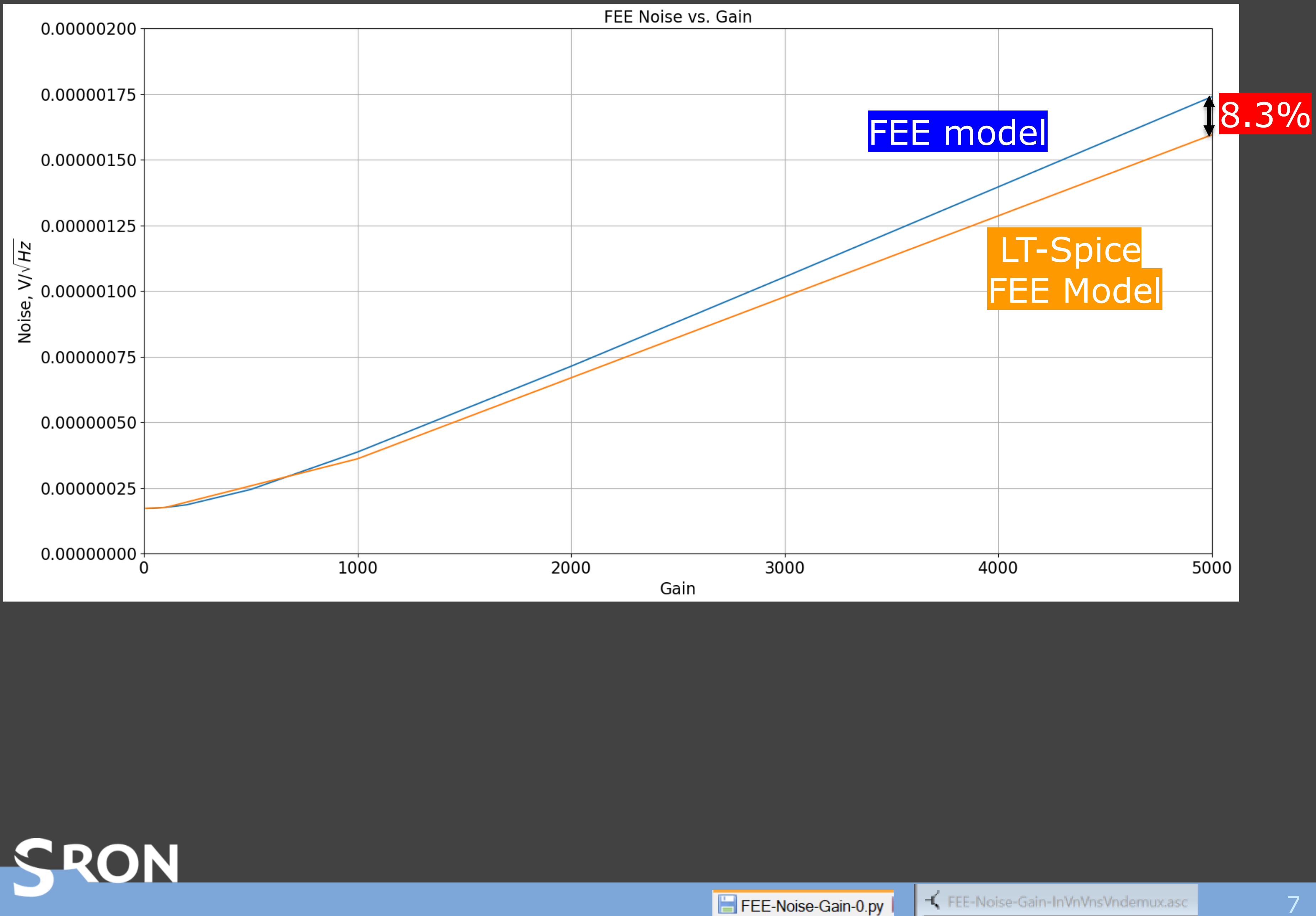


The best fits in Fig. 5 illustrate the identical (within the uncertainty) current noise and the voltage noise of the LNA as what we found from 50 mK data, confirming the model. Thus, we have now derived the noise data of our LNA.

