ICTSS 2019

IPS04-05
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Experimental Evaluation of Null Method and DC-AC Conversion for Operational Amplifier Testing

Division of Electronics and Informatics, Gunma University

Shogo Katayama, Riho Aoki, Yuto Sasaki, Kosuke Machida,
Takayuki Nakatani, Jianlong Wang, Anna Kuwana,
Kazumi Hatayama, Haruo Kobayashi,

ROHM Co., Ltd.

Keno Sato, Takashi Ishida, Toshiyuki Okamoto, Tamotsu Ichikawa

OUT LINE

- Research Background
- Null method
  - Feature of Null method
  - Offset Voltage Measurement
- DC-AC conversion technique
  - DC-AC conversion circuit
  - Offset Voltage Measurement
- Conclusion

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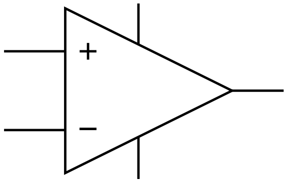
Research Background

Operational Amplifier (OP Amp.)

Differential input



Single-ended output

Past Analog computers

IoT technology prevails

IoT : Internet of Things

Today Analog circuits key components

Required

High-quality and low-cost testing
as mass production shipping stage

Research Goals

Operational amplifier precision measurement method

Null method

Laboratory level measurement

- High precision
- Long time

Automated Test Equipment (ATE)

Mass production testing

- Short time
- System noise issues

◆DC-AC conversion technique

Precise DC voltage measurements

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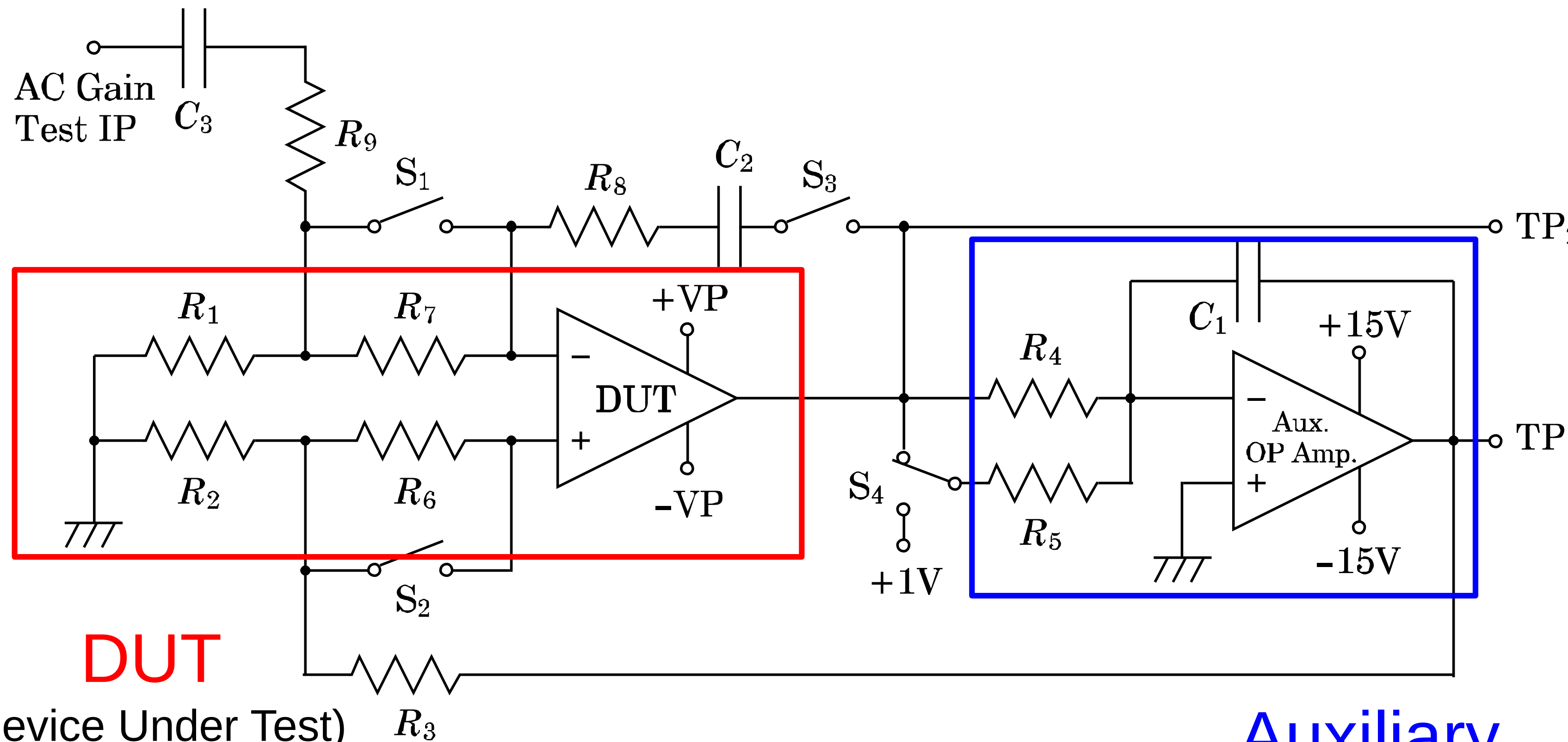
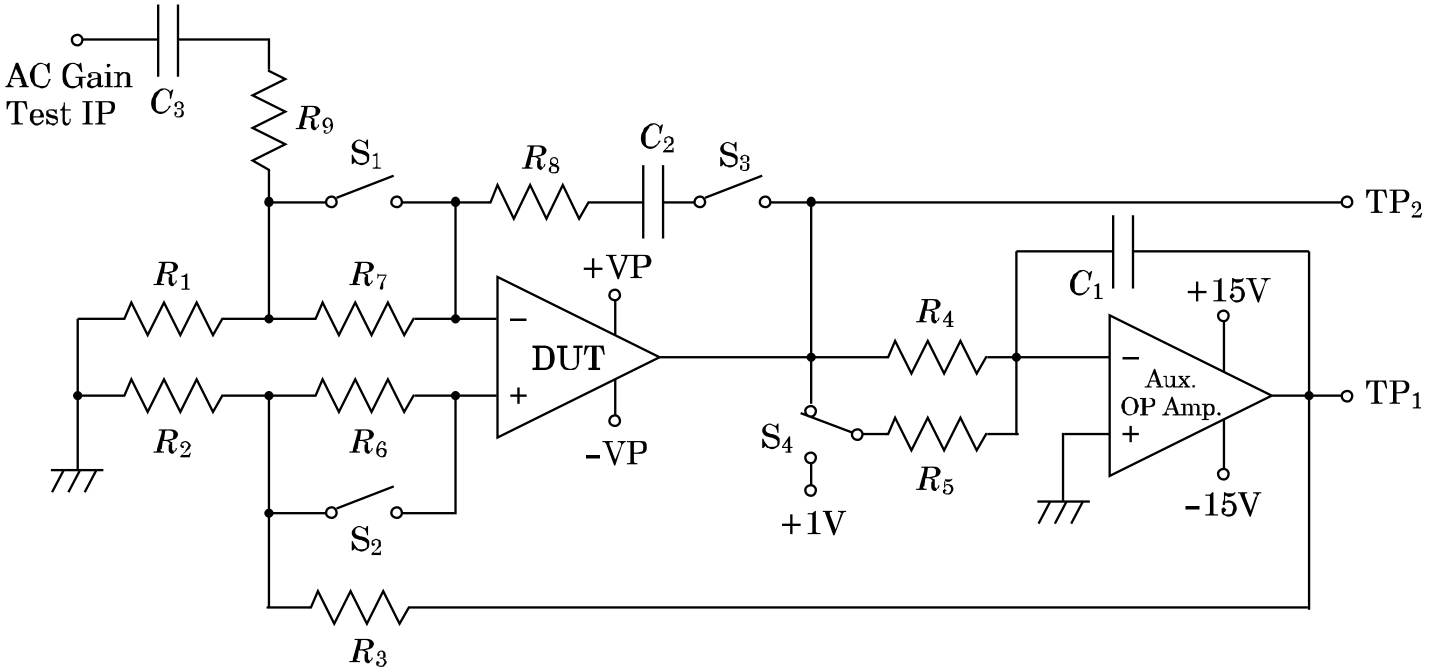
Null Method



DUT
(Device Under Test)

