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Low Frequency Noise Measurement and Noise Modeling

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BIP -AK

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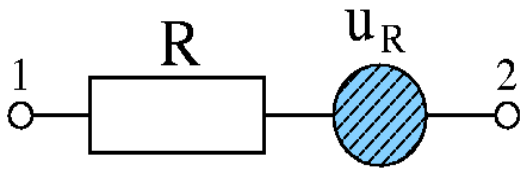
A leap ahead in mixed signal

Outline

- Noise Sources
- Measurement Principle
- Noisebox
- Noise Measurements
- Noise Parmeter Extraction

Resistor Noise

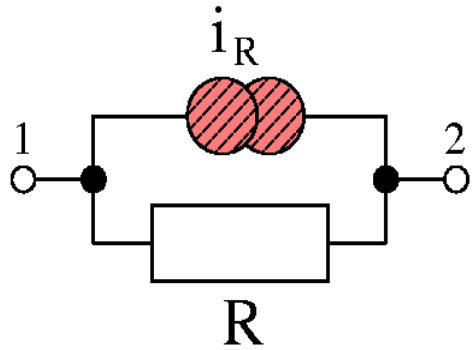
Voltage Noise Source



$$u_R = \sqrt{4kTBR}$$

$$S_{u_R} = \frac{u_R^2}{B} = 4kTR$$

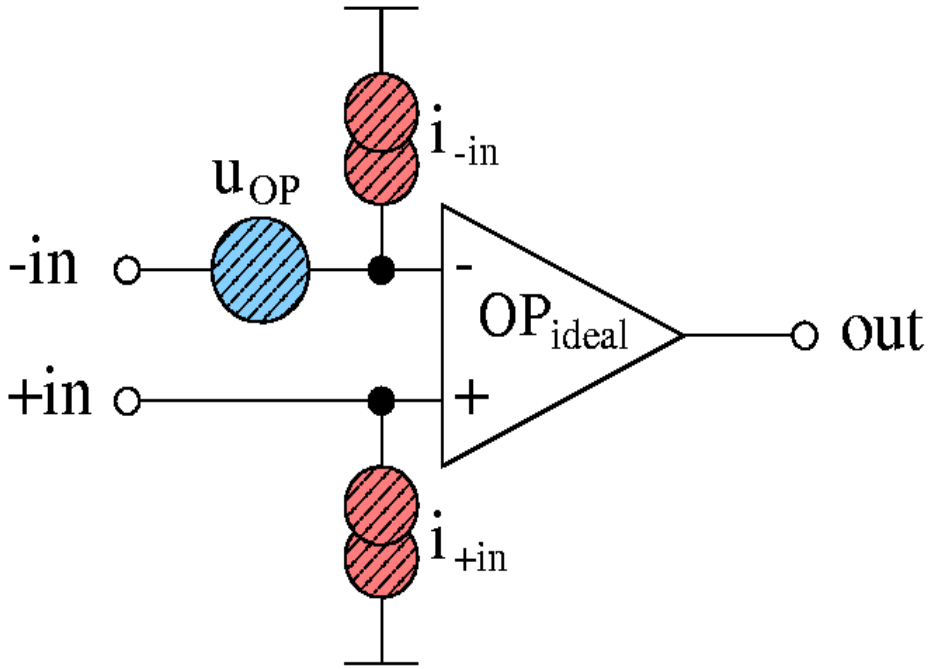
Current Noise Source



$$i_R = \sqrt{\frac{4kTB}{R}}$$

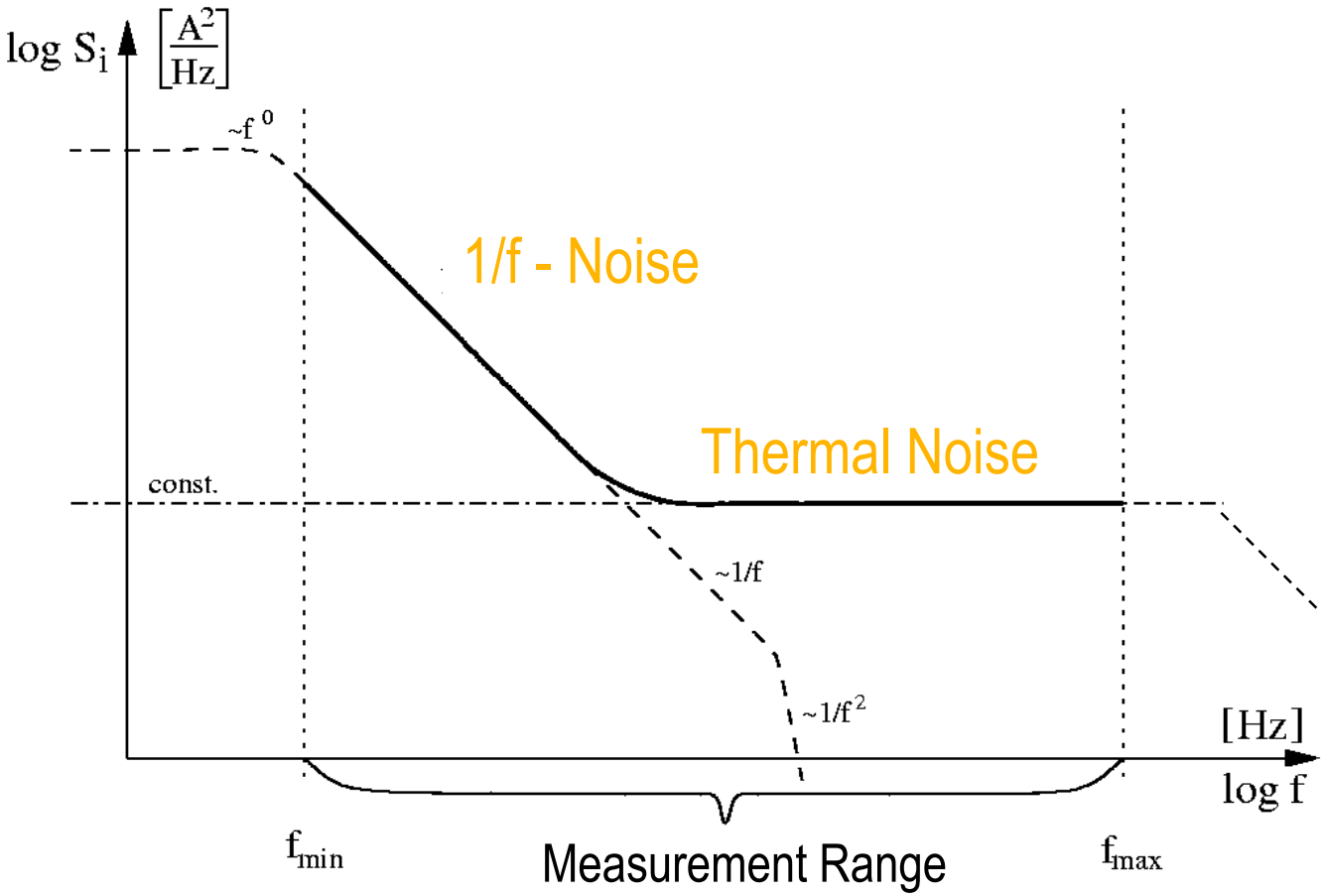
$$S_{i_R} = \frac{i_R^2}{B} = \frac{4kT}{R}$$