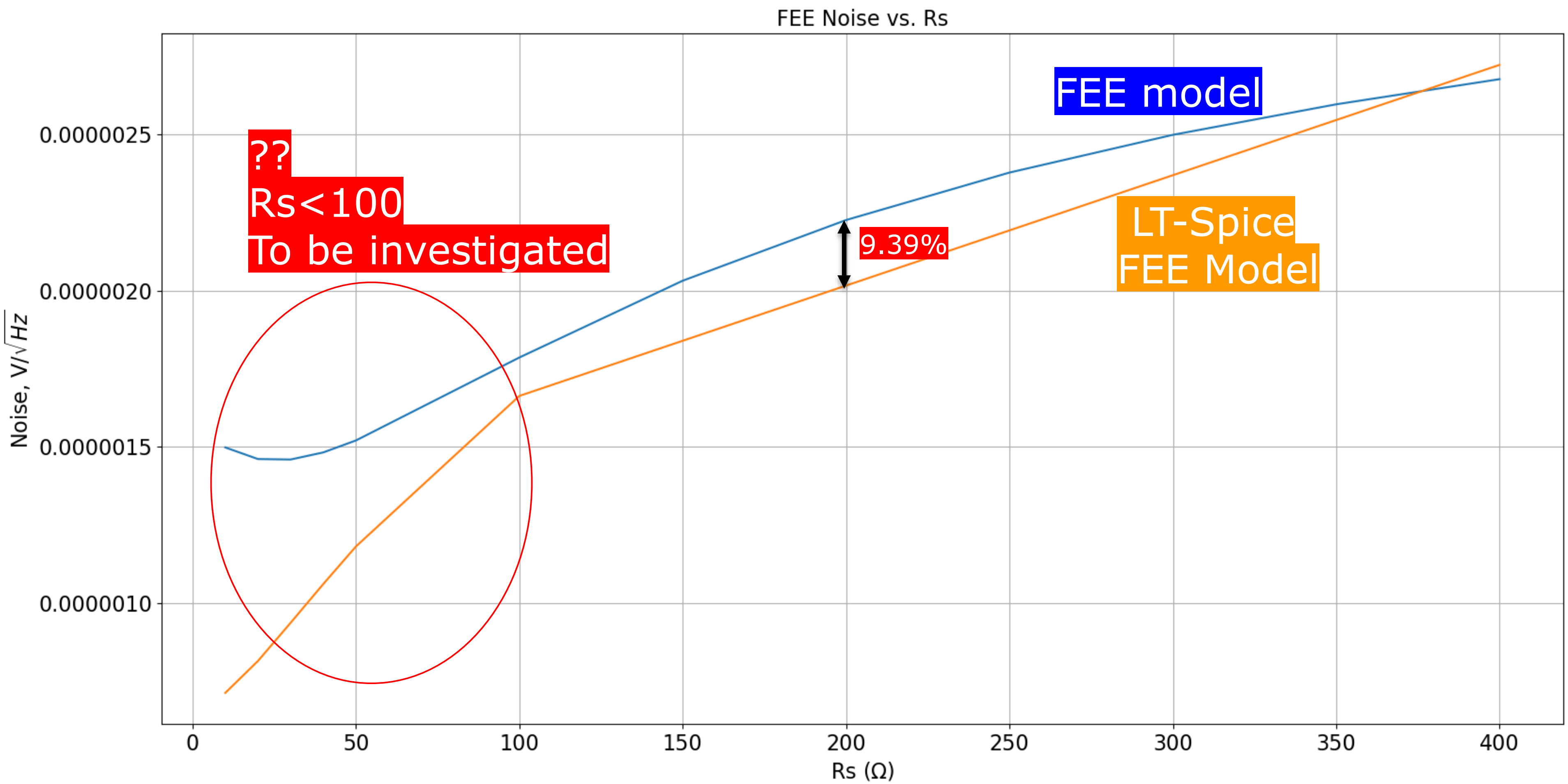
after Wang et al., 2020

LT-Spice Model



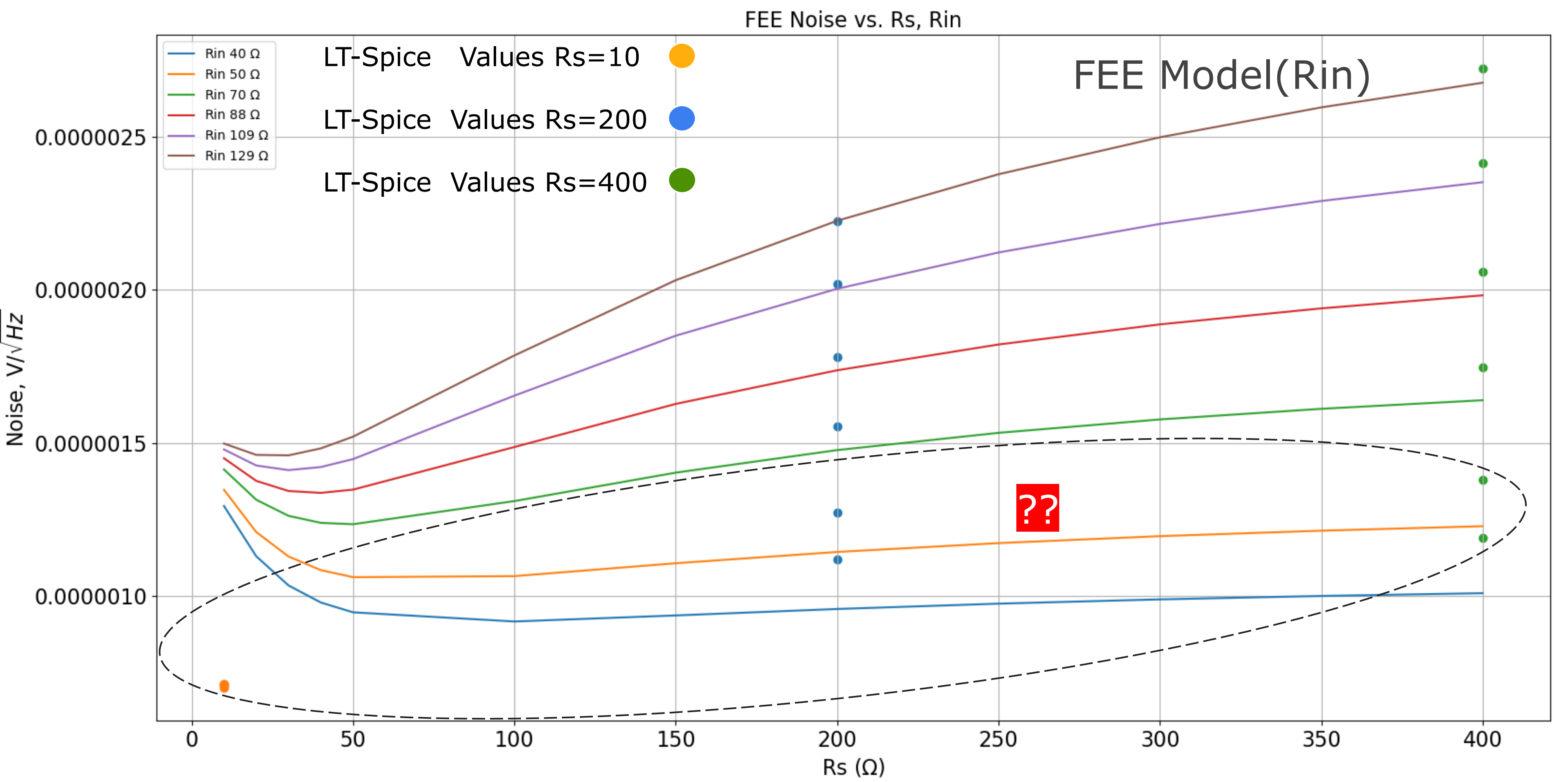

FEE Noise vs. Gain
Noise, $V/\sqrt{Hz}$
0.00000200
0.00000175
0.00000150
0.00000125
0.00000100
0.00000075
0.00000050
0.00000025
0.00000000
0
1000
2000
3000
4000
5000
Gain
FEE model
8.3%
LT-Spice
FEE Model
FEE-Noise-Gain-0.py
FEE-Noise-Gain-InVnVnsVndemux.asc

