Summing Node Test Method: Simultaneous Multiple AC Characteristics Testing of Multiple Operational Amplifiers

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ROHM Co., LTD.

Outline

- Research Background and Objective
- Null Method and Summing Node Method
- Simultaneous Measurement of Multiple AC Characteristics with Summing Node Method
- Harmonic Distortion, SNR, THD+N Measurement with Summing Node Method
- Conclusion

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- **Research Background and Objective**
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Research Background

IoT（Internet of Things）

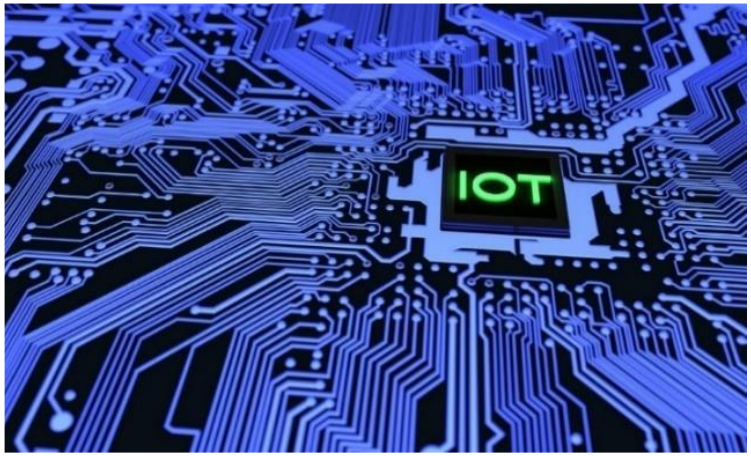
LSI for Automotive

↓

Requires High Reliability

↓

Importance of Testing and Evaluation



Mass Production Test

- **High Quality**
- **Low Cost**

Research Objective

Null Method for OP-Amp Test Circuit

Versatility and Accuracy

- **Prototype Evaluation / Laboratory Level**

Long Test Time

- **Not Suitable for Mass Production Test**

Op Amp Testing is often omitted at shipping stage.
But for reliability, its testing should be done.

✓ **Requires Fast Test Method**

Research Goal

Test Method for ATE

- **Versatility**
  - Supports many performance indices
- **High Accuracy**
  - Equivalent to the conventional method
- **Fast Test Time**
  - Simultaneous and parallel measurement

✓ **Proposal of Summing Node Method**

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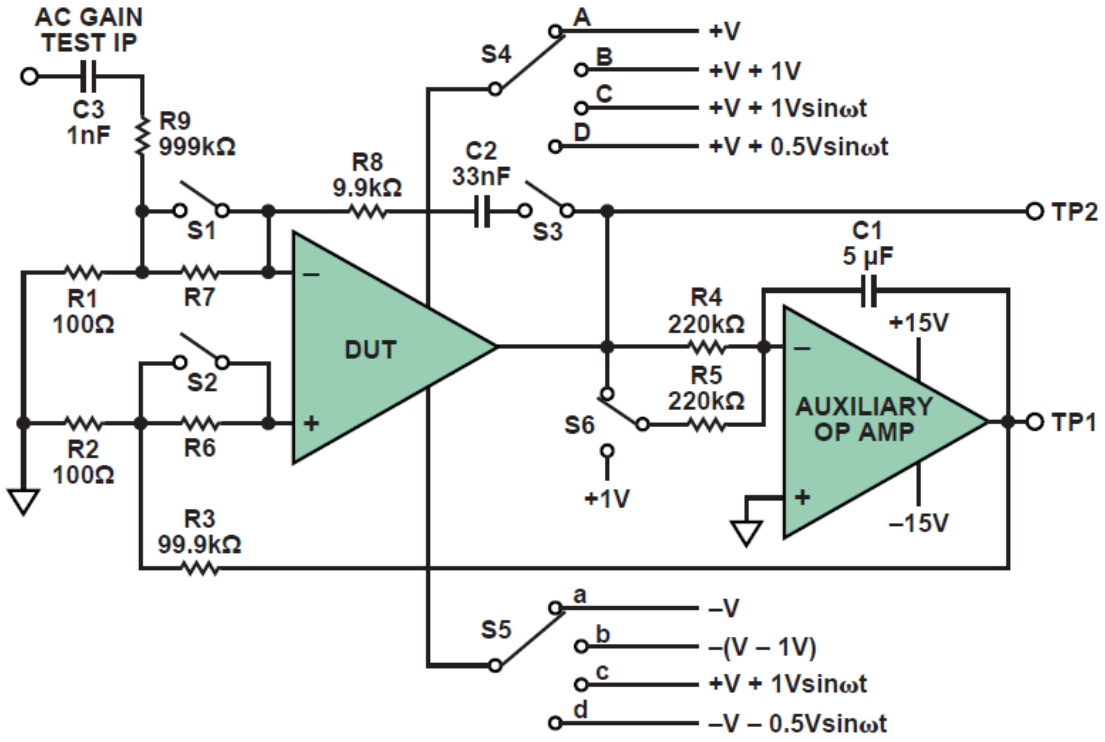
Conventional Test Method

