Evaluation of High-Precision Nano-Ampere Current Measurement Method for Mass Production

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Outline

- **Research Background and Objective**
- **Nano Ampere Current Testing**
- **Proposed Method**
- **Experiment**
- **Conclusion**

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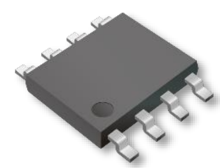
Research Background

Mobile and wearable devices



Conventional

Low power consumption LSI

Battery life

Low power consumption is important

Research Objective

Nano Ampere Current Testing

Requirements

- Fast Testing
- High Accuracy and High Stability

Proposed Method

- FFT-Based DC-AC Conversion

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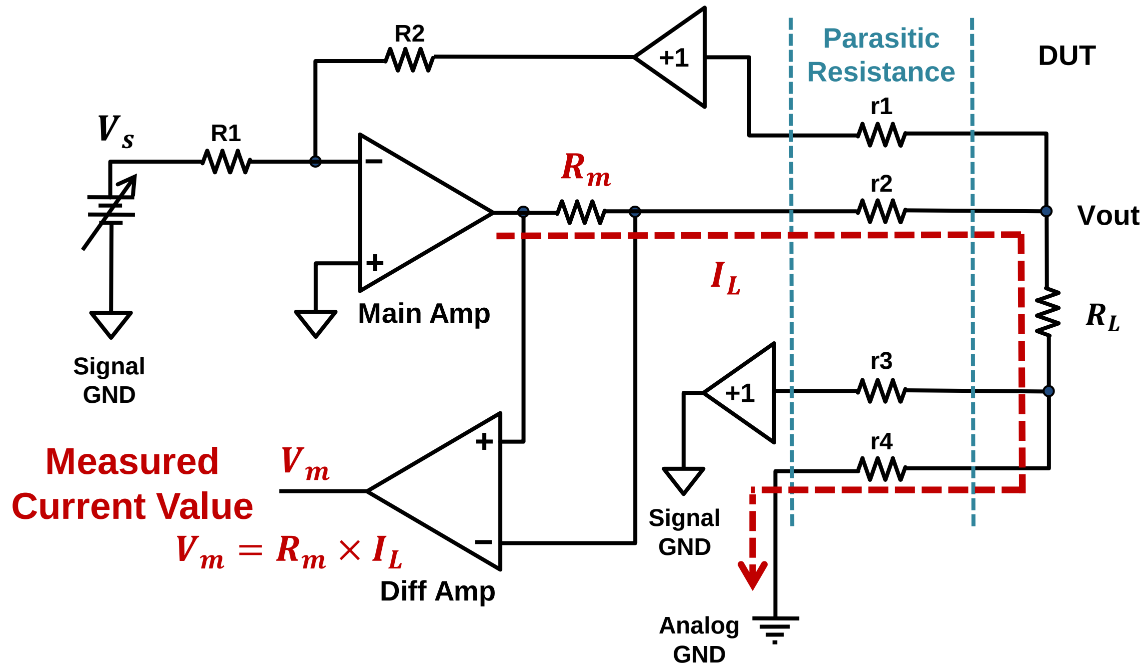
Nano Ampere Current Testing

Voltage Source / Current Measurement (VSIM) in ATE system



Large current sense resistor *Rm* *(MΩ order)* *causes* slow testing

Noisy environment in ATE

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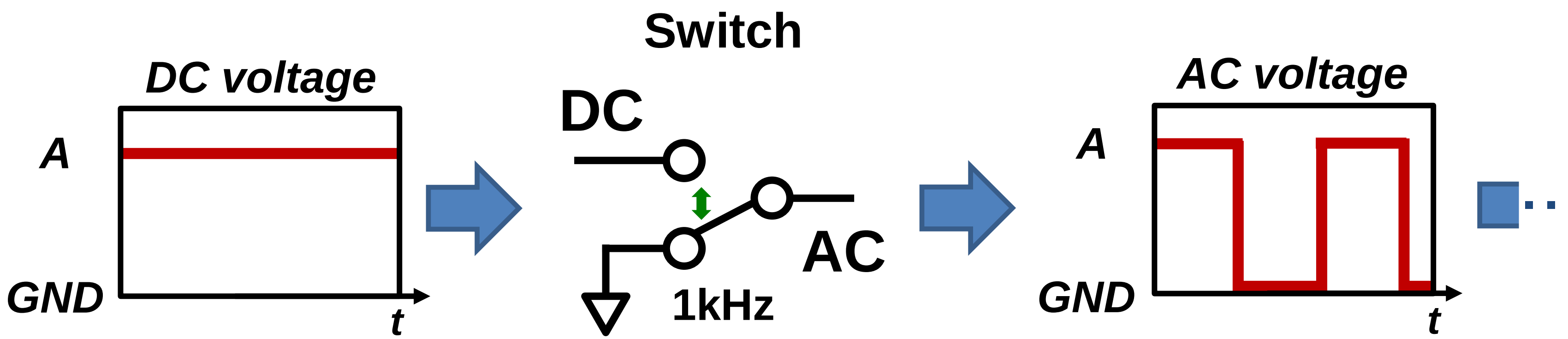
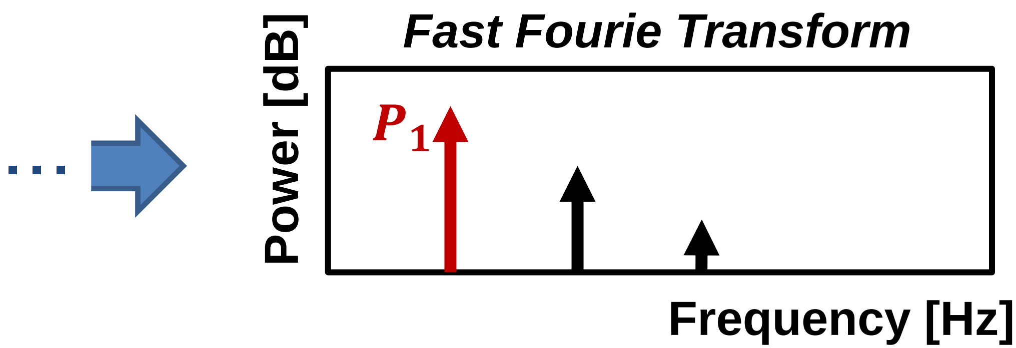
FFT-based DC-AC Conversion