Operational Amplifier Noise

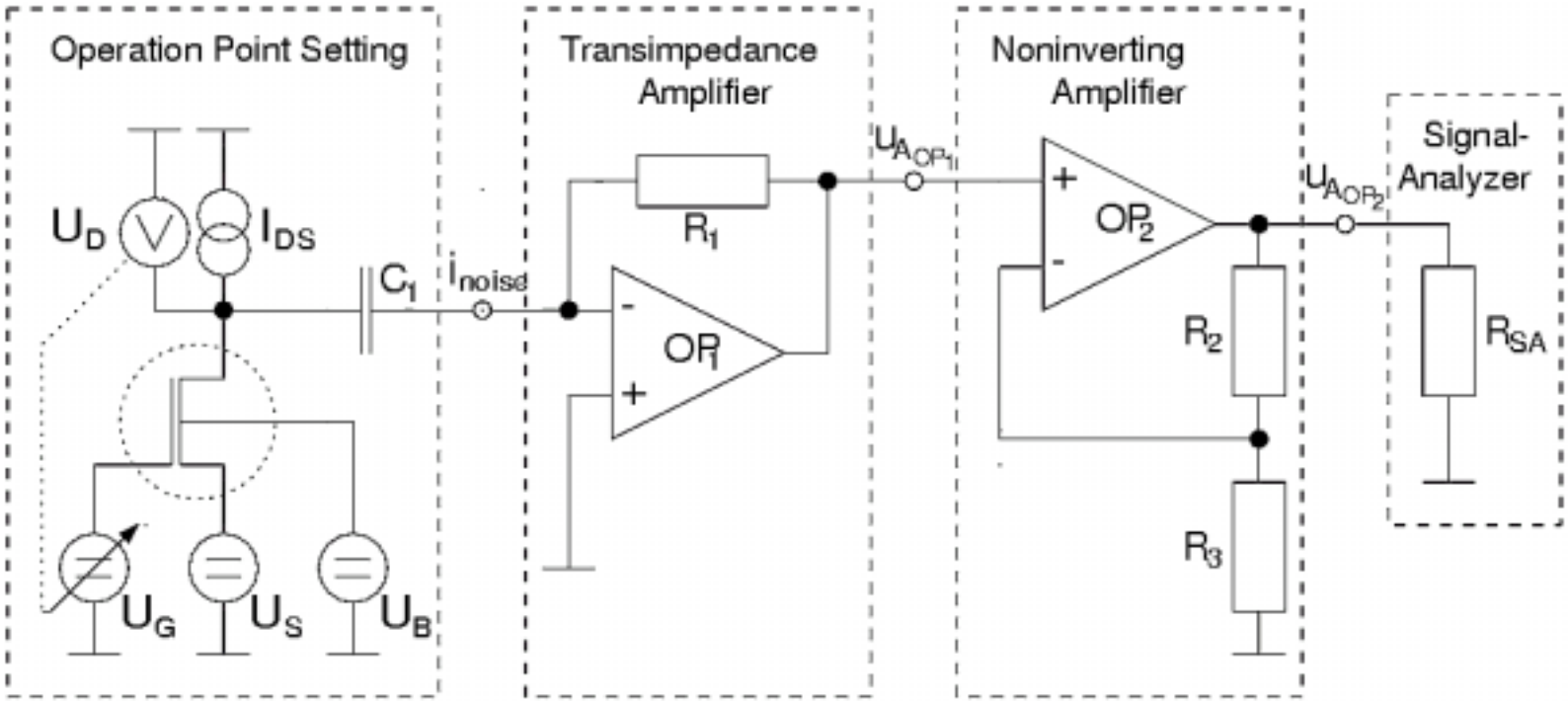


All noise sources are placed on the input of an ideal operational amplifier

Flicker Noise and Thermal Noise



Measurement Principle



Dimensioning

- Minimum Current Noise for a BIP Transitor with Ic=0.5µA

$$i_{n,min\,BIP} = \sqrt{2 \cdot q \cdot I_c} = \sqrt{2 \cdot 1.6E-19 \cdot 5E-7} = 0.4 \frac{pA}{\sqrt{Hz}}$$

- The ohmic resistance on measurement node i_{NOISE} must exceed

$$R_{input} = \frac{4kT}{i_{n,min}^{\ 2}} \geq 500k\Omega$$

- A Signal Analyzer has a voltage noise range of $u_{SA,min} \approx 1 \frac{\mu V}{\sqrt{Hz}}$