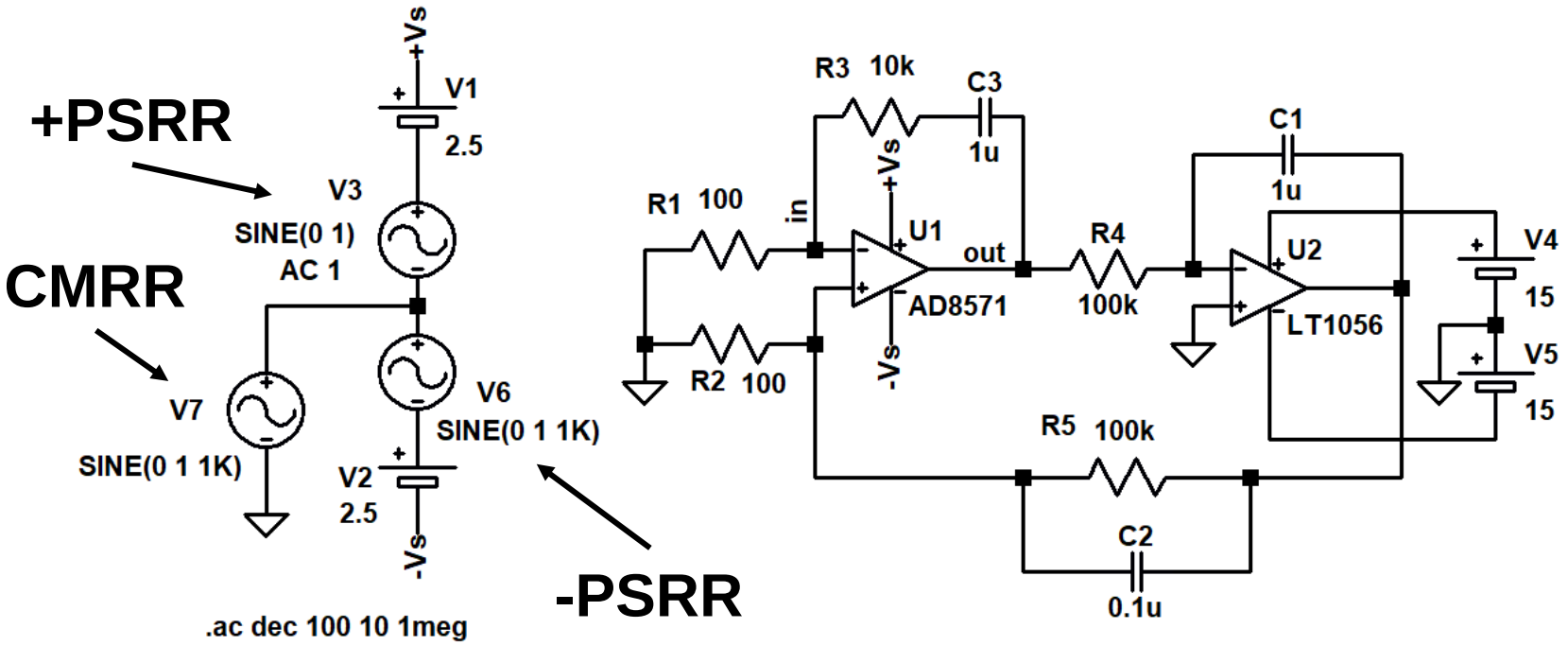
Null Method for OP-Amp Test Circuit



[1] James M. Bryant, ”Simple Op Amp Measurement”, Analog Dialogue, vol.45, pp 21-23 (2011)