Conversion flow



$V(t) = A$

$V(t) = (4A)/\pi \left\{ sin(\omega t) + \frac{1}{3} sin(3\omega t) + \frac{1}{5} sin(5\omega t) + \cdots \right\}$



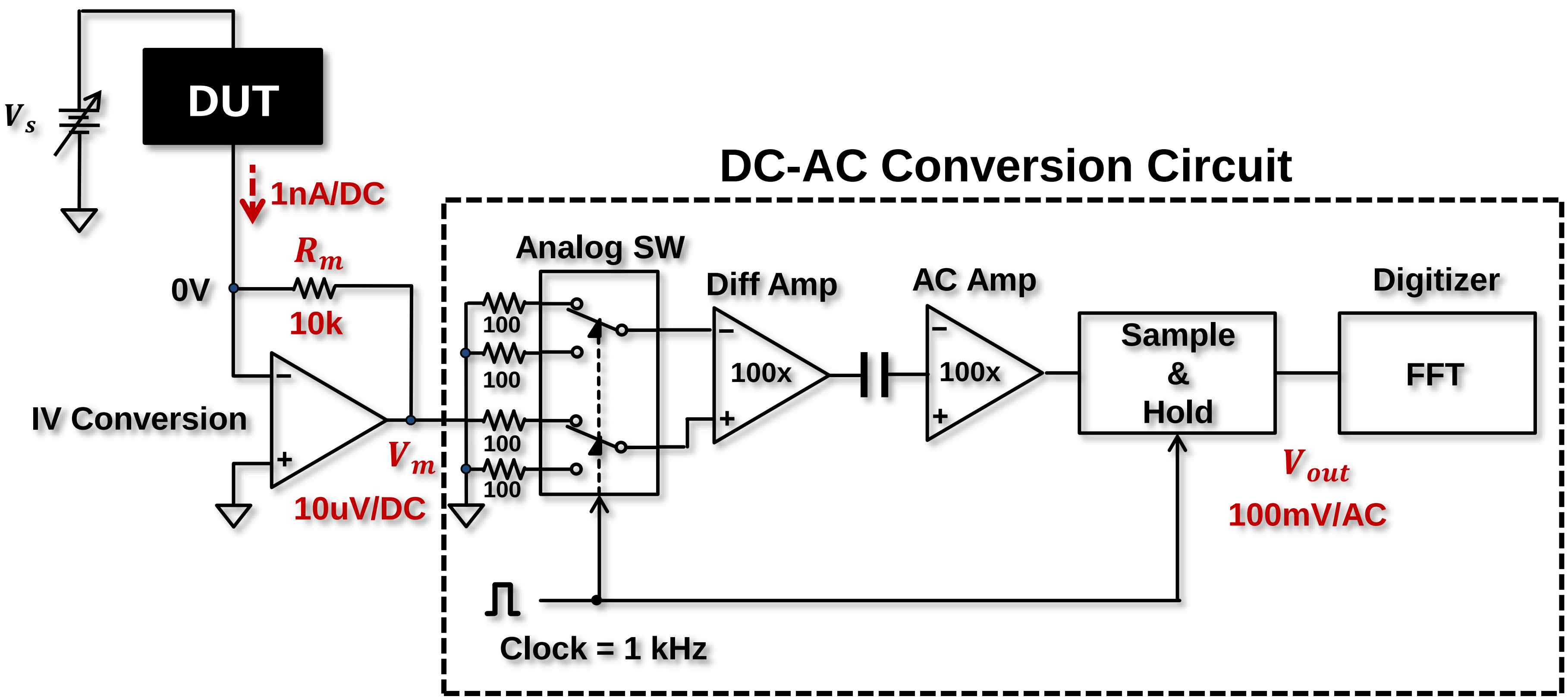
$A = \frac{10\text{^}\left(\frac{P_1}{20}\right) \cdot 2\sqrt{2}}{\frac{4}{\pi}}$