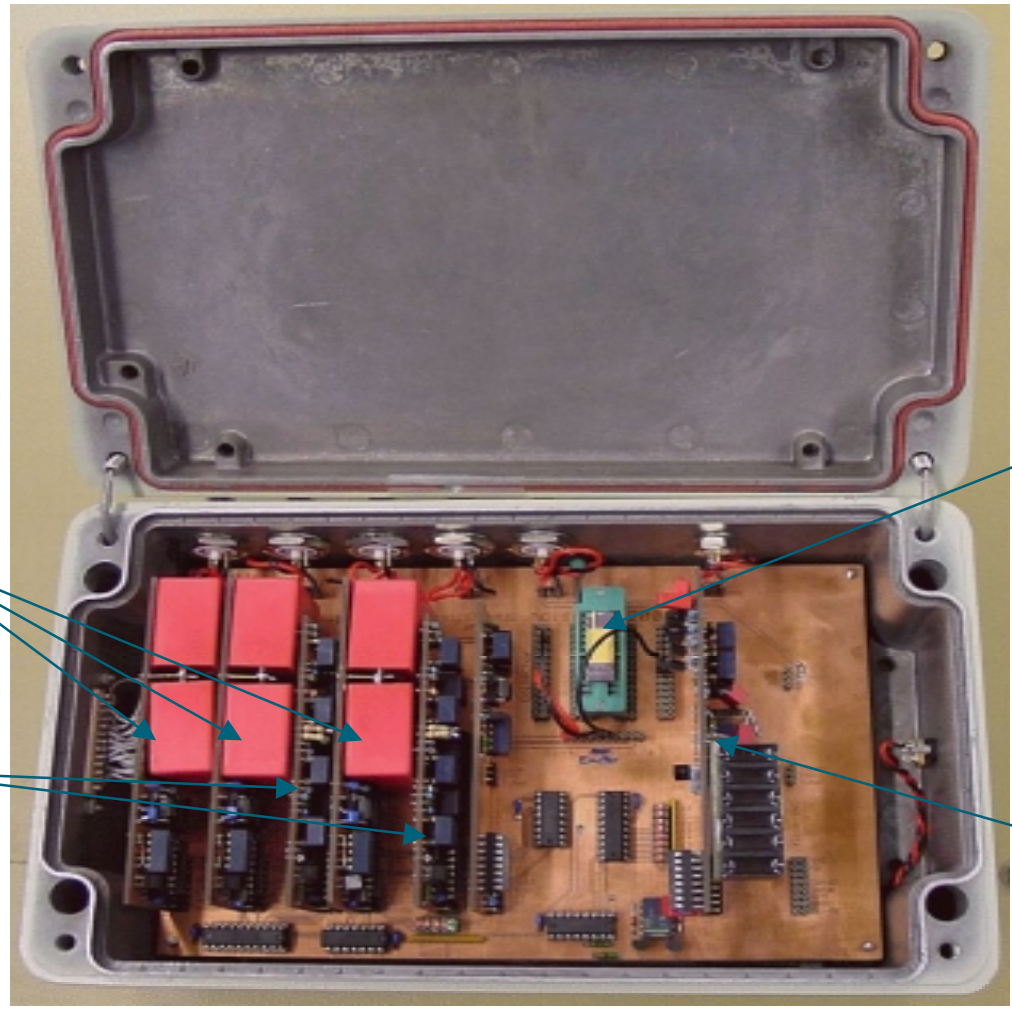
Noisebox Features

- Current Range: 500nA to 10mA
- Frequency Range: 1Hz to 100kHz
- Noise Levels down to 0.2 pA/sqrt(Hz)
- Measurement Devices MOS, BIP, Resistor
- Parameter Extraction SPICE and BSIM3V3 Model
- Rbb Extraction for BIP Transistors

Noisebox Main Parts

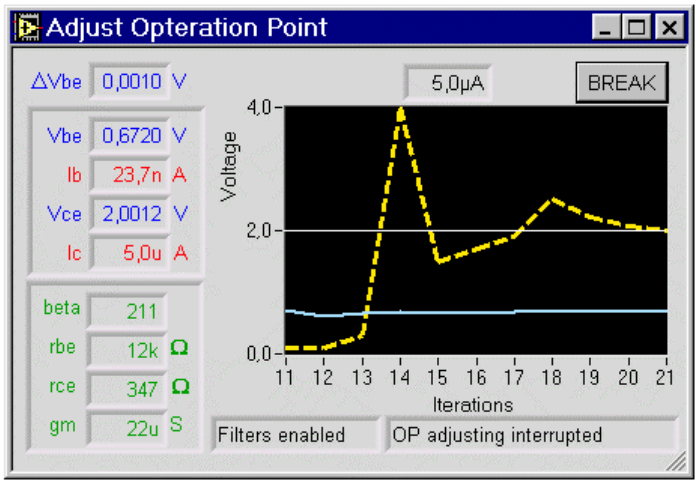
- Shielded Box
- Modular Design
- Active Filtered Sources
- High Resolution Noise Amplifier
- Controlled by PC Software
- Fully Automatic Measurements