PSRR, CMRR Measurement by Null

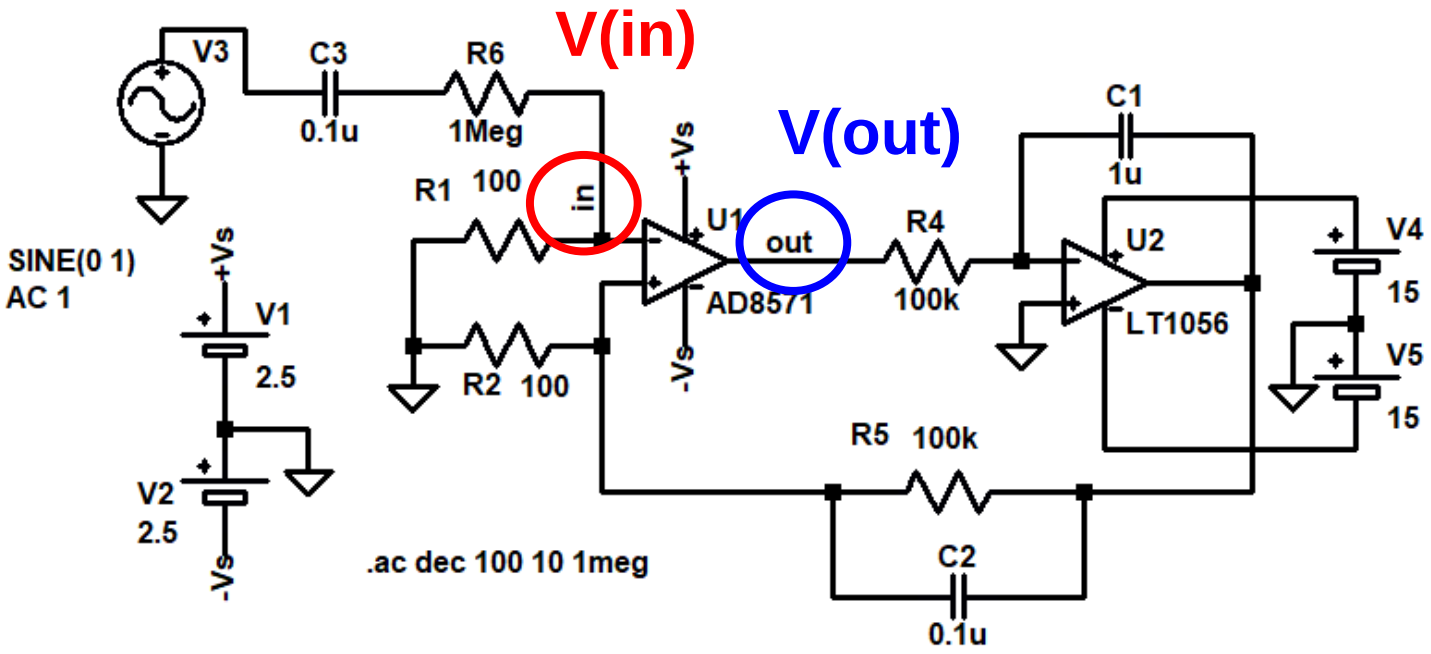
Measurement Circuit by Null Method



$$\text{PSRR, CMRR} = 20\log_{10}\frac{V(ac)}{V(out)} + 40\ [\text{dB}]$$

AOL Measurement by Null

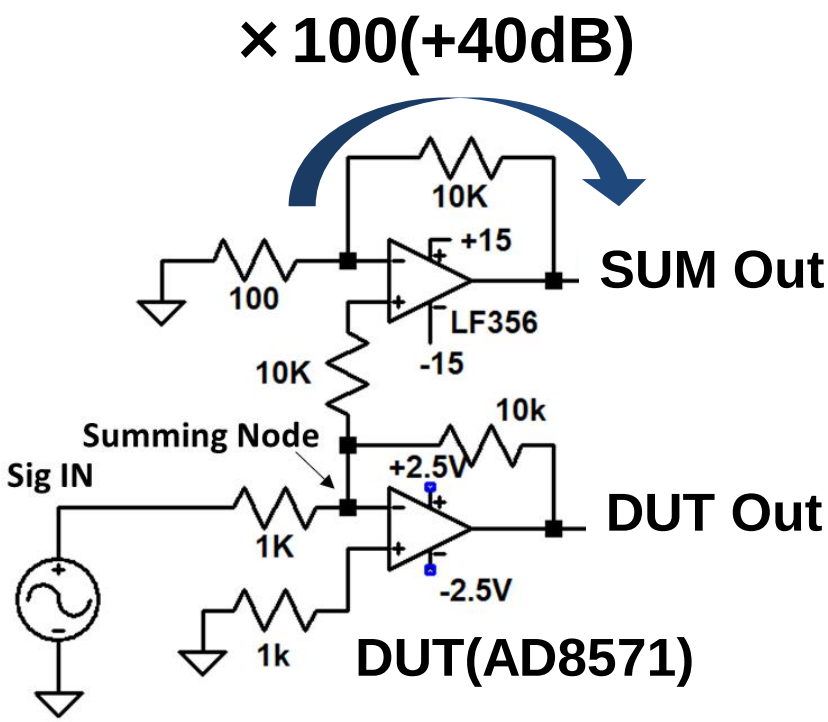
Measurement Circuit by Null Method