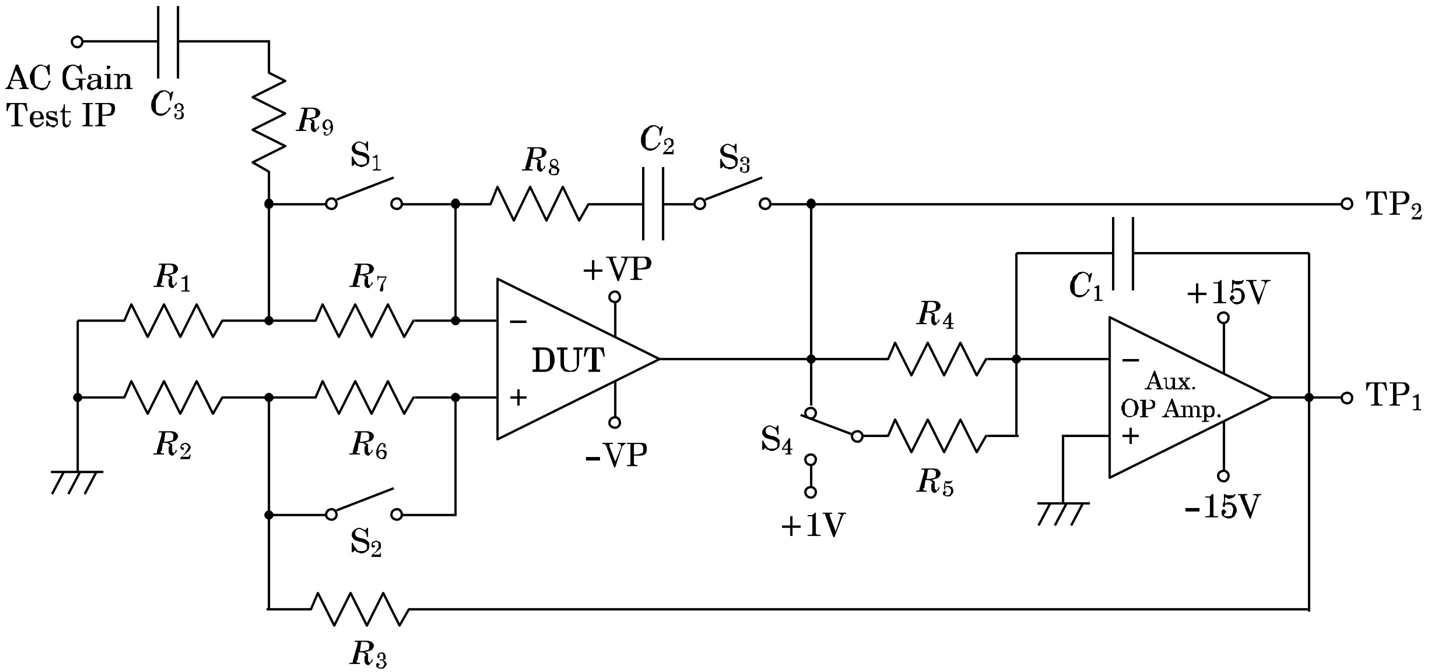
Auxiliary
OP Amp.
Integrator

Null Method Measurement Parameters



Parameters	S1	S2	S3	S4	+VP	−VP
Offset	ON	ON	OFF	Out	$+V$	$-V$
Offset Bias Current	ON/OFF	ON/OFF	OFF	Out	$+V$	$-V$
DC Gain	ON	ON	OFF	Out/+1	$+V$	$-V$
AC Gain	ON	ON	OFF	Out	$+V$	$-V$
CMRR (DC)	ON	ON	OFF	Out	$+V/+V+1$	$-V/-(V-1)$
PSRR (DC)	ON	ON	OFF	Out	$+V/+V+1$	$-V/-(V-1)$
CMRR (AC)	ON	ON	ON	Out	$+V+\sin(\omega t)$	$-V+\sin(\omega t)$
PSRR (AC)	ON	ON	ON	Out	$+V+0.5\sin(\omega t)$	$-V-0.5\sin(\omega t)$

Feature of Null Method



Switches S1, S2, S3, S4, +VP, −VP

Widely used to measure many parameters

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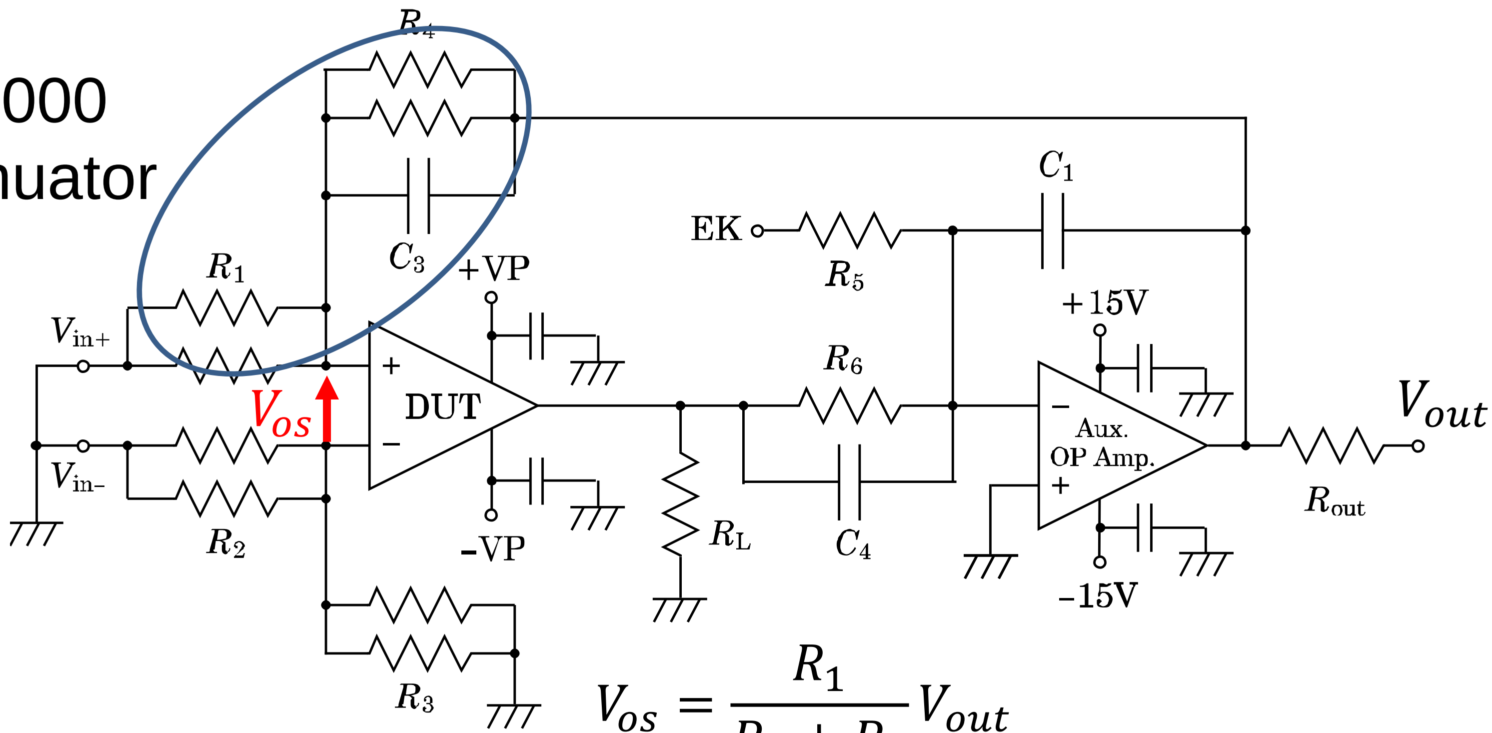
Offset Voltage Measurement with Null Method

1:1000
Attenuator



$$V_{os} = \frac{R_1}{R_1 + R_4} V_{out}$$

$$R_1 : R_1 + R_4 = 1:1000$$

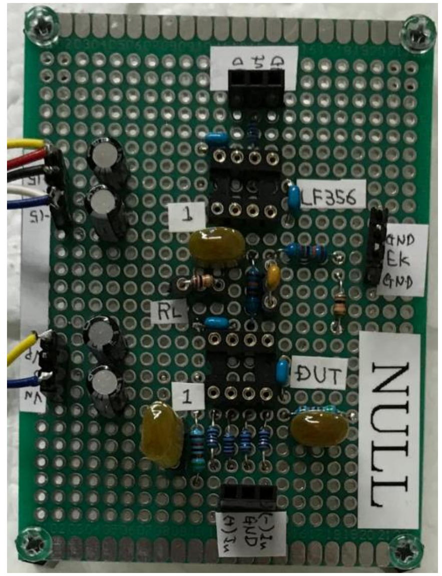
Offset Voltage V_{os}
A few μV to A few mV

Difficulty

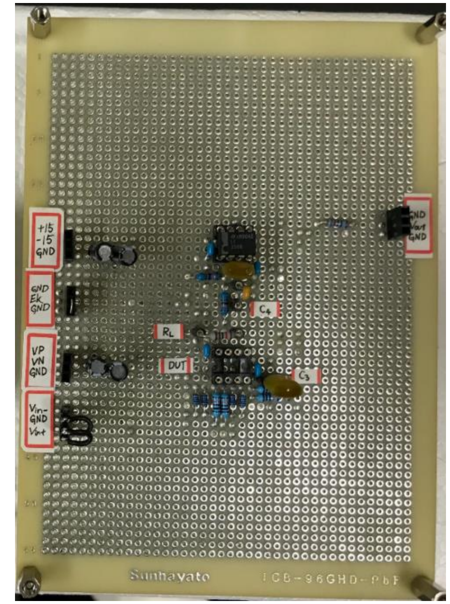
$V_{out} = 1000 V_{os}$
Offset Voltage A few mV