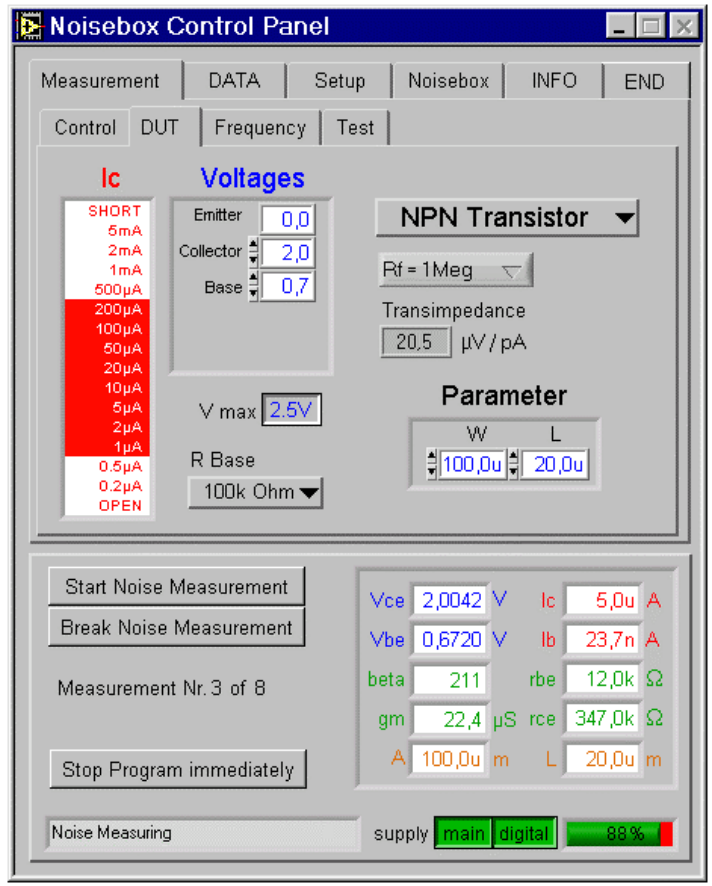
Noisebox Rev.3



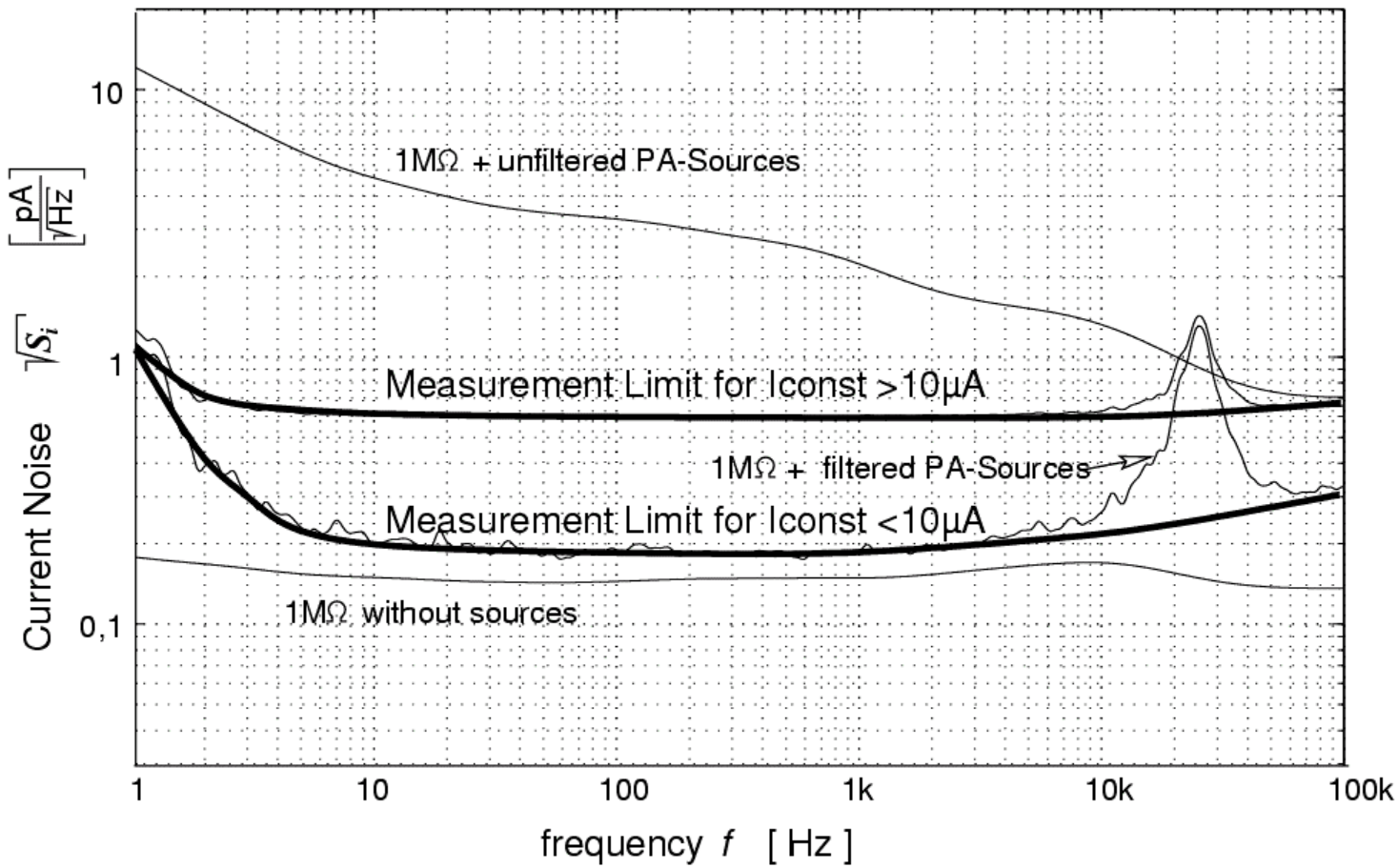
Noisebox Software

- Measurement Setup
- Adjust Operation Point
  including Parameter Measurement
- Noise Measurement
  including Measurement Correction
- Parameter Extraction