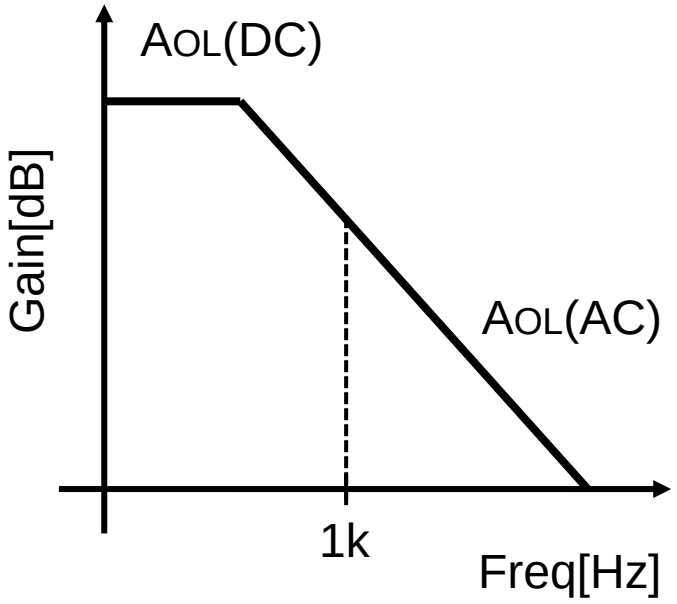


$$AOL = 20\log_{10}\frac{V(out)}{V(in)}\ [dB]$$

Proposed Summing Node Method

Measurement Circuit of Summing Node (SN) Method



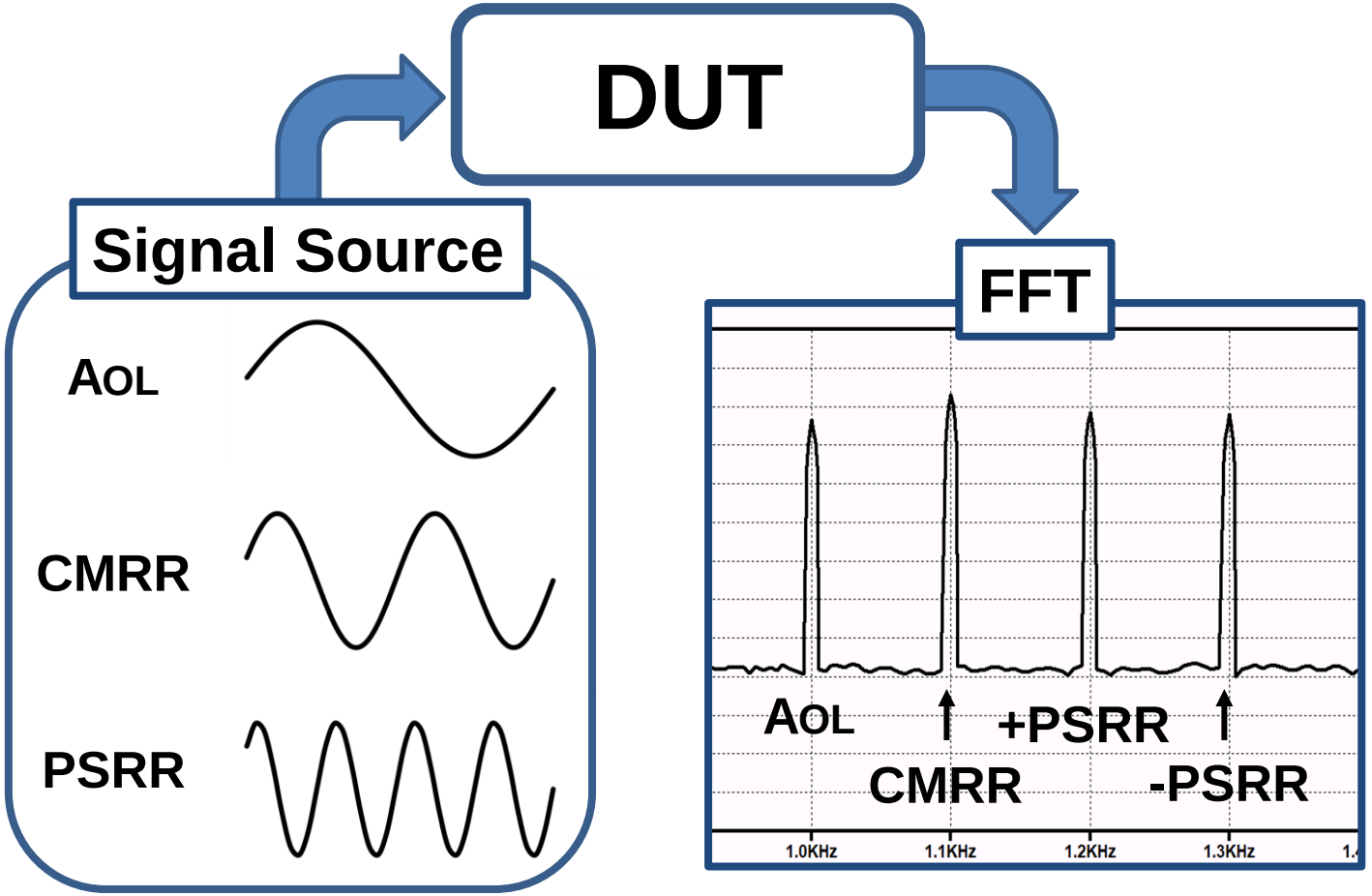


Gain Characteristic

Ex. A_{OL} = DUT Out – (SUM Out – 40) + ΔA [dB]