Easy

Measurement Circuit using the Null Method

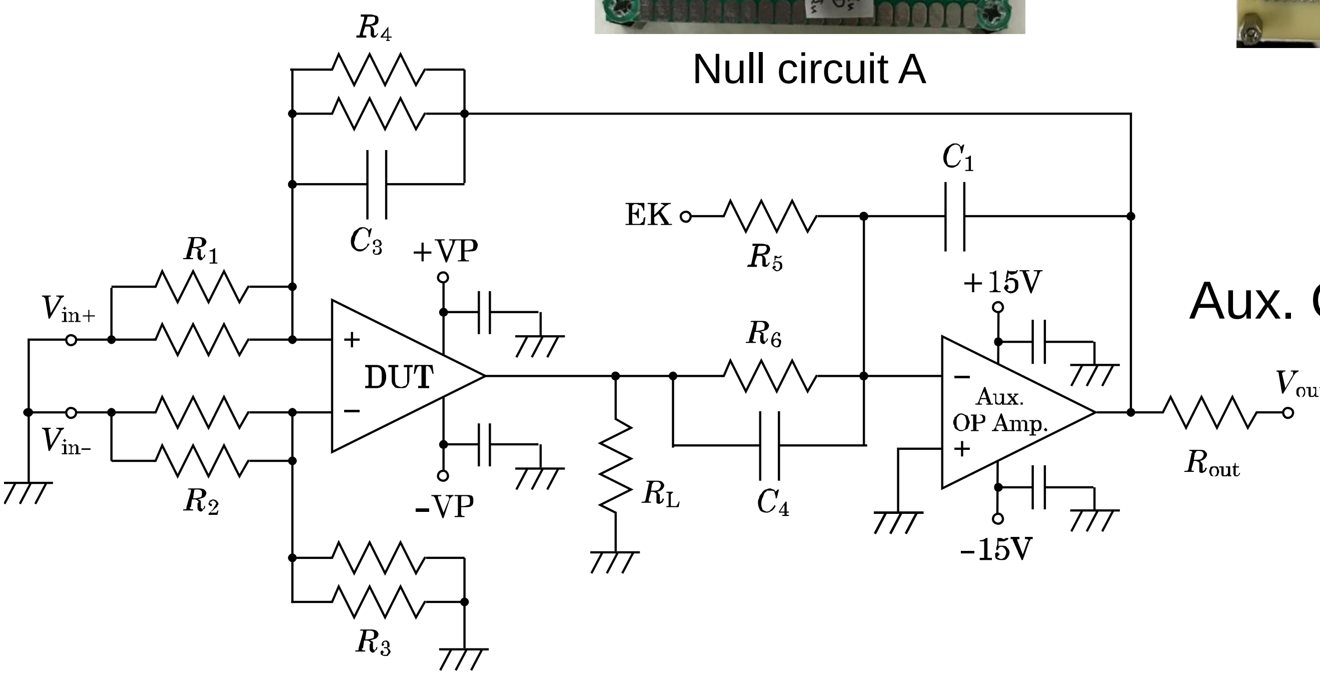


Null circuit A



Null circuit B

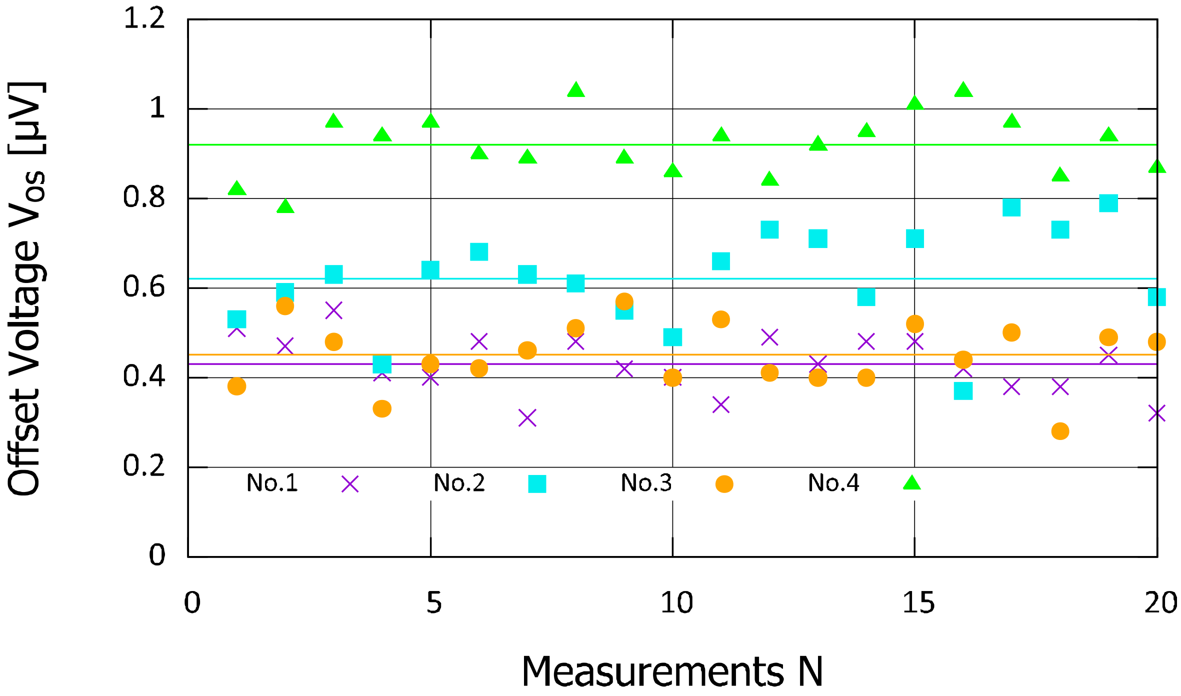
DUT : AD8571

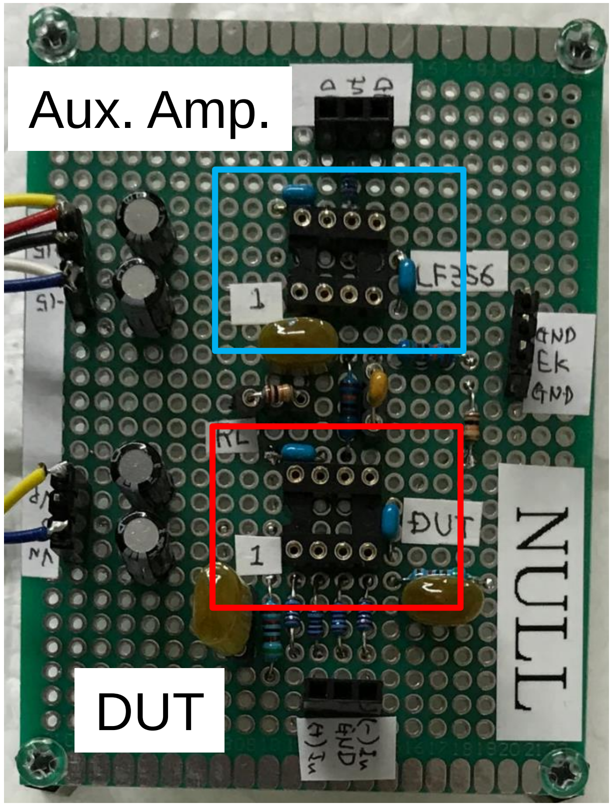


Aux. OP amp. : LF356

$$R_1 = 100\Omega$$
$$R_4 = 100\text{k}\Omega$$

Offset Voltage Measurement Result by Null Circuit A

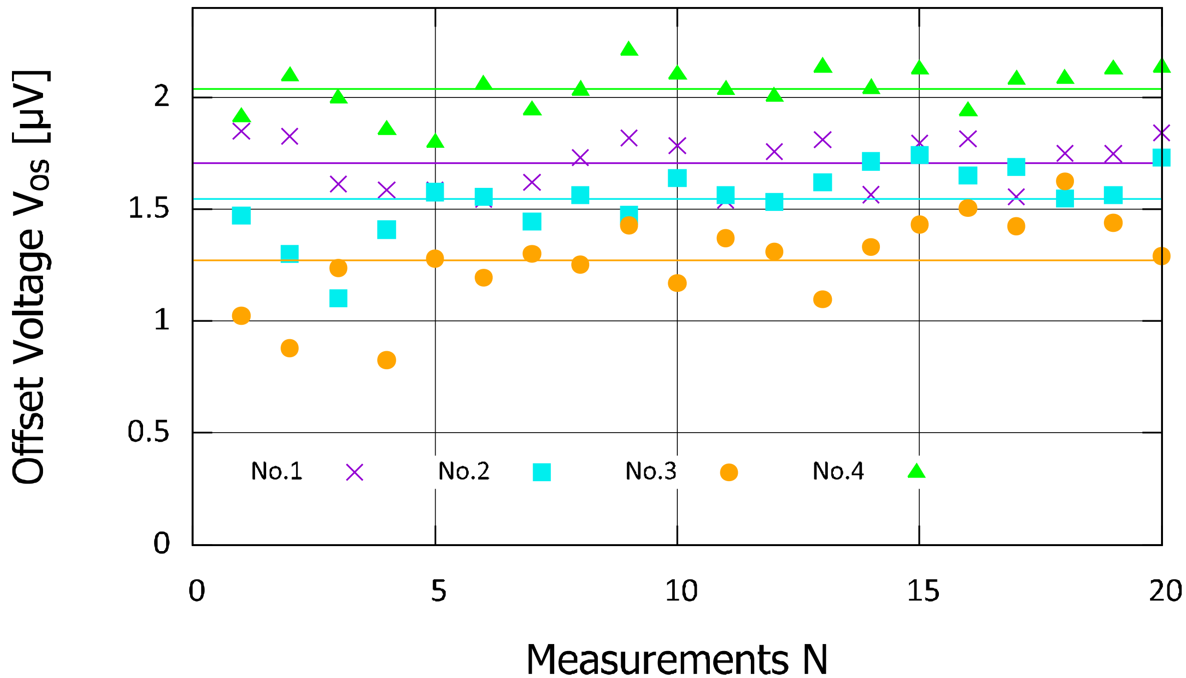


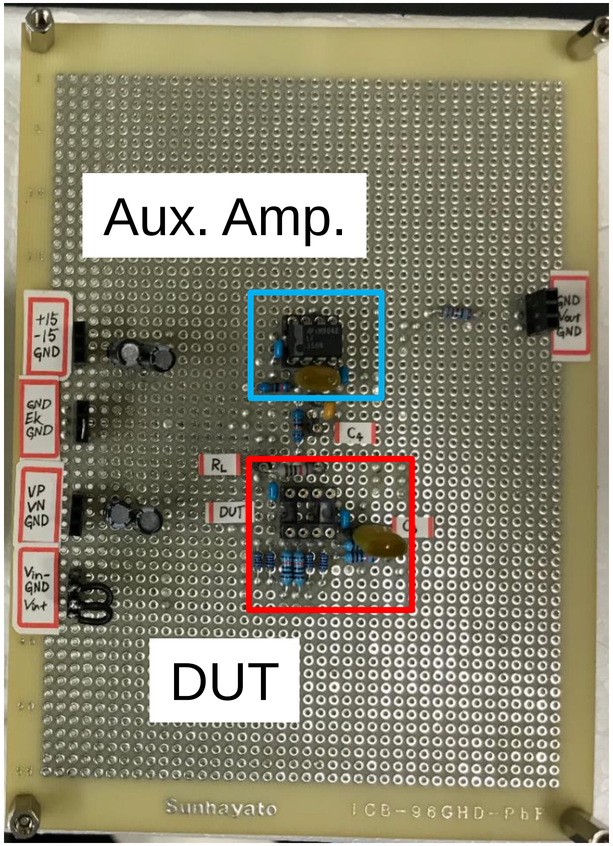


V_{os} measured values : 0.4μV to 0.9μV

Null circuit A