SRON

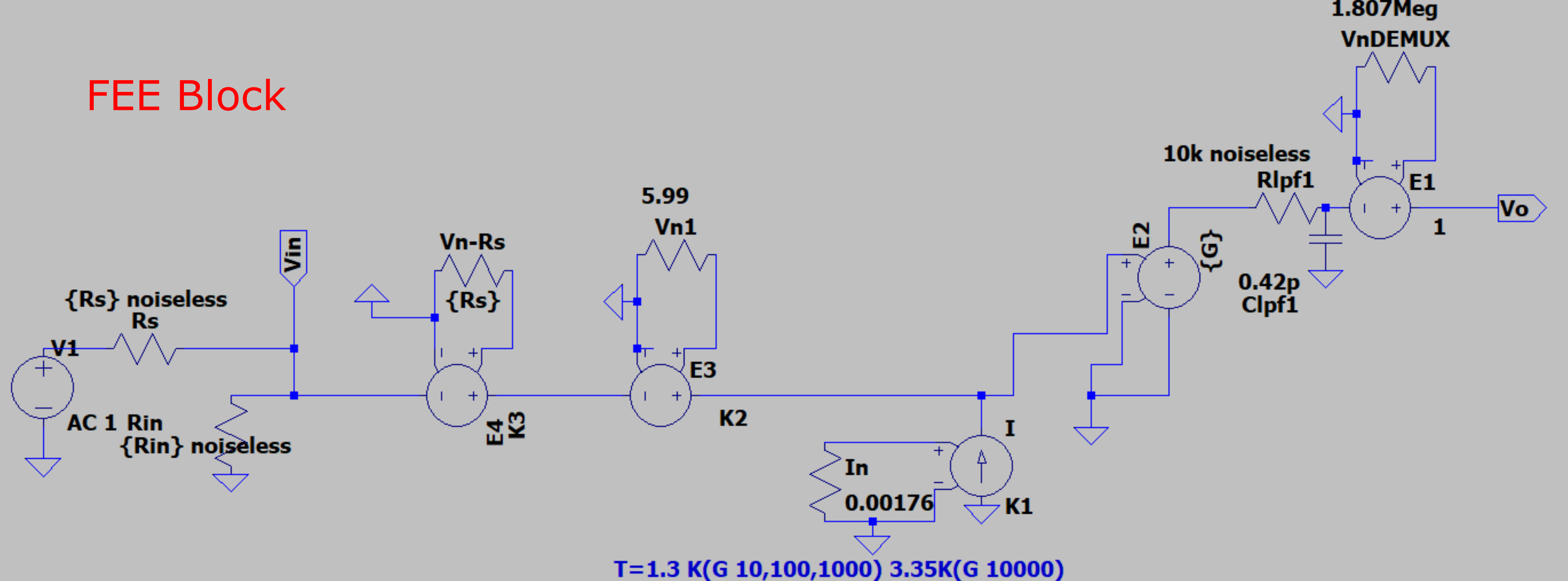


FEE-Noise-Gain-InVnVnsVndemux-Rs.asc

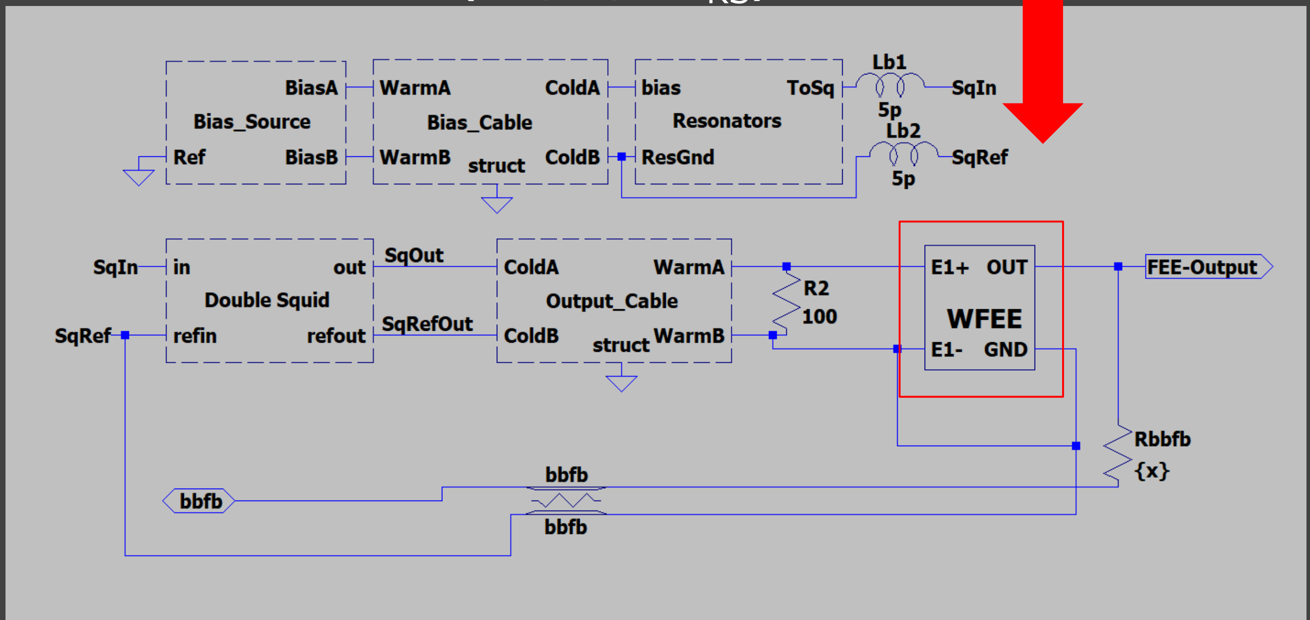
FEE-Noise-Rs.py


FEE Noise vs. Rs, Rin
Rin 40 Ω
Rin 50 Ω
Rin 70 Ω
Rin 88 Ω
Rin 109 Ω
Rin 129 Ω
LT-Spice Values Rs=10
LT-Spice Values Rs=200
LT-Spice Values Rs=400
FEE Model(Rin)
??
0.0000025
0.0000020
0.0000015
0.0000010
Noise, V/√Hz
0
50
100
150
200
250
300
350
400
Rs (Ω)

FEE Block



The LTSpice FEE Transformed Noise values (Vn,In, Vn_{RS}) is extracted from the Noise Model written in Python to match the measurement.



FEE block also includes Vndemux, Gain, Bandwidth, Rs, Rin.
To be used for FDM BBFB.

- Backup Slides

$R_{\_Lead}$

$V^2_{measured}$ =
V^2_{Demux} + $Gain^2\,(I^2_n .\, R^2_s + V^2_n + 4.k_B \,.\, T.(R_s - R_{lead}) + 4.k_B \,.\, T_{lead} .\, R_{lead}) .$
$(R_{in}/(R_{in} + R_s))^2)$

Rlead=0.5 Ohm

Tlead=100K

If $R_{lead} \sim 0$
(Test points)

$V^2_{measured} = V^2_{Demux} + Gain^2\,(I^2_n .\, R^2_s + V^2_n + 4.k_B \,.\, T.R_s).\,(R_{in}/(R_{in} + R_s))^2)$

T=1.3K, Gain=5000, R_{in}=88, R_s=10-400 Ohm

In=5.4pA/root(Hz)