DC voltage is converted to fundamental power spectrum

Proposed Circuit for GND side

Measurement circuit

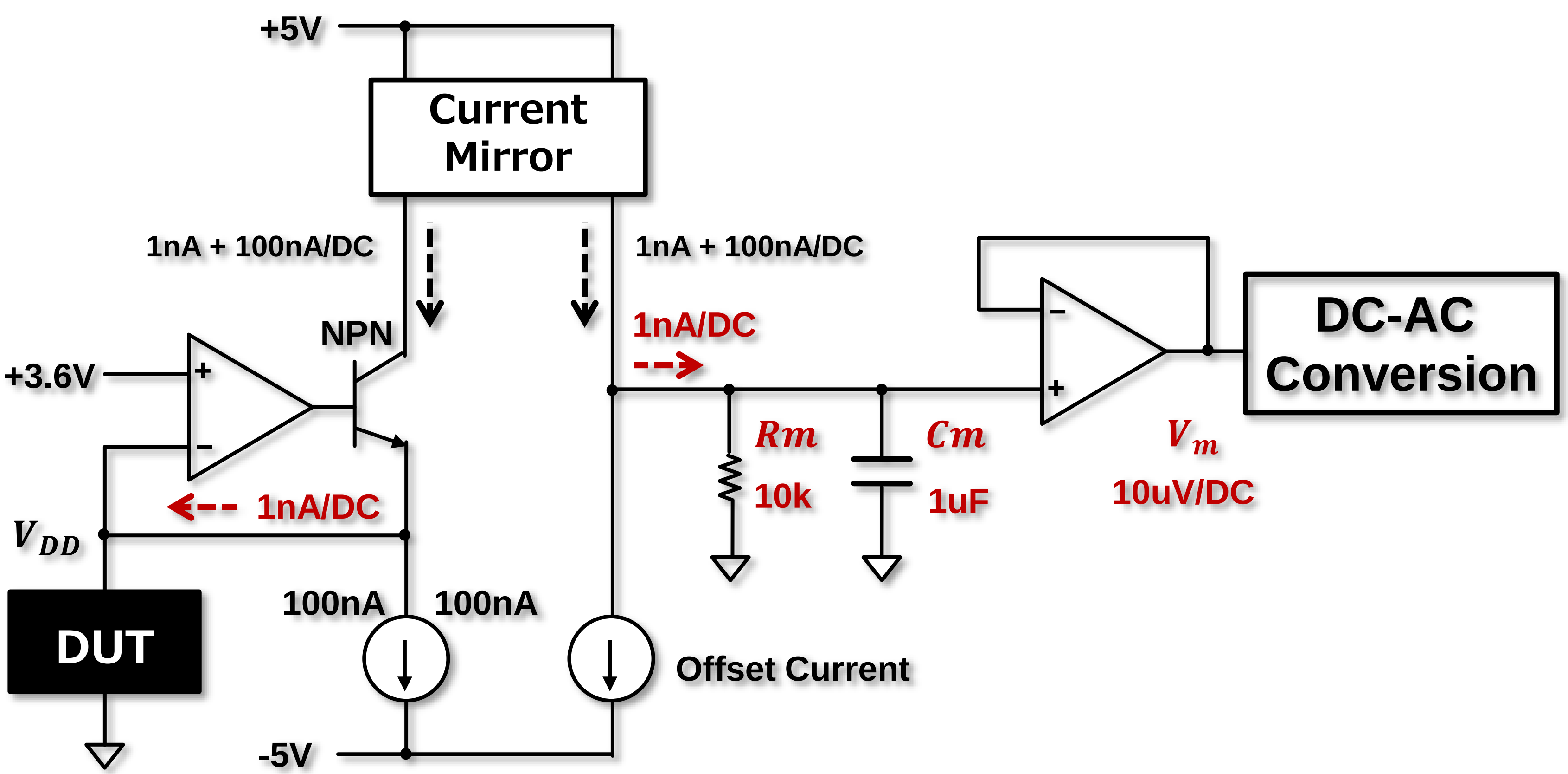
For GND side



Proposed Circuit for VDD side