ΔA: Correction value obtained by simulation

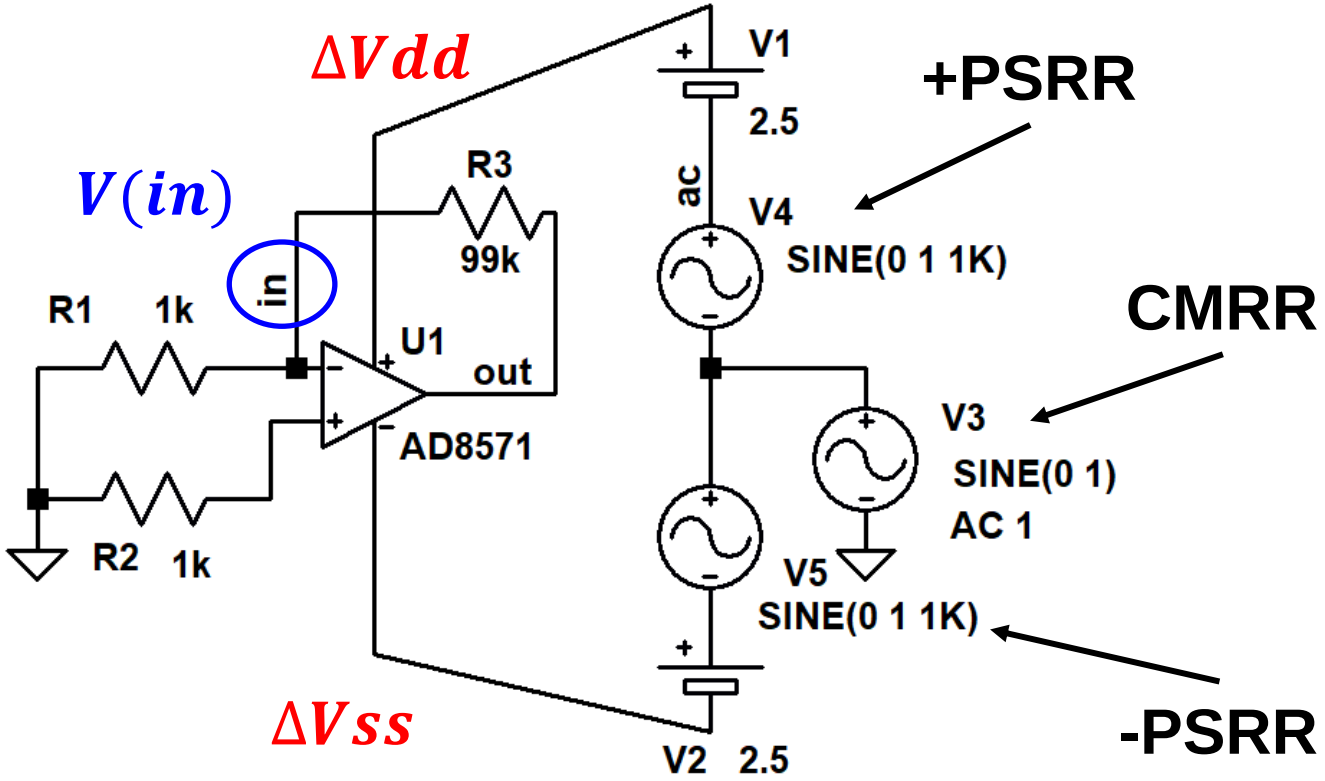
FFT-based Measurement for SN



- ✓ Different frequency for each test item
- ✓ For SN, simultaneous testing of multiple parameters for one DUT is possible.