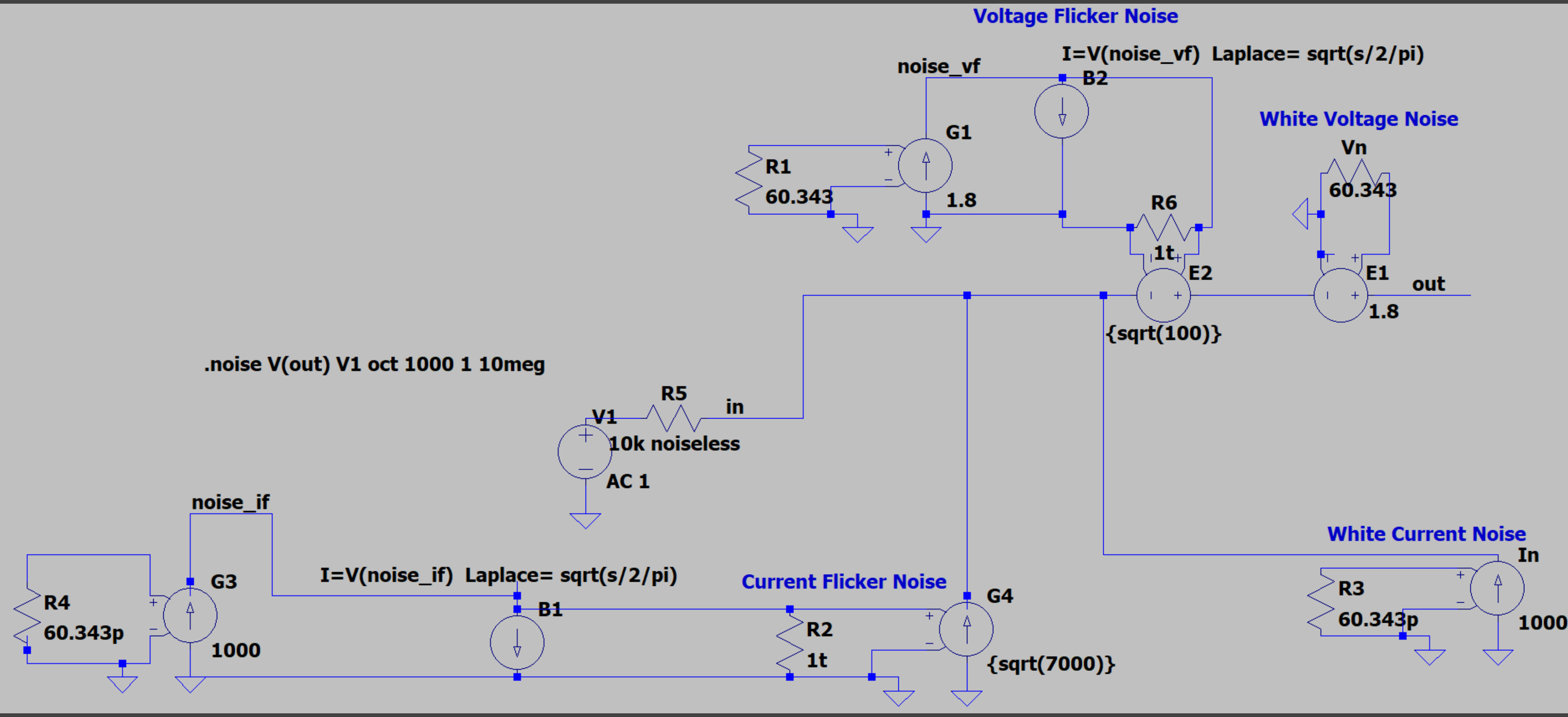
Vn=315pV/root(Hz)

V_{demux}=173nV/root(Hz)

k_B=Boltzmann constant
(1.38e-23)

SRON

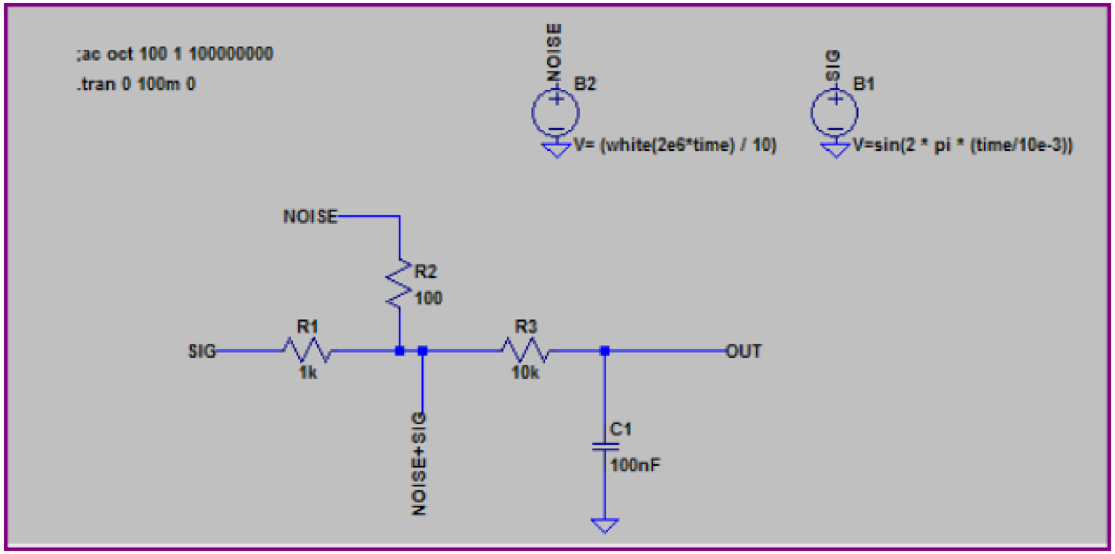
Flicker Noise, Thermal Noise Simulation for a commercial Amplifier