Offset Voltage Measurement Result by Null Circuit B





Null circuit B

V_{os} measured values : 1.2μV to 2μV

Difference by 1μV between circuit A, B

Thermo-electromotive force (EMF) effects

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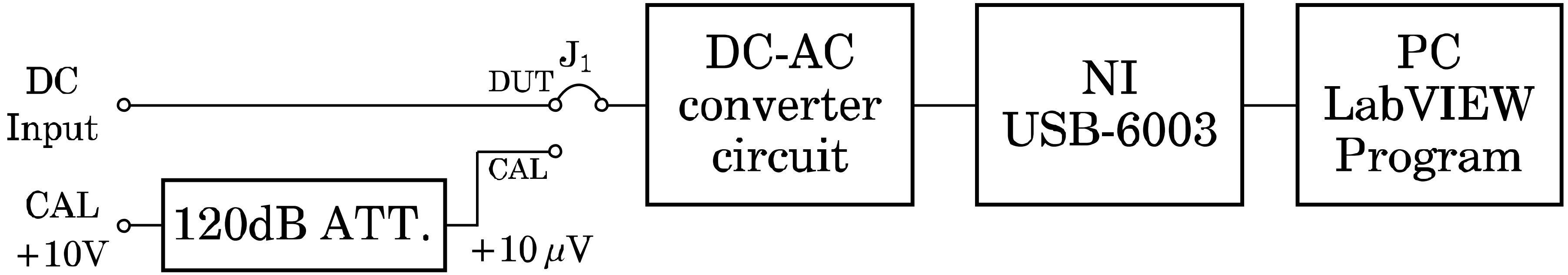
DC-AC Conversion Circuit



- DC-AC conversion circuit

  CMOS switching IC : Chops small DC voltage

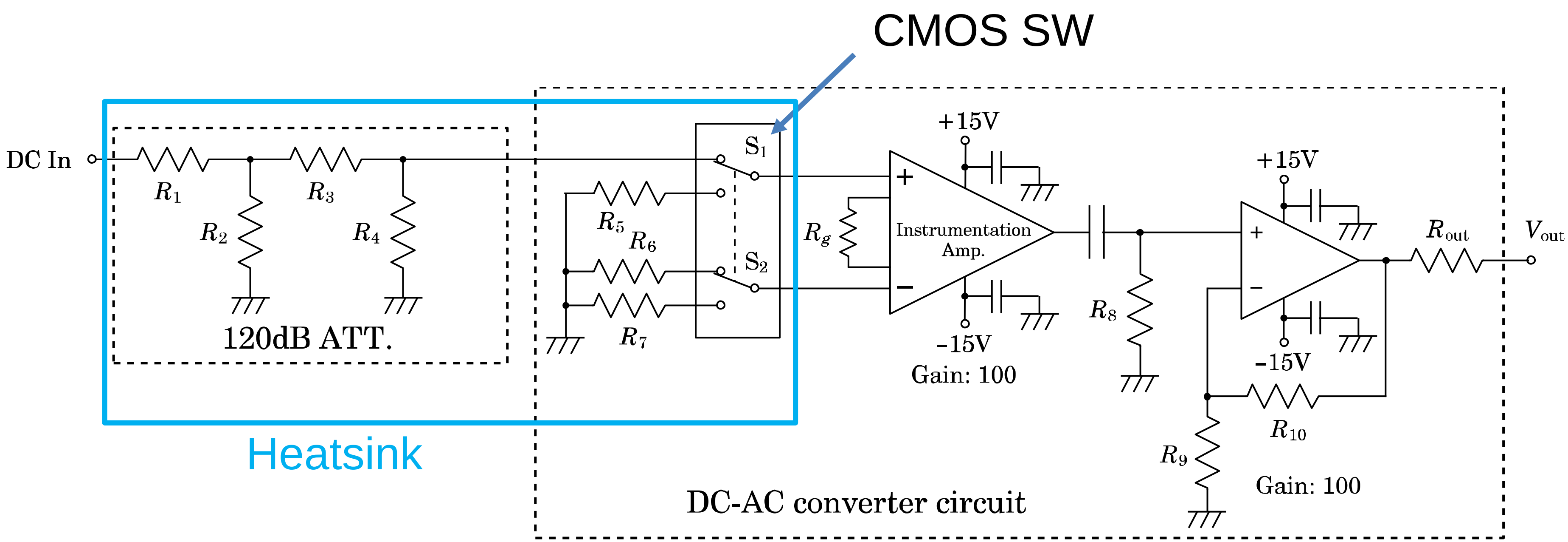
- NI USB-6003

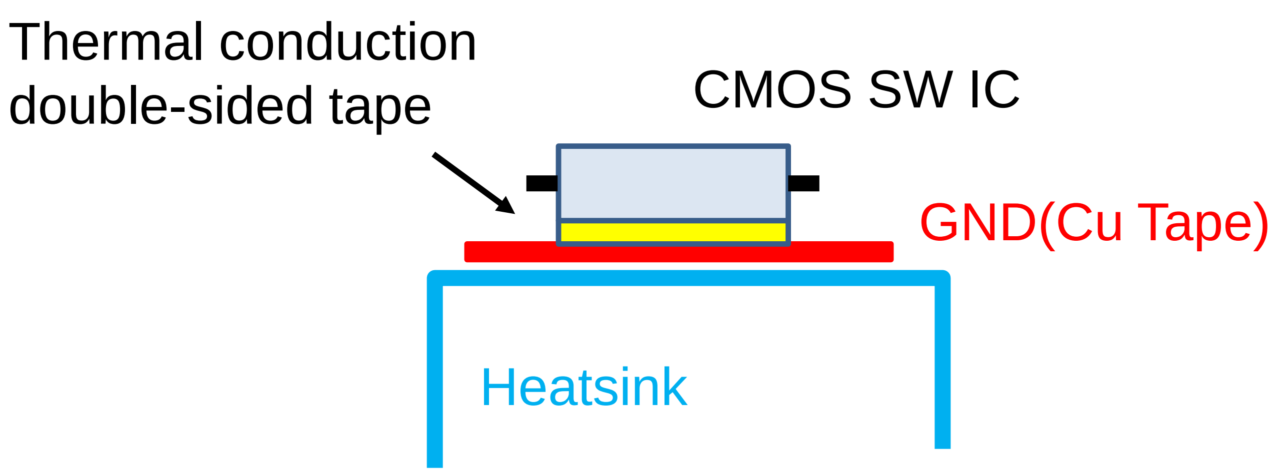
  Acquire outputs of DC-AC conversion circuit