Measurement Circuit

For VDD Side



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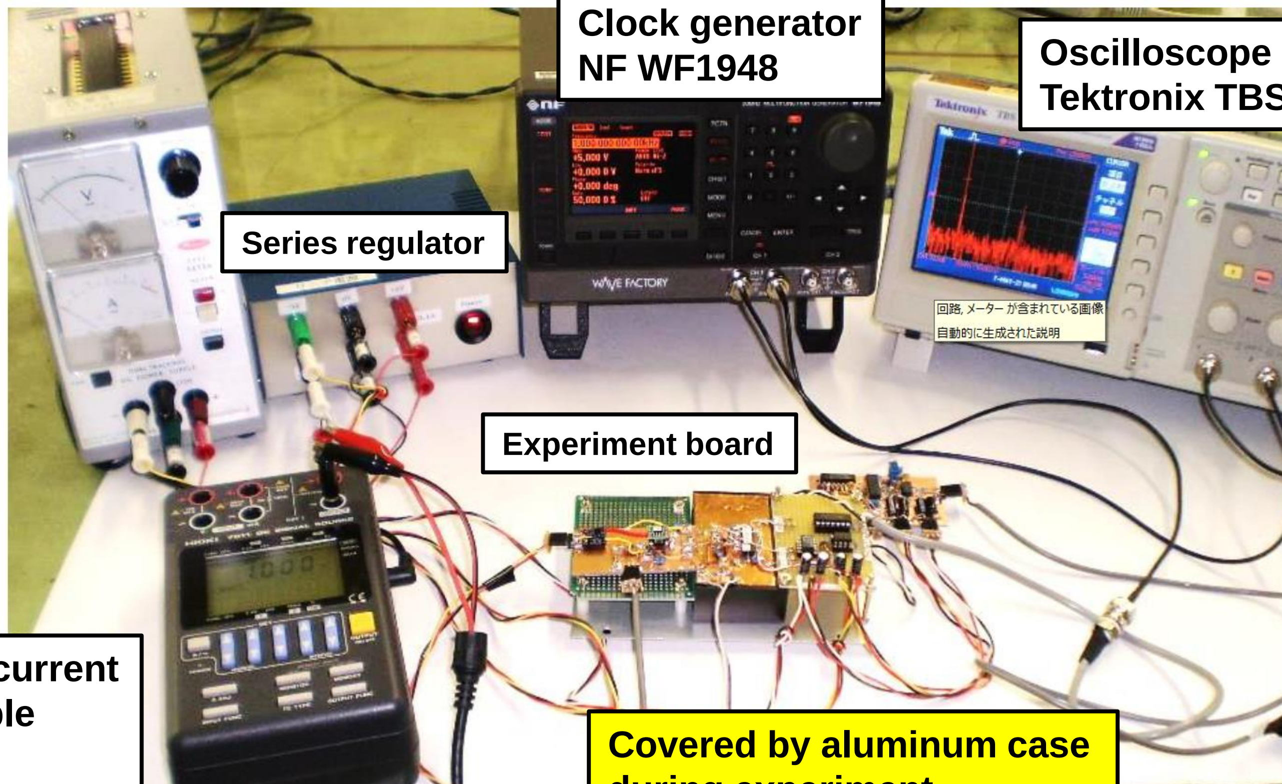
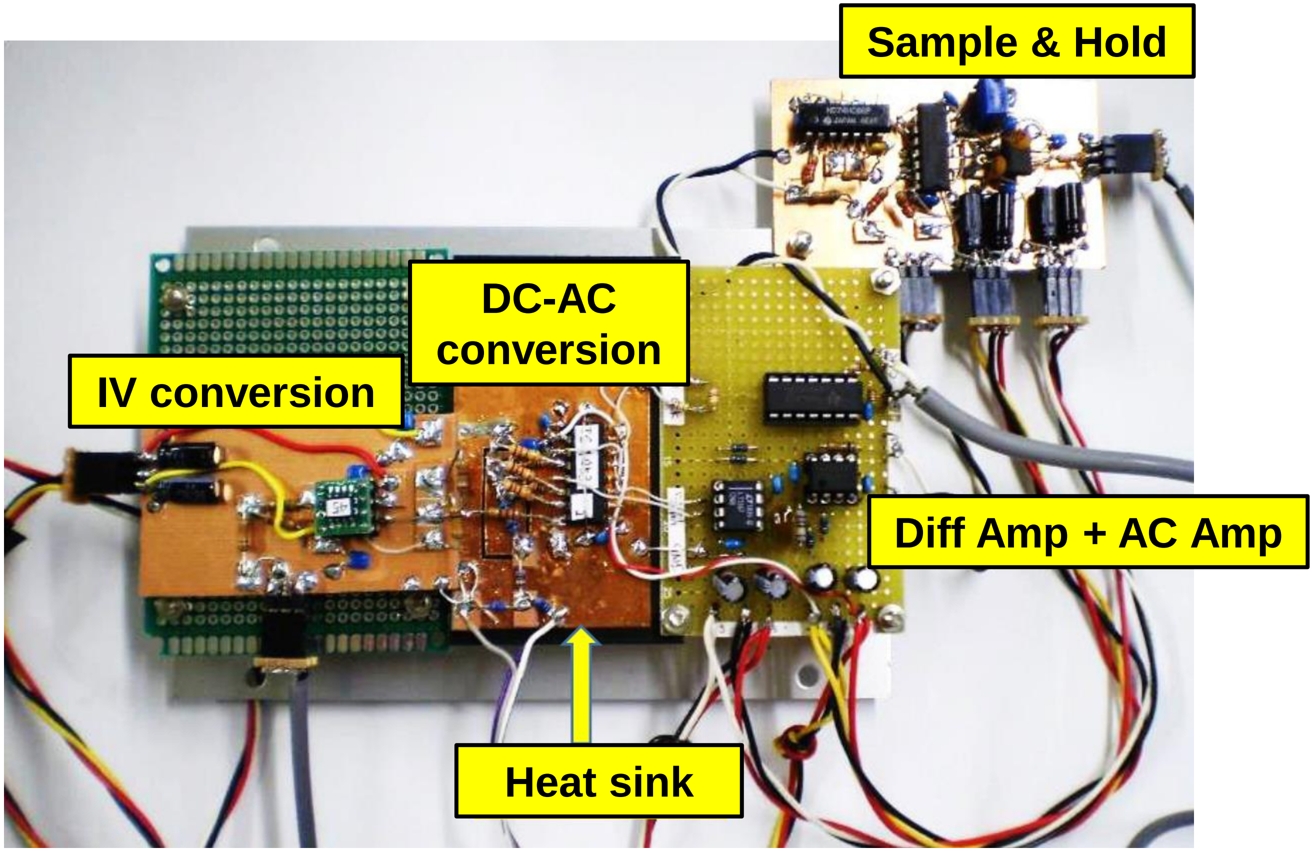
Equipment Configuration