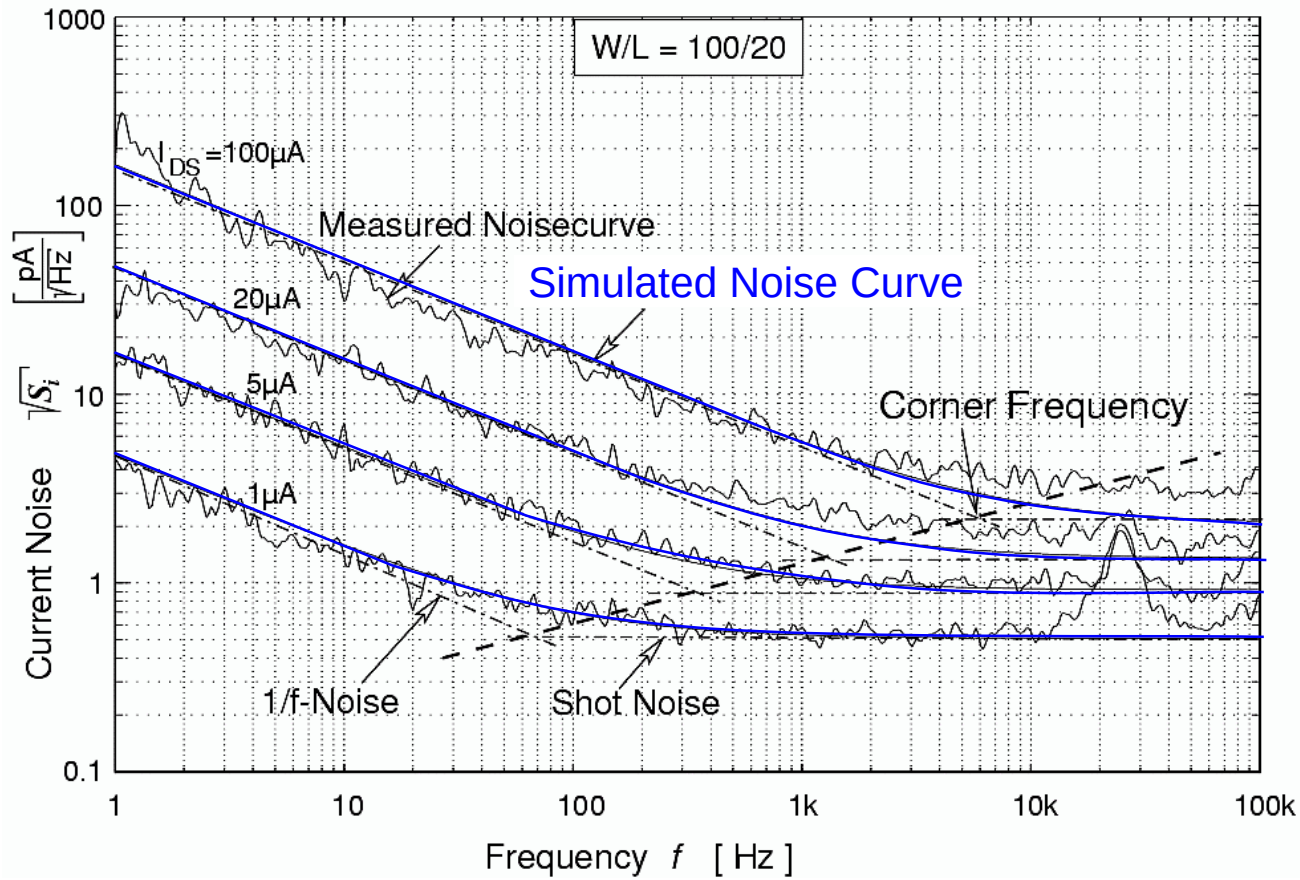


Noisebox Measurement Range



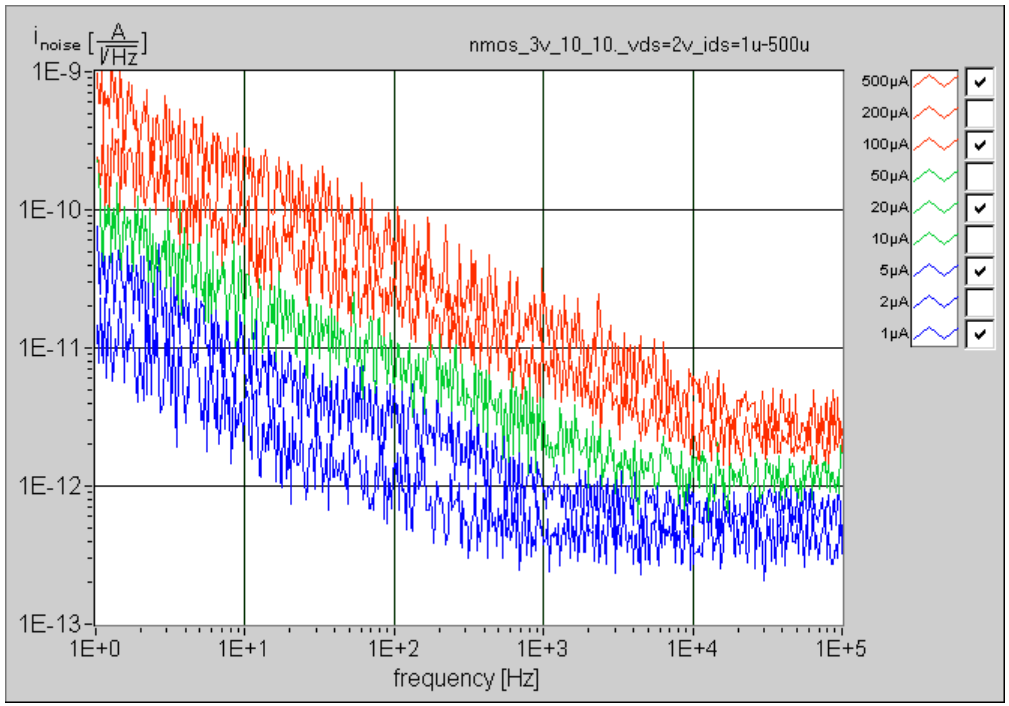
Noisebox resolution limits for different operation points