- LabVIEW program

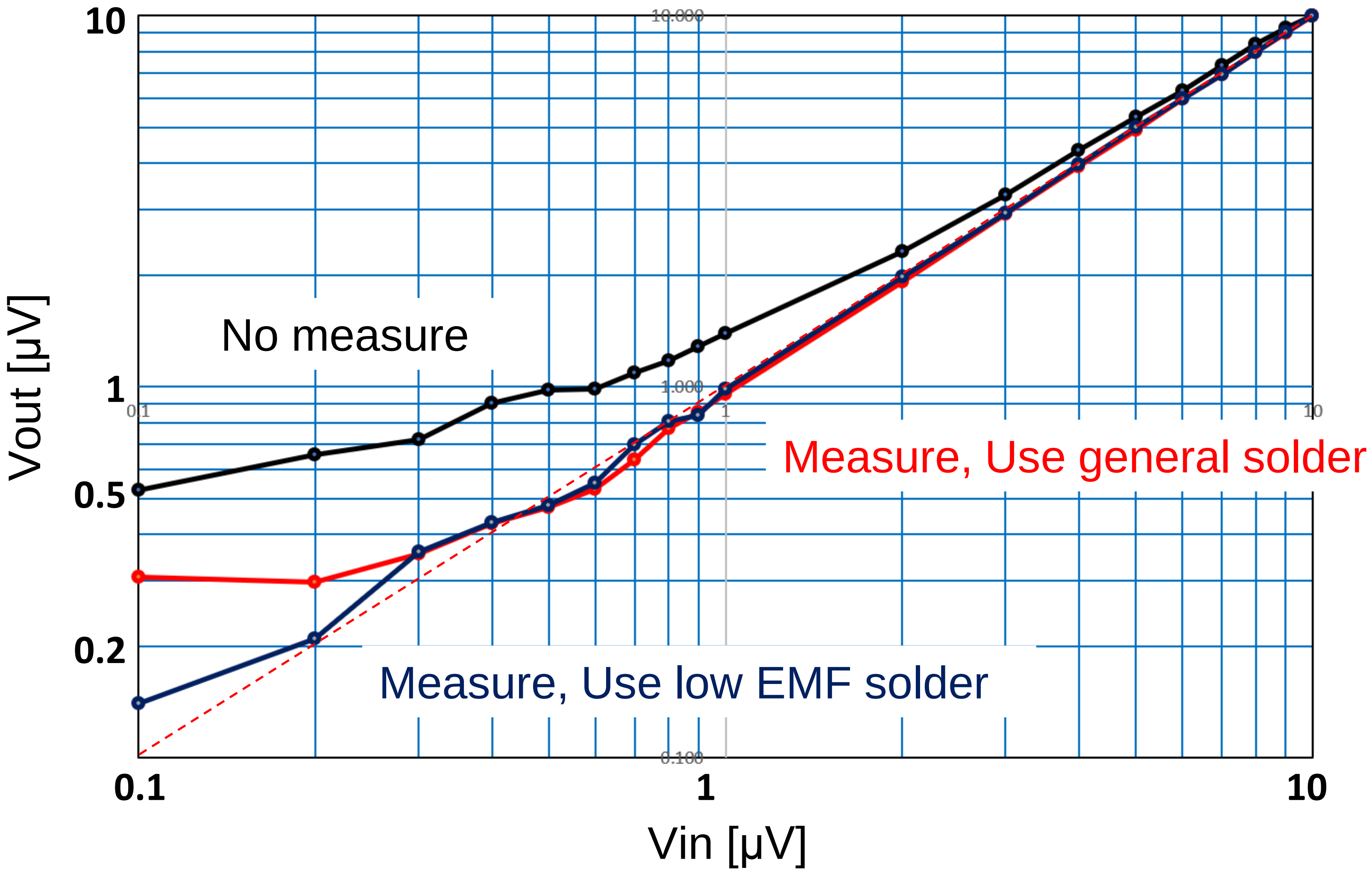
  FFT : Measures DC-AC conversion clock spectrum

EMF Measure


CMOS SW
DC In
R1
R2
R3
R4
120dB ATT.
R5
R6
R7
S1
S2
Rg
+15V
Instrumentation Amp.
-15V
Gain: 100
R8
+15V
-15V
R10
R9
Gain: 100
Rout
Vout
DC-AC converter circuit
Heatsink


Thermal conduction double-sided tape
CMOS SW IC
GND(Cu Tape)
Heatsink

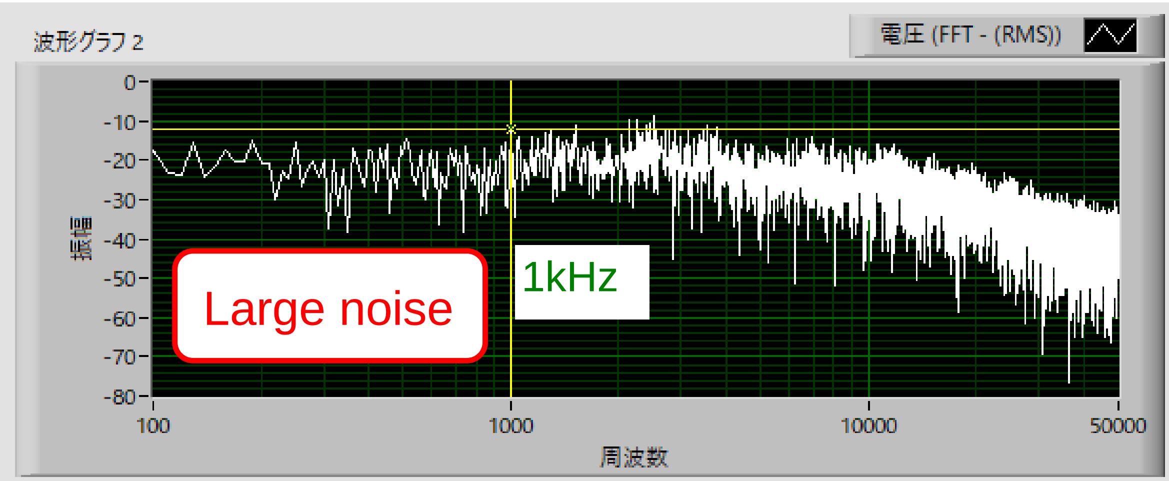
EMF Measure Result



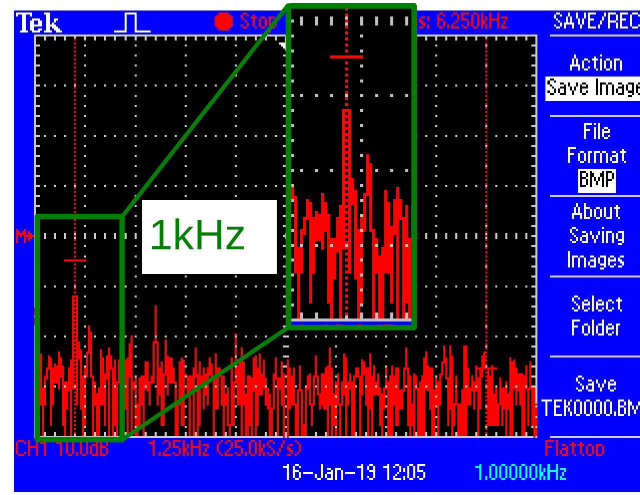
Temperature equalization / Use low EMF solder :

Linearity improve

DC-AC Conversion Spectrum Measurement



Spectrum of LabVIEW program (Average : 100)



Spectrum of oscilloscope (Average : 64)