Overall experiment environment



Experiment Board

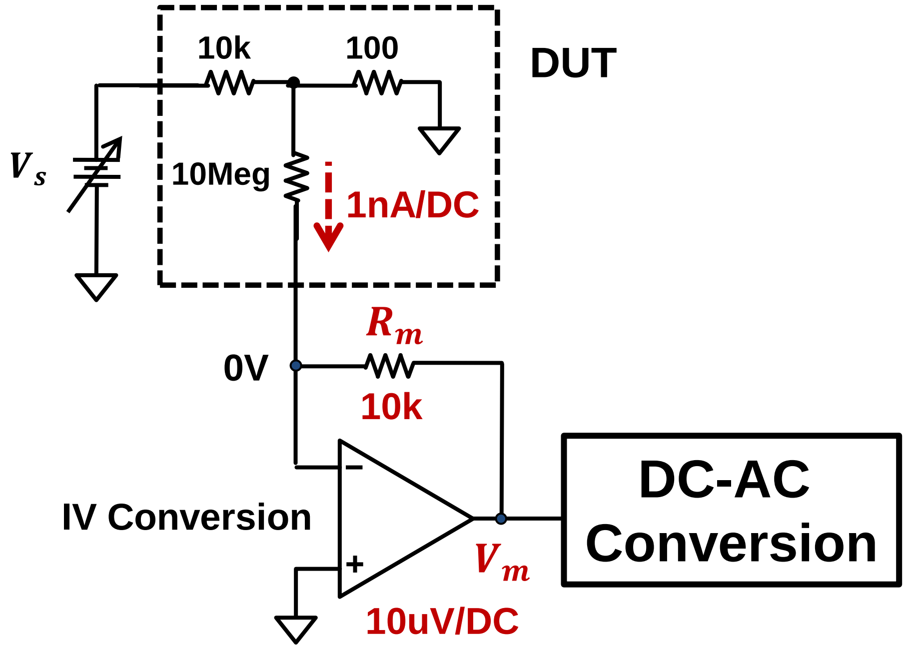
Board configuration



Resistive Load DUT

Experiment conditions

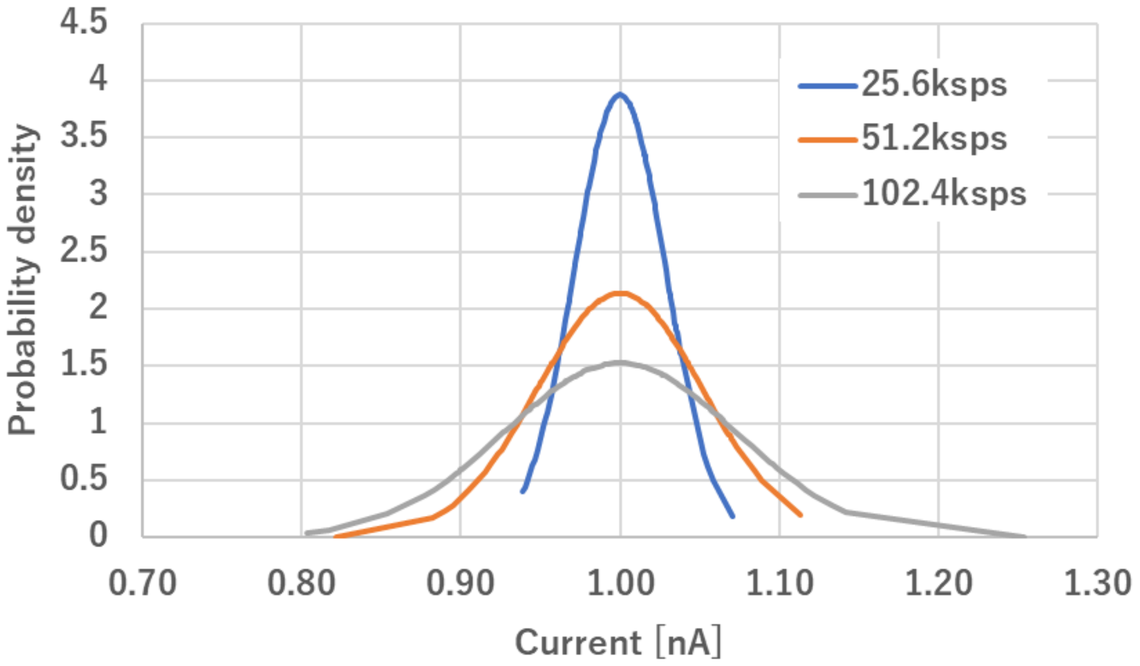
- Sampling rate : 25.6ksps, 51.2ksps, 102.4ksps
- Input current : 1nA, 10nA
- Feedback register Rm : 10kΩ, 100kΩ