PSRR, CMRR Measurement by SN

Measurement Circuit by Summing Node (SN) Method

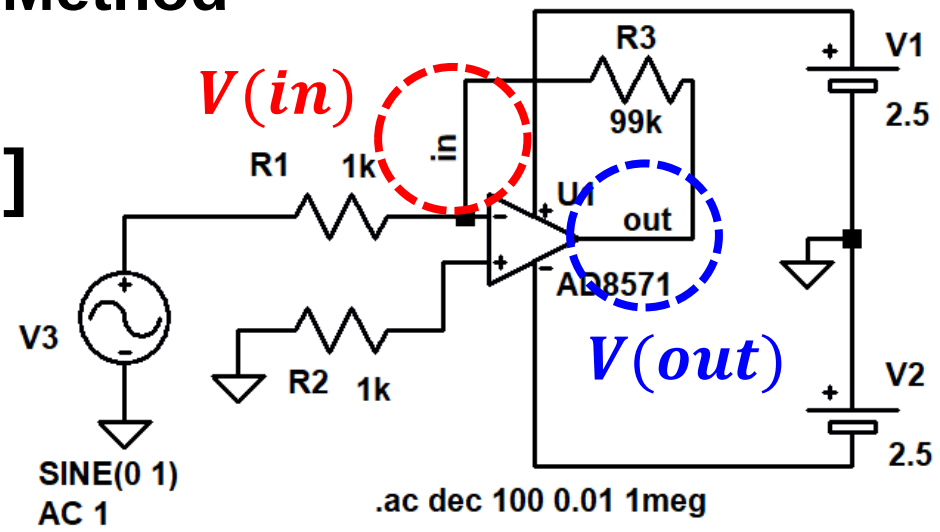


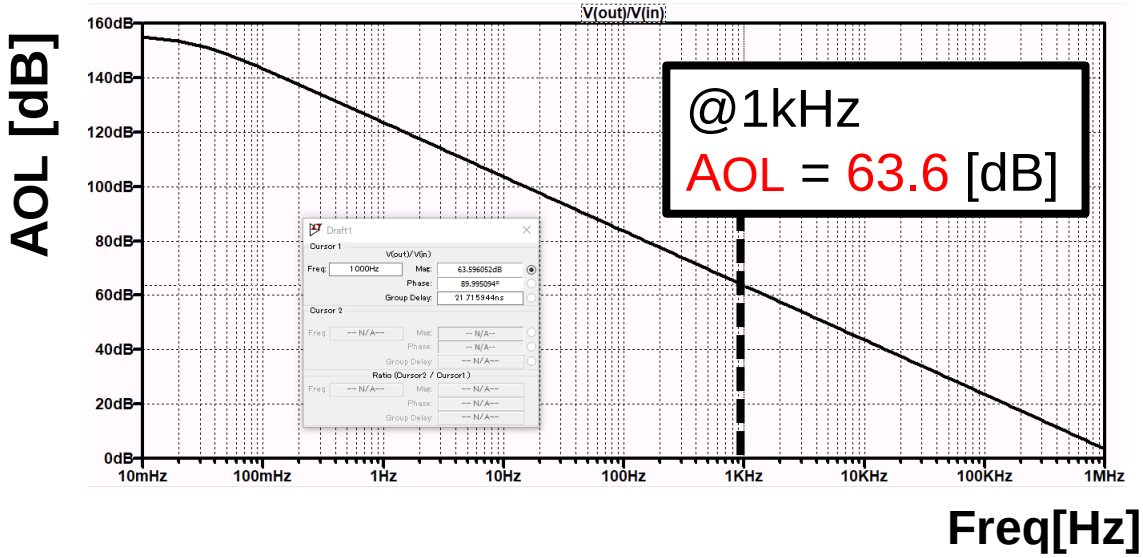
$$\text{PSRR, CMRR} = 20\log_{10}\frac{V(ac)}{V(in)}\ [\text{dB}]$$