Averaging technique

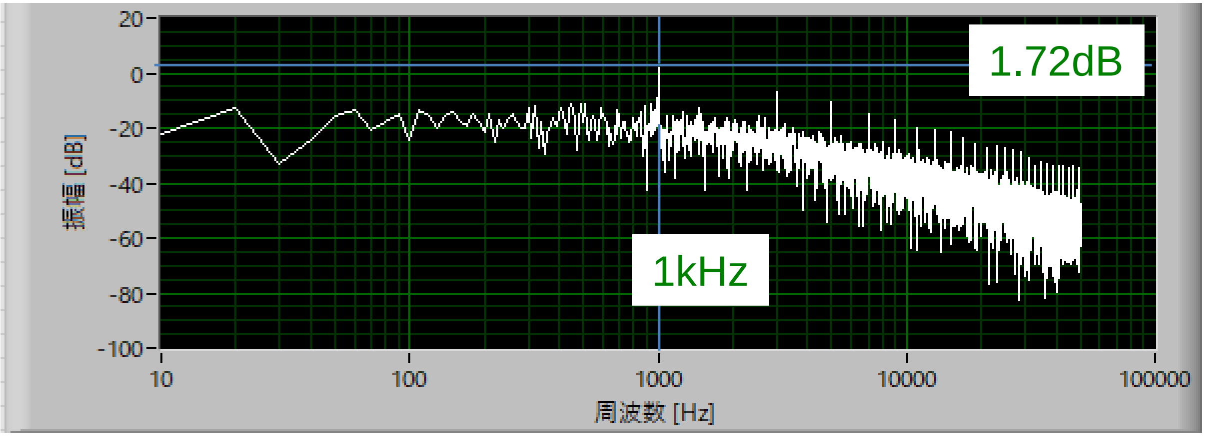
- LabVIEW program

  Averaging in frequency domain

- Oscilloscope FFT function

  Synchronization averaging in time domain

Improvement Averaging Technique



Spectrum of improved LabVIEW program (Average : 10)

Synchronization averaging with chopping clock

Noise effects Reduction

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Measurement Circuit using the DC-AC Conversion Circuit