Effect of Sampling Rate

Comparison by probability density

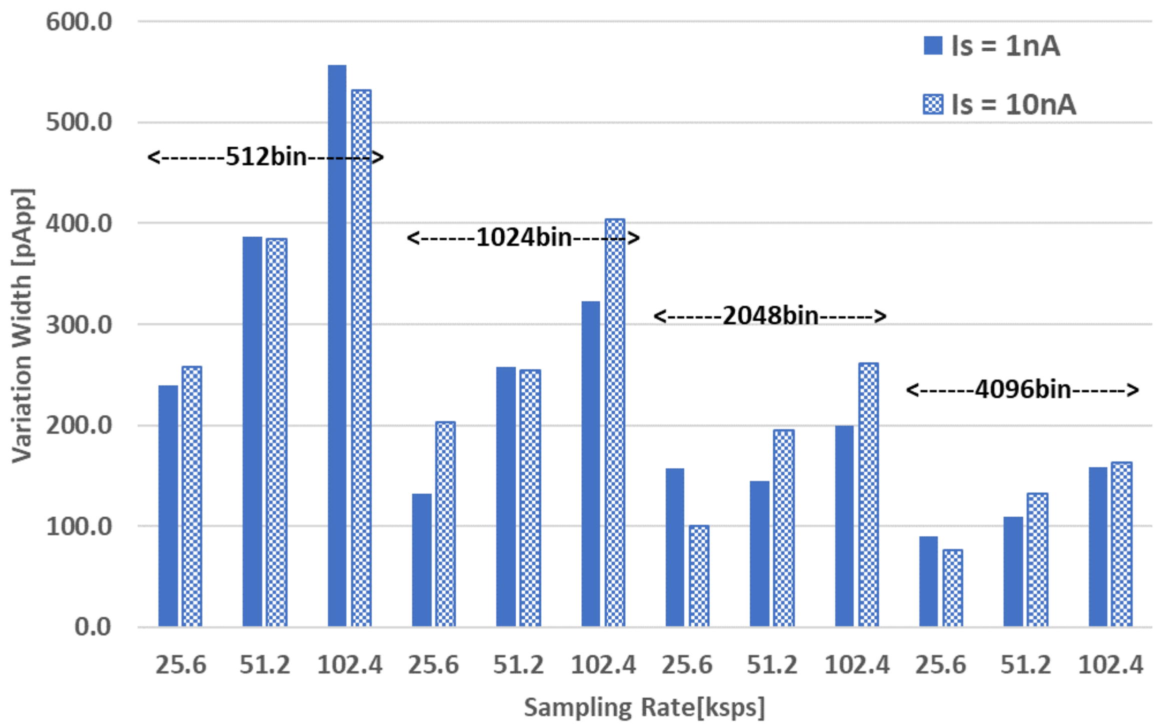
Sample points = 1024 bins



The longer the sampling time, the smaller the data variance

Effect of Input Current *Is*

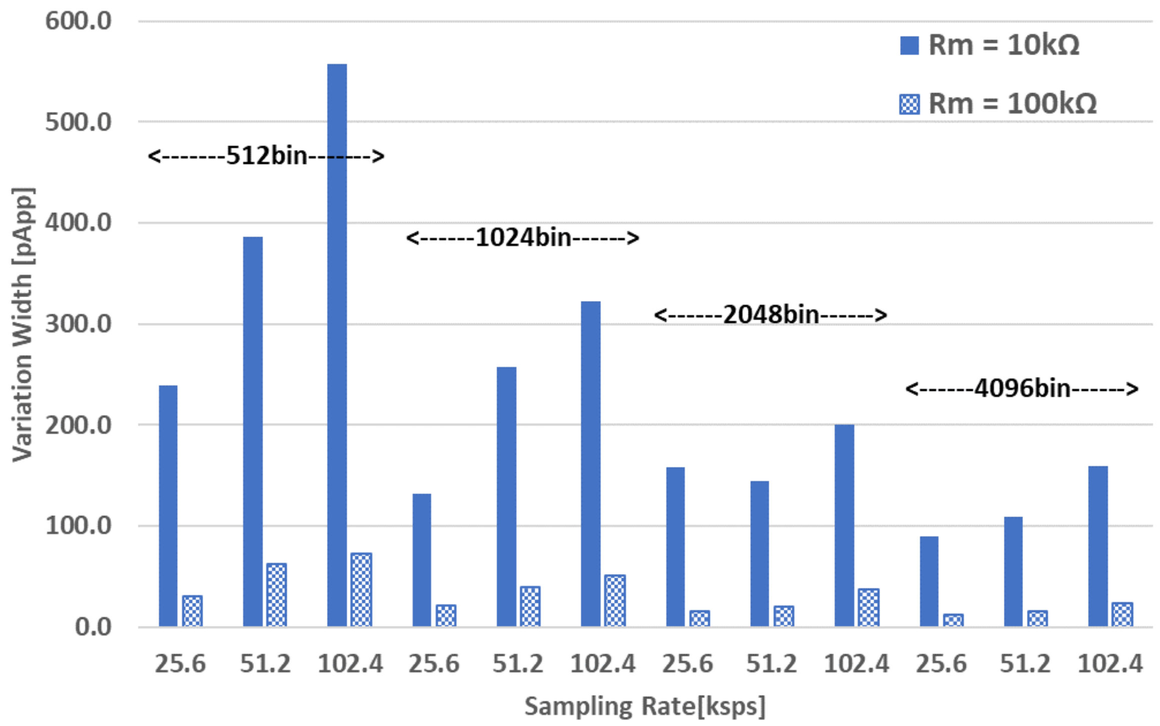
Comparison of variation width



Input current does not affect data variation