AOL Measurement by SN

Measurement Circuit by SN Method

$$\text{AOL} = 20\log_{10}\frac{V(out)}{V(in)}\ [\text{dB}]$$





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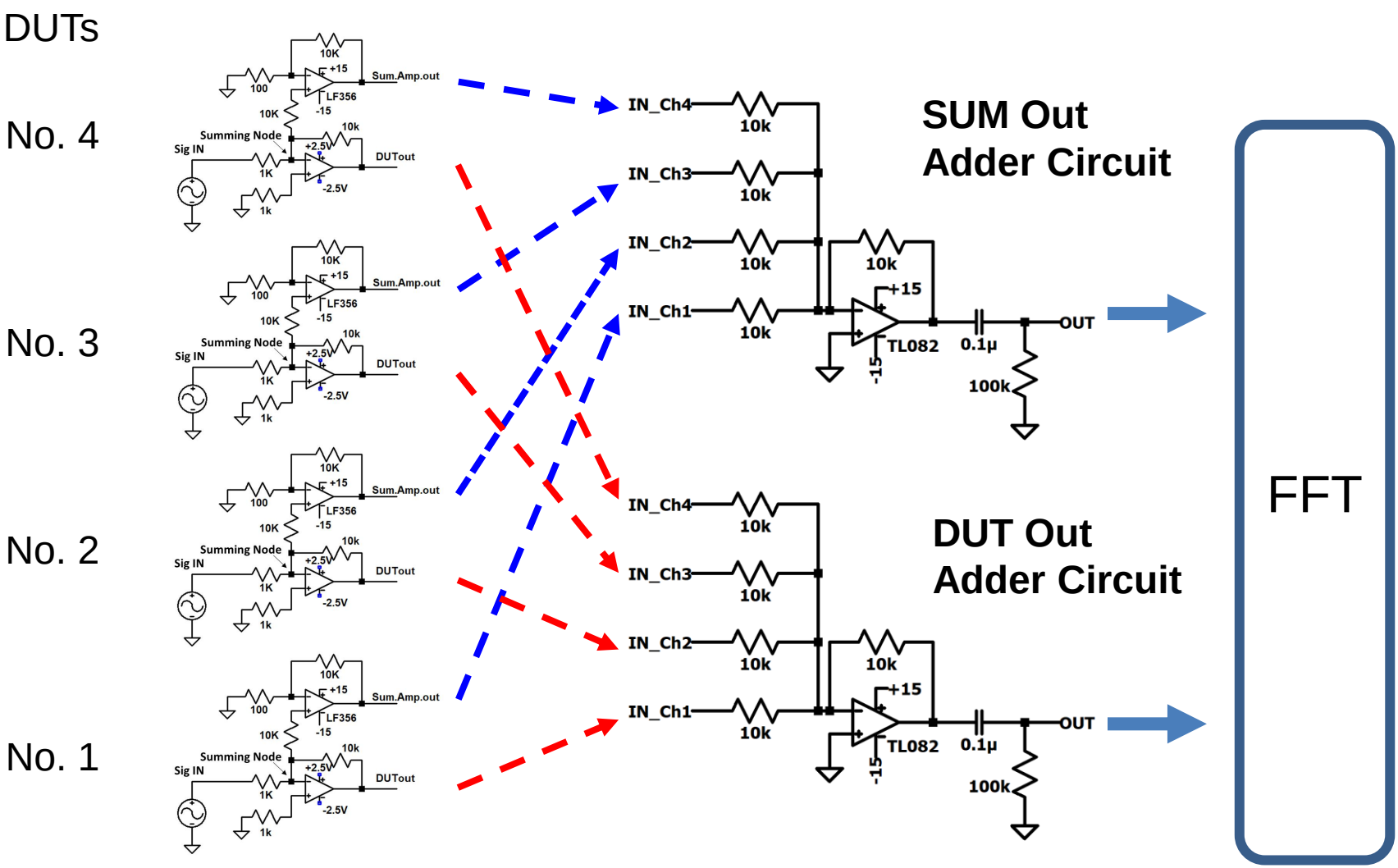
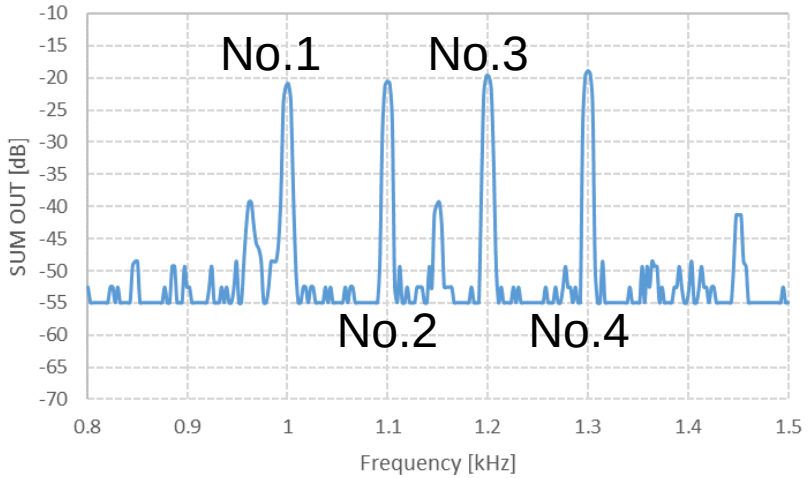
Simultaneous Measurement of A_{OL}