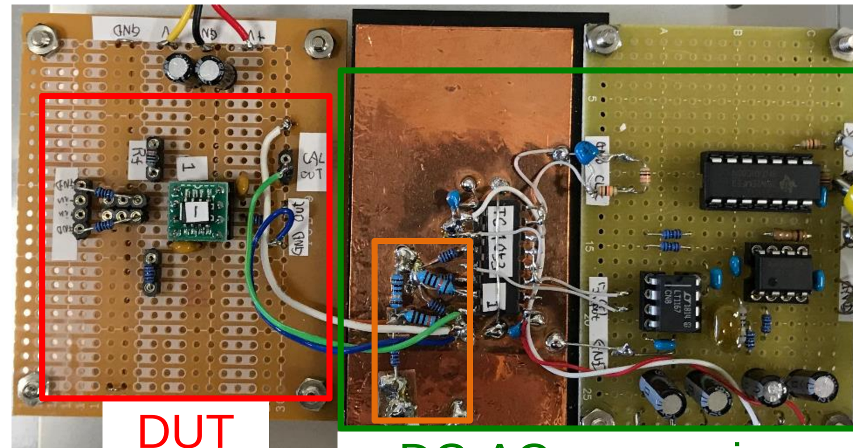
Synchronization averaging

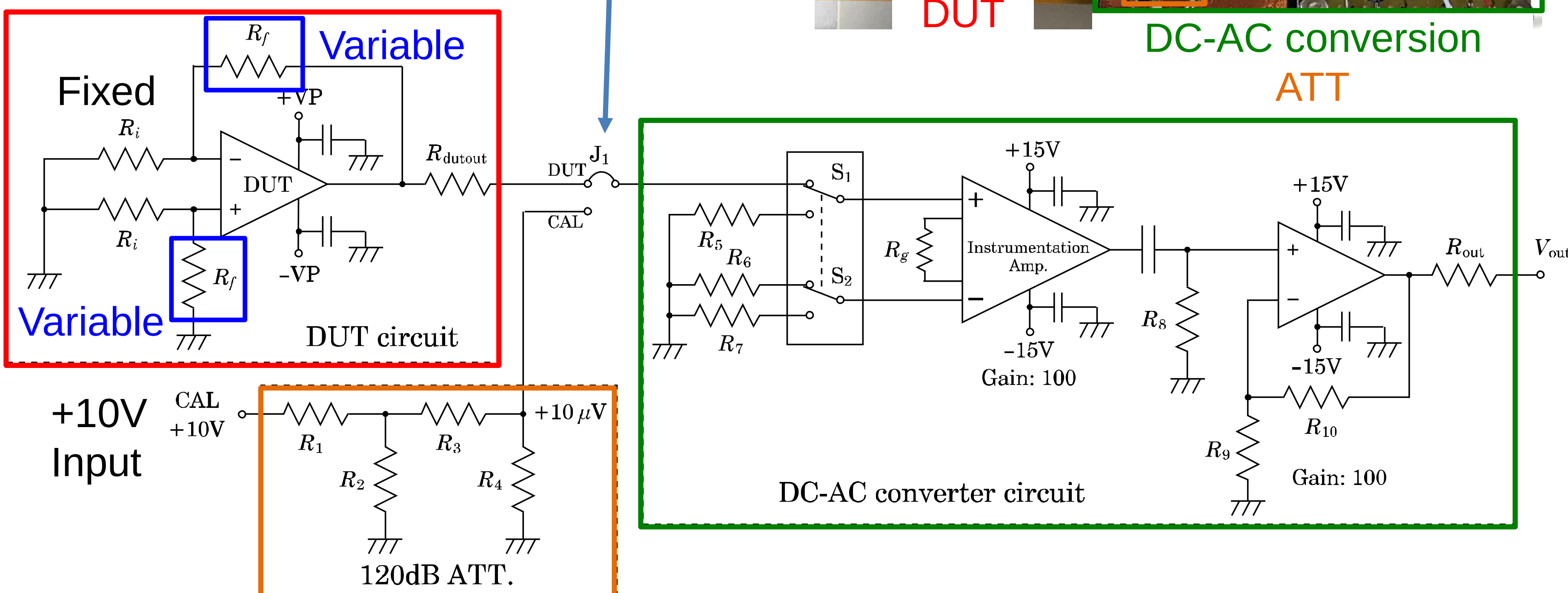
Average : 10

DUT gain: $\frac{R_f}{R_i}$

Switched CAL

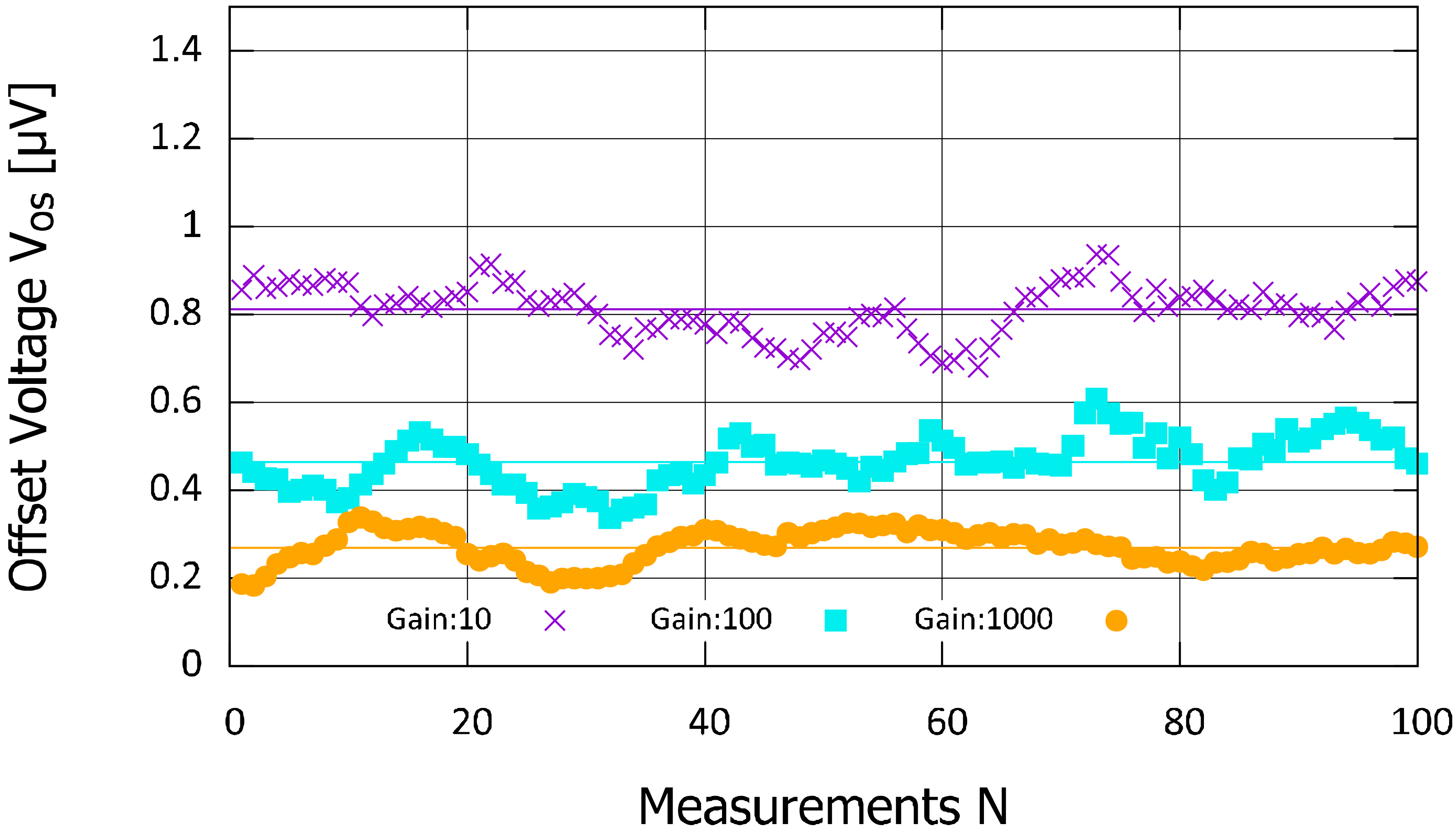
Normalized 10μV





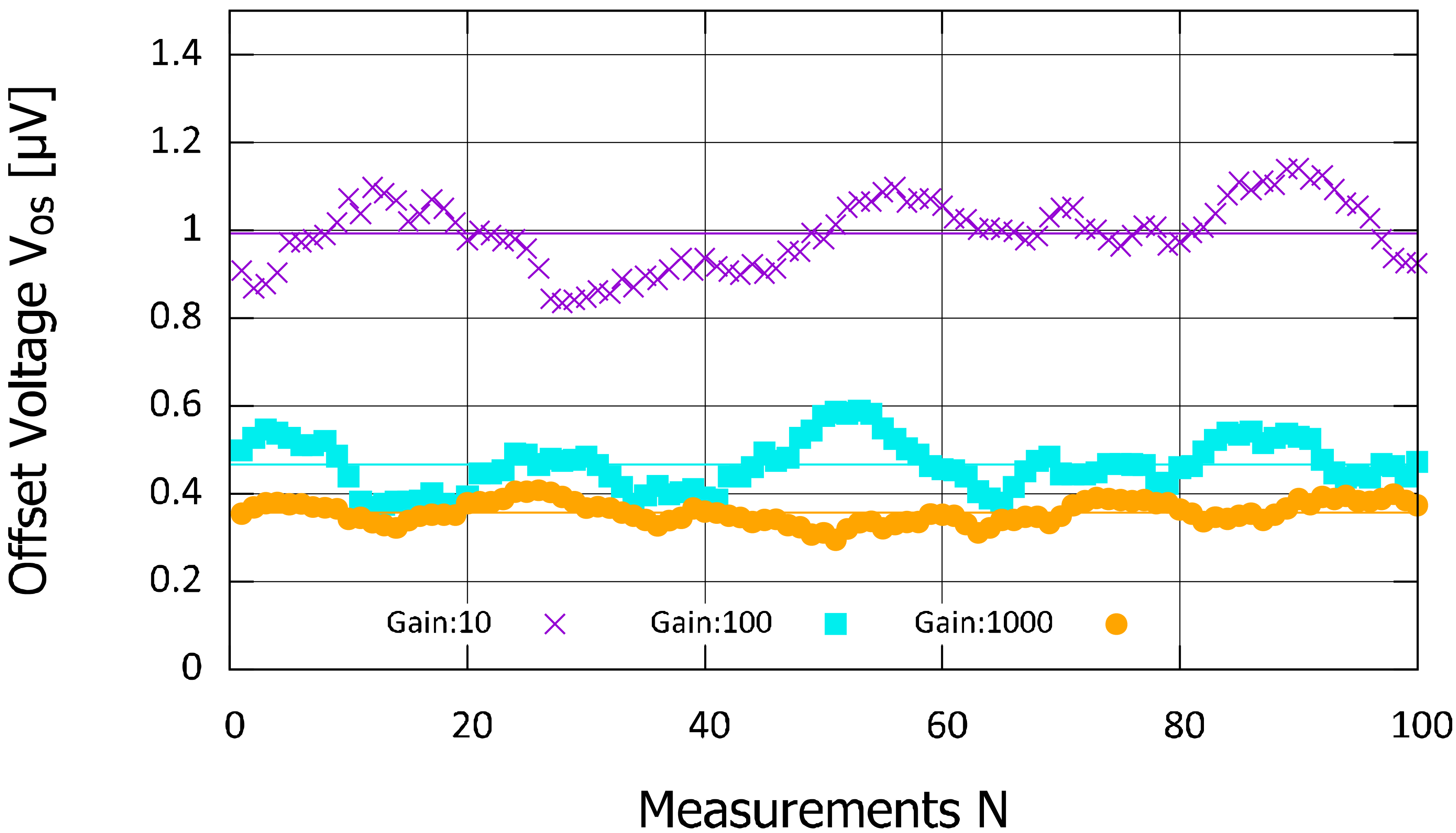
Offset Voltage Measurement Result by DC-AC Conversion Circuit I

Sample : No.1 DUT gain : ×10 (×), ×100 (■), ×1000 (●)



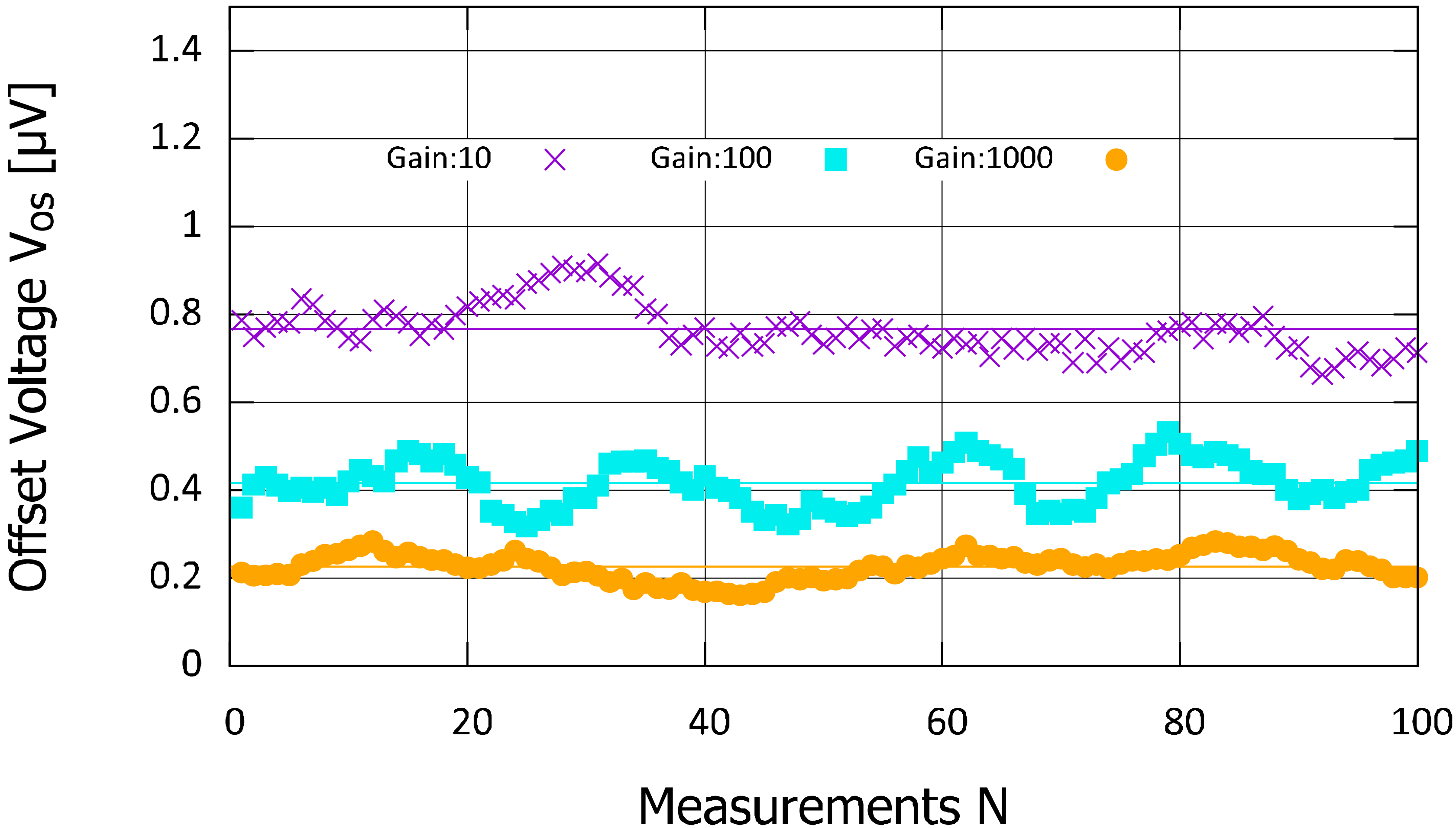
Offset Voltage Measurement Result by DC-AC Conversion Circuit II

Sample : No.2 DUT gain : ×10 (×), ×100 (■), ×1000 (●)