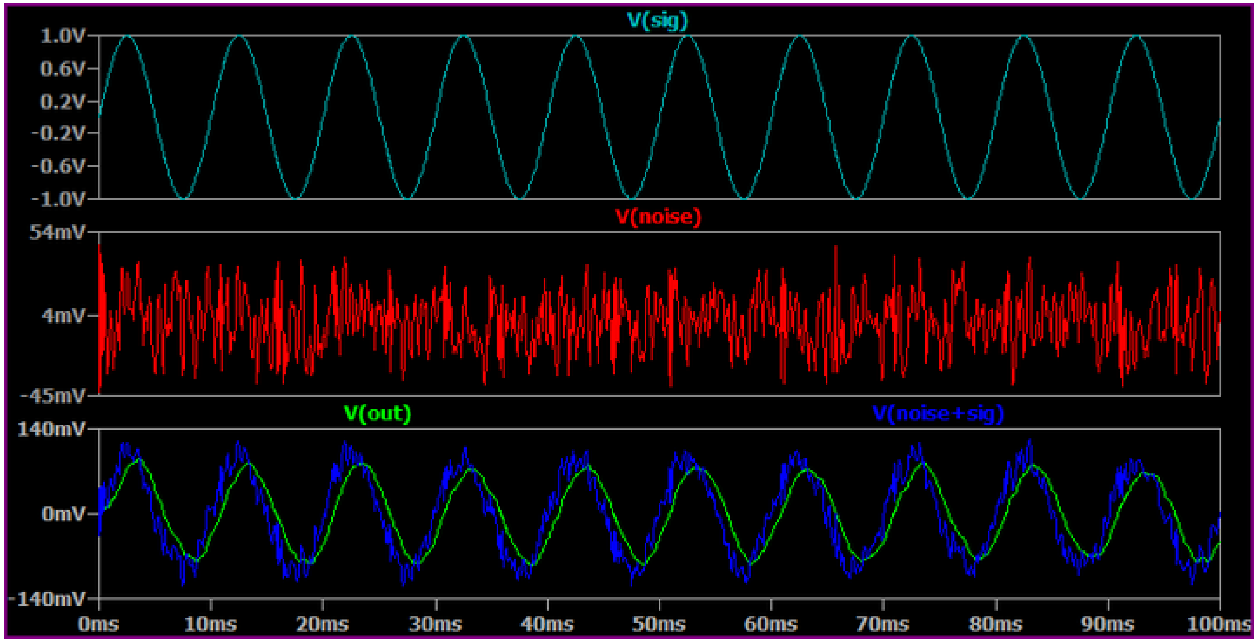
OPA838 input noise model

Reproduced from [2]

Transient Noise Analysis LT-Spice



Simulation:



SRON

After [3]

References:

- [1]

Wang et al., 2020

- [2]

https://axotron.se/blog/voltage-and-current-noise-sources-in-ltspice-noise-simulations/

- [3] https://electronics.stackexchange.com/questions/55233/how-do-you-simulate-voltage-noise-with-ltspice

- [4]

https://www.allaboutcircuits.com/technical-articles/how-to-perform-transient-analysis-noise-simulation-LTspice/

SRON