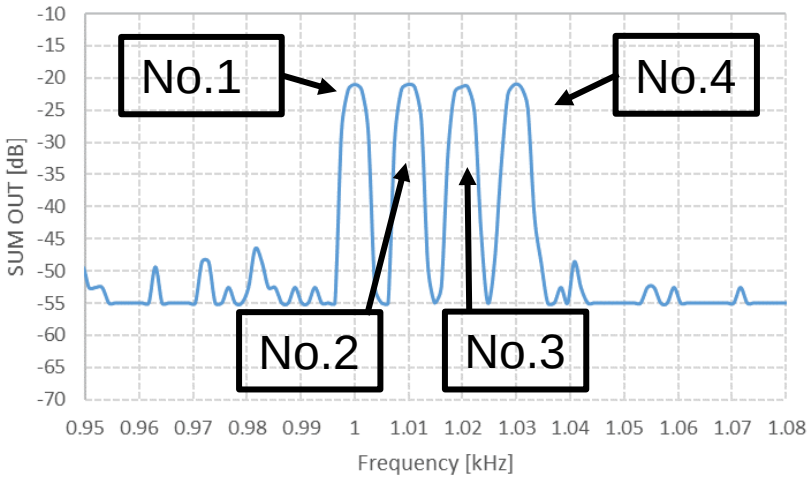


Simultaneous Measurement Results

100Hz Scale



10Hz Scale

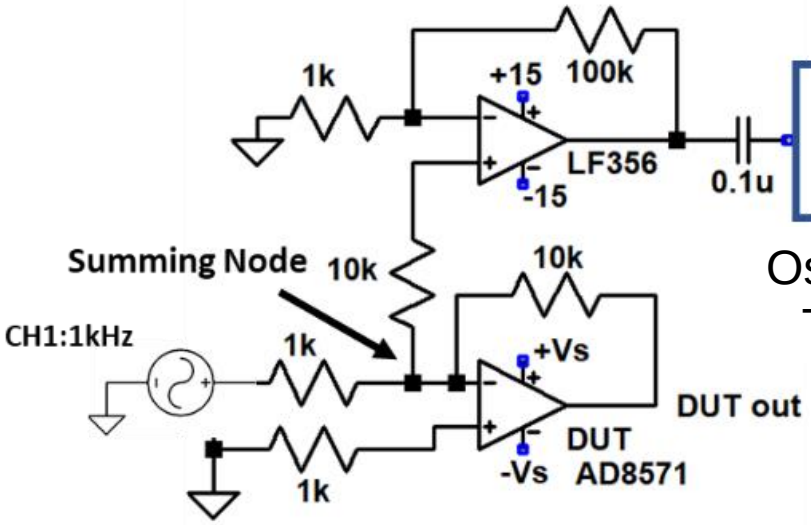


AOL can be measured even at narrow frequency scale of about 10Hz

✓ **Parallel testing for multiple DUTs**

➡ **Faster**

Measurement of Multiple ACs



Oscilloscope
TBS1062