MOS Transistor



Typical current noise of a NMOS transistor for different drain currents

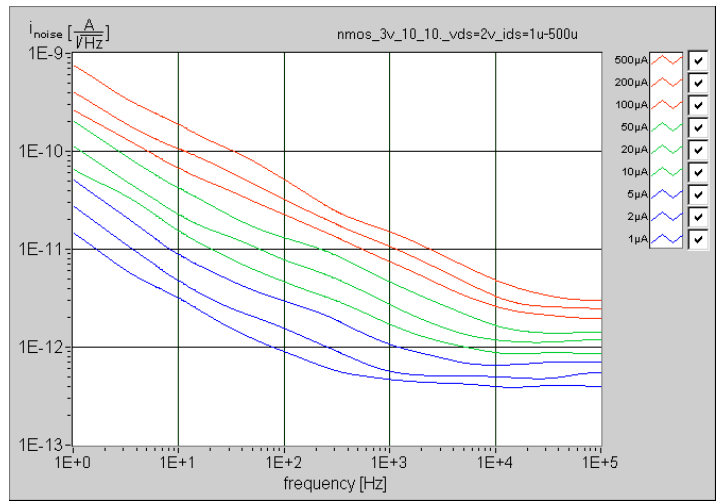
Measurement Correction



- Elimination of Outliers
- Gain Correction
- Filter Correction
- Smooth Measurement

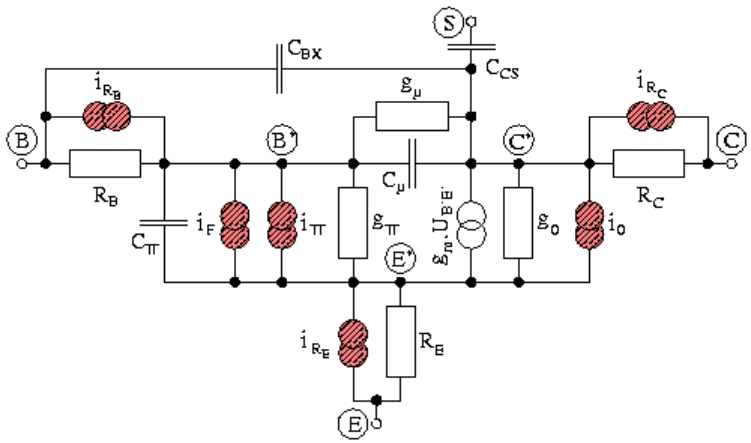
NMOS Transistor W/L = 10µm/10µm

measured and smoothed



Noise Sources for BIP Transistor

Small Signal Equivalent Circuit



$S_{iRB} = 4 \cdot k \cdot T/RB \cdot A^2$

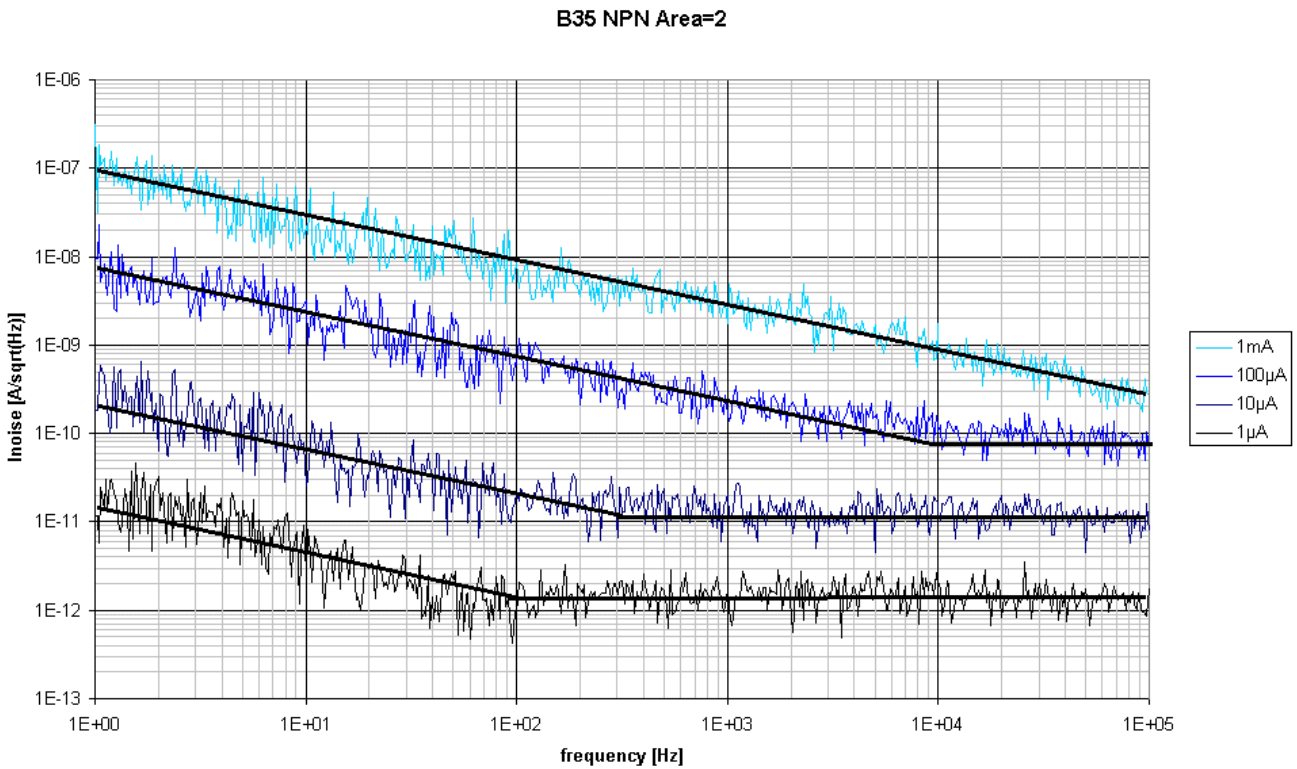
$S_{i\pi} = 2 \cdot q \cdot I_b \cdot A^2$

$S_{if} = KF \cdot I_b^{AF} \cdot A^2$

$S_{i0} = 2*q*I_c$

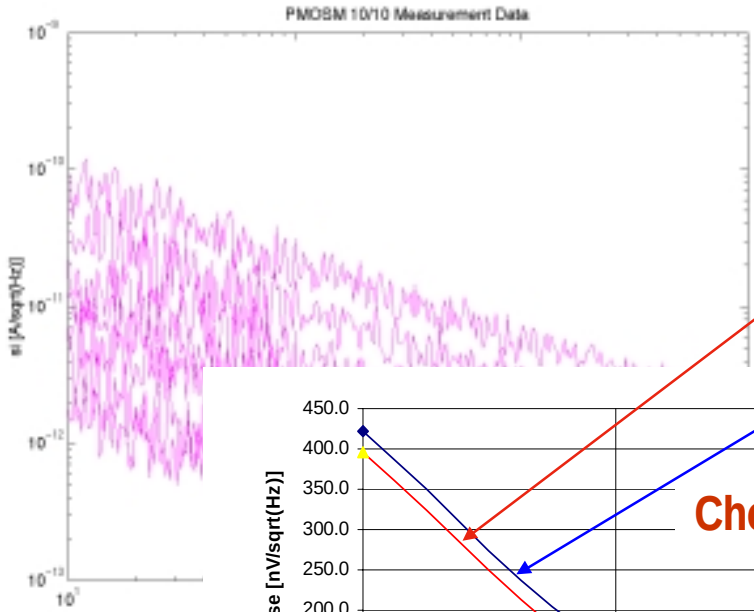
$S_4 = 4 \cdot k \cdot T / R_C$

Bipolar Noise Curves



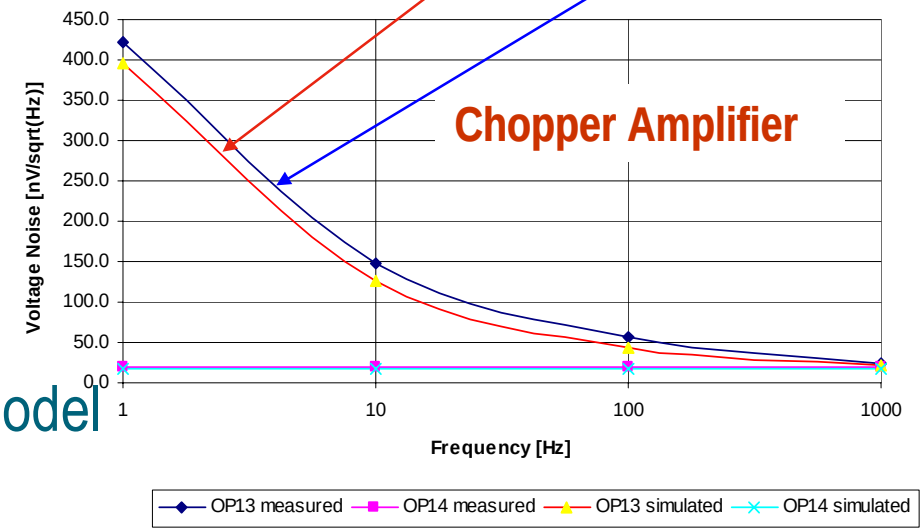
Bipolar Transistor BCE121 A = 0.8µm^2

Analog Simulation Results - Chopper Amplifier



Simulation

Measurement



0.35µm Process

BSIM3V3 MOS noise model

Error < 10%

Conclusion

- Fast and accurate Noise Parameter Extraction for

  Analog Mixed-Signal process characterisation
- Applicable for both MOS and BIP transistors
- High resolution limit
- Adaptable for noise measurements of:

  JFETs

  HResPoly resistors

  Systems (OPA, DAC, etc.)