Effect of Feedback Resister *Rm*

Comparison of variation width

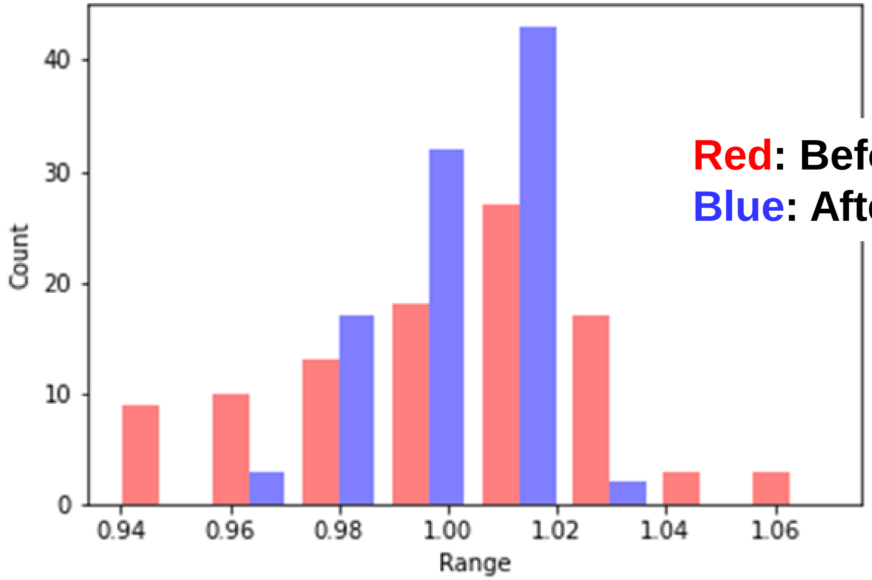


The larger *Rm*, the smaller the data variance

Moving Average

Smoothing effect

- **Moving average (4 times) processing,**
  ➡ **Variation reduction by about 50%**



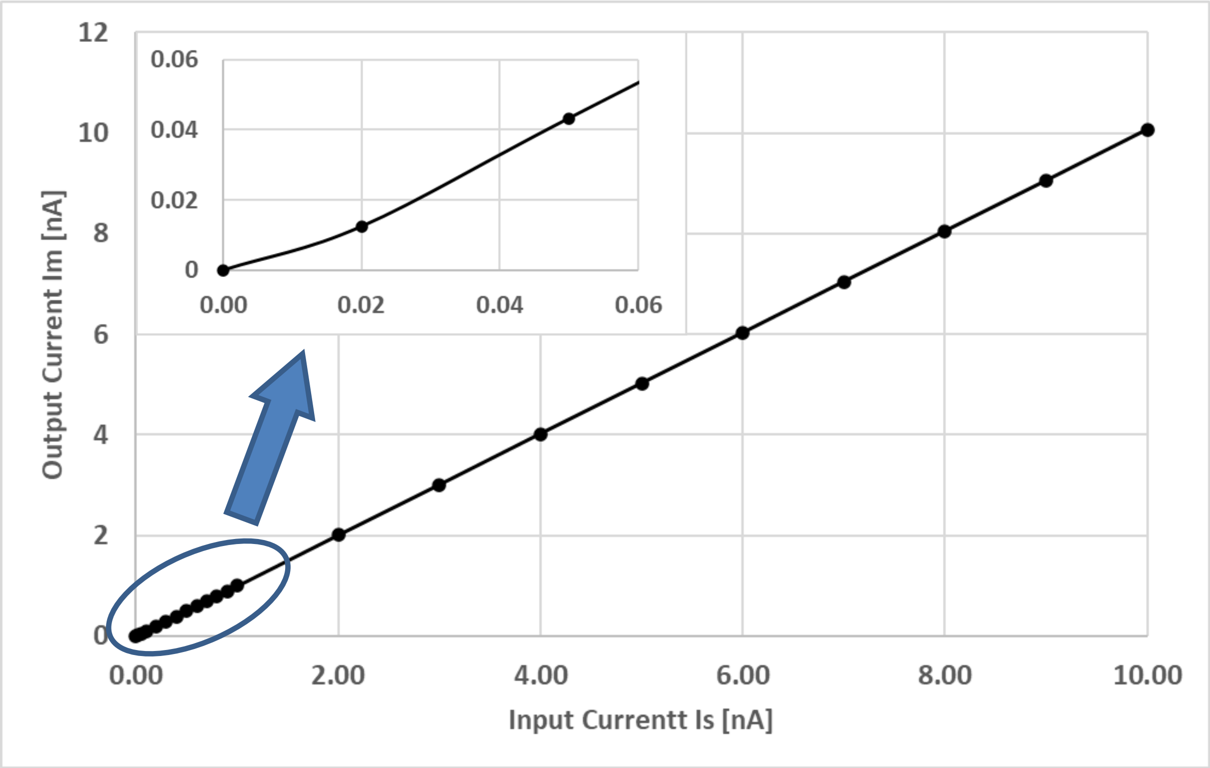
Red: Before moving average
Blue: After moving average

Variation width at 1024-bin, 25.6ksps (40msec/frame)

Measurement Linearity

Limit of measurable current value

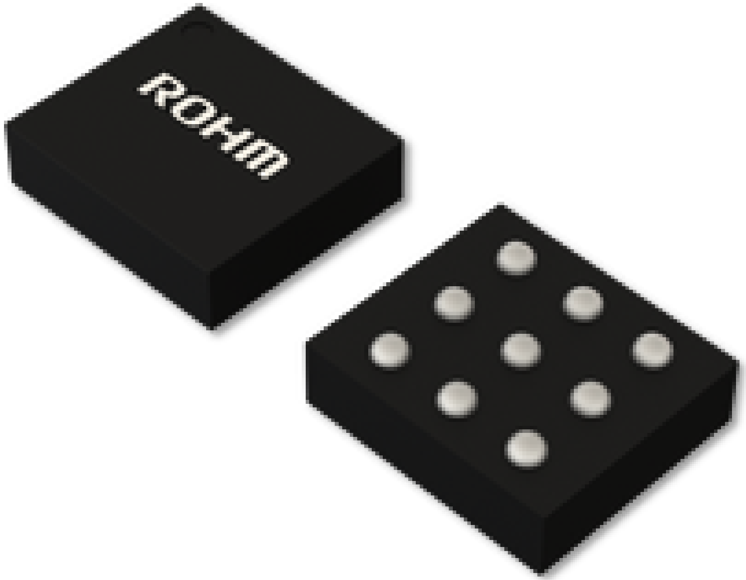
Rm = 100k, fs = 25.6ksps, sample point = 1024bin (40ms/frame)



Maintains linearity as low as measured current of 0.02nA

Verification with Actual DUT

BD70522GUL
Nano Energy™ Ultra Low Iq Buck Converter



Datasheet

- ***Standby Current Ist* : 50nA (typ)**
- ***Operating Quiescent Current Iq* : 180nA (typ)**

Results of VDD side

Verification with 5 devices

Device	No.1	No.2	No.3	No.4	No.5	Average
Ist [nA]	9.27	7.23	3.26	3.52	2.36	**5.13**
Variation width [nApp]	0.546	0.393	0.513	0.446	0.388	**0.457**
Iq [nA]	145.3	149.4	144.6	141.1	138.7	**143.8**
Variation width [nApp]	88.3	33.8	267.1	529.5	11.4	**186.0**

Spike ⇩ ***Removed***

Device	No.1	No.2	No.3	No.4	No.5	Average
Iq [nA]	143.7	149.0	141.7	133.2	138.6	**141.2**
Variation width [nApp]	0.248	0.346	0.305	0.332	0.201	**0.286**

- **Variation width smaller than 1nA**
- ***Iq* requires removal of spike components**

Results of GND side

Verification with 5 devices

Device	No.1	No.2	No.3	No.4	No.5	Average
Ist [nA]	12.30	4.27	4.15	2.53	2.25	5.1
Variation width [nApp]	3.62	3.32	3.66	4.29	3.66	3.71
Iq [nA]	147.1	150.7	143.8	134.7	140.1	143.3
Variation width [nApp]	4.69	75.5	38.0	33.7	57.0	41.8

Spike ⇩ ***Removed***

Iq [nA]	147.1	150.7	143.8	134.7	140.1	143.3
Variation width [nApp]	3.95	8.64	3.77	3.64	3.85	4.77

Need to improve variation width

- **Add Low Pass Filter etc.**

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Conclusion

- **Proposal of nano current testing method**
  - ➢ **FFT-based DC-AC conversion**
- **Sub-Nano current detection of 20pA level**
  - ➢ **test time of 40 msec**
- **Current variation width less than 1nA**
  - ➢ **BD70522GUL V_{DD} side verification**
  - ➢ **Additional verification required in GND side**