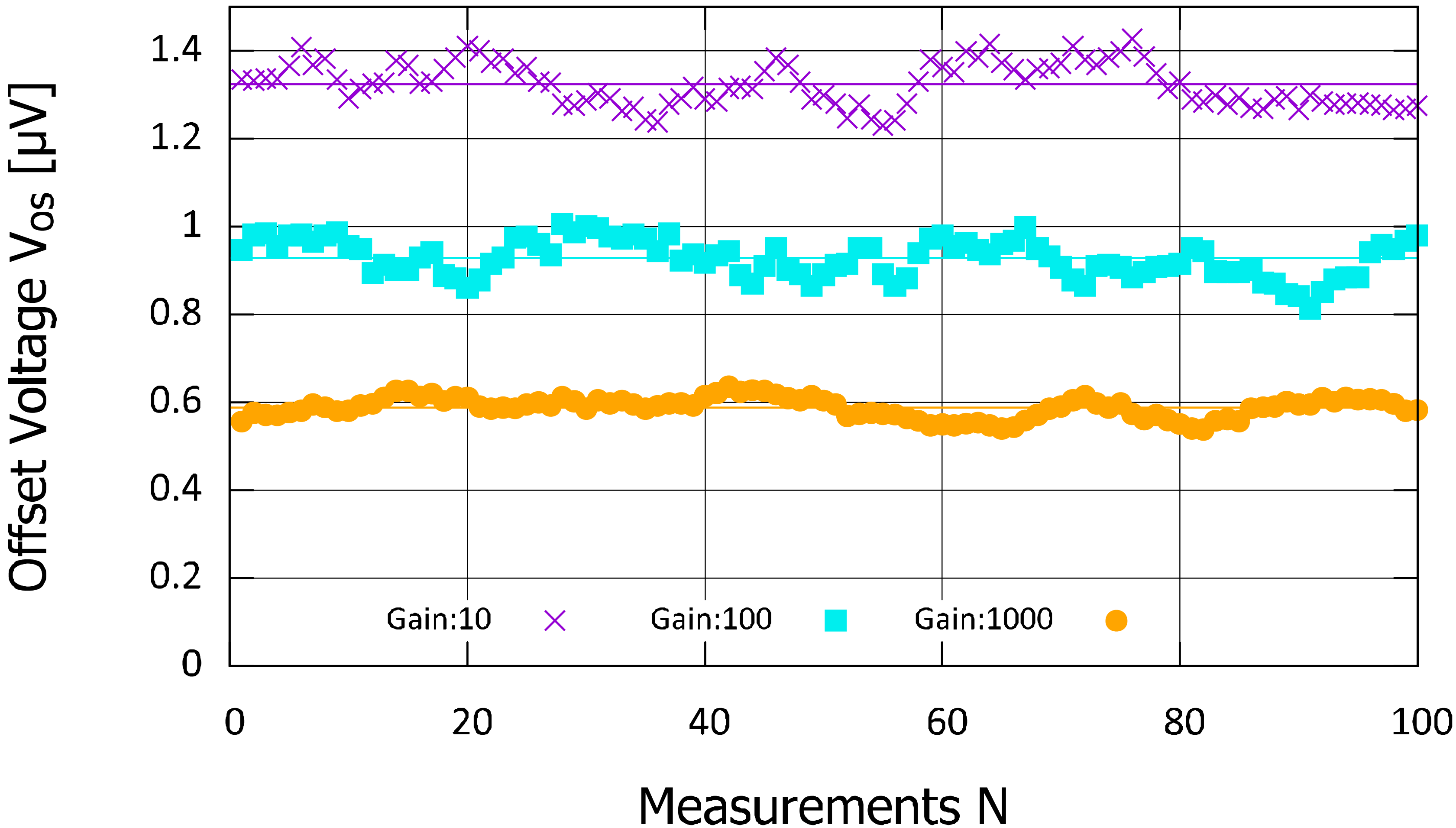
Offset Voltage Measurement Result by DC-AC Conversion Circuit III

Sample : No.3 DUT gain : ×10 (×), ×100 (■), ×1000 (●)

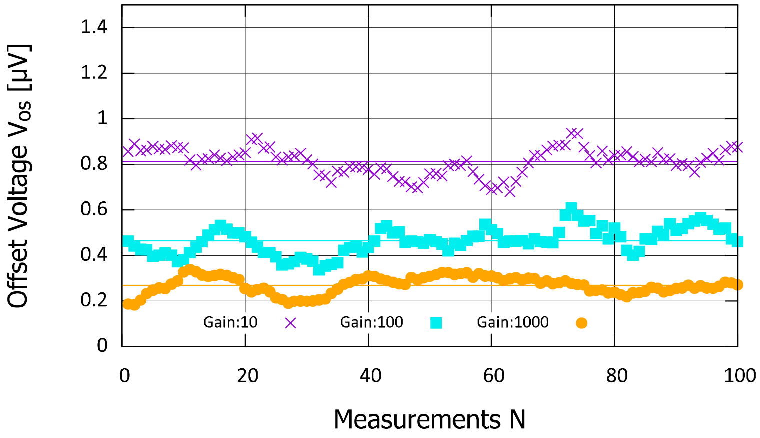


Offset Voltage Measurement Result by DC-AC Conversion Circuit IV

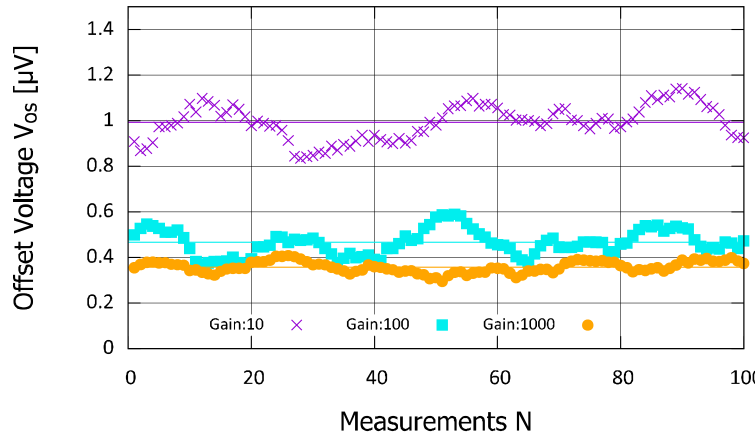
Sample : No.4 DUT gain : ×10 (×), ×100 (■), ×1000 (●)



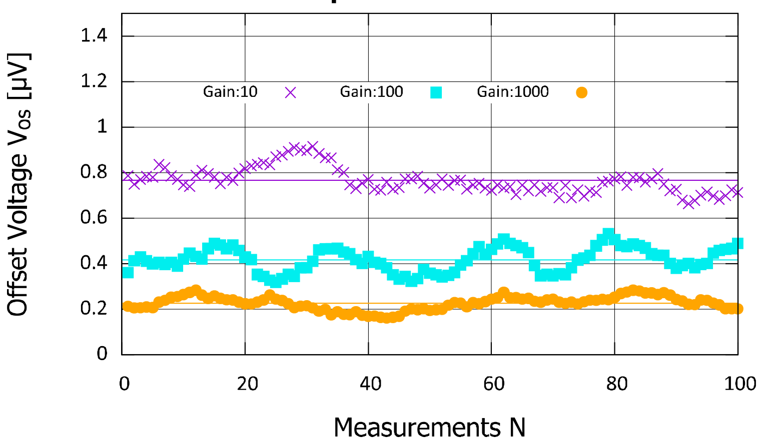
Offset Voltage Measurement Result by DC-AC Conversion Circuit



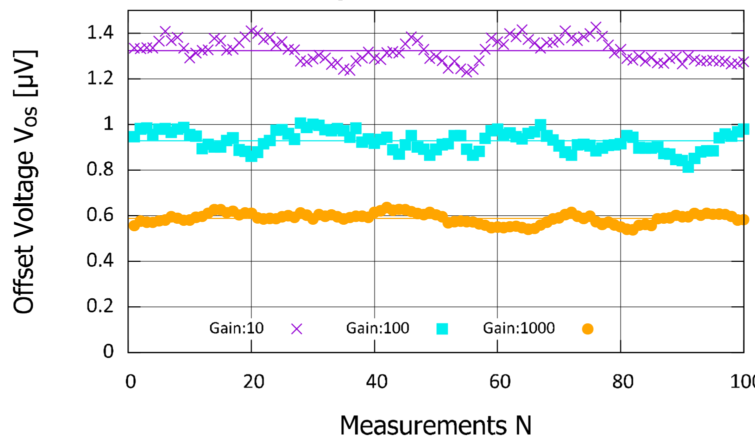
Sample : No.1



Sample : No.2



Sample : No.3



Sample : No.4

Gain increase → Offset Voltage decrease

Characteristic of AD8571

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Conclusion (Null Method)

OP amp. precision measurement at mass production testing

- Experimental comparison for high-precision DC voltage measurement

Null method / DC-AC conversion circuit

- Null method

EMF effects : Large

Conclusion (DC-AC Conversion Circuit)

OP amp. precision measurement at mass production testing

◆ Experimental comparison for high-precision DC voltage measurement

➢ DC-AC conversion circuit

EMF measure

Use low EMF solder : Linearity Improve

Noise reduction

Synchronization averaging in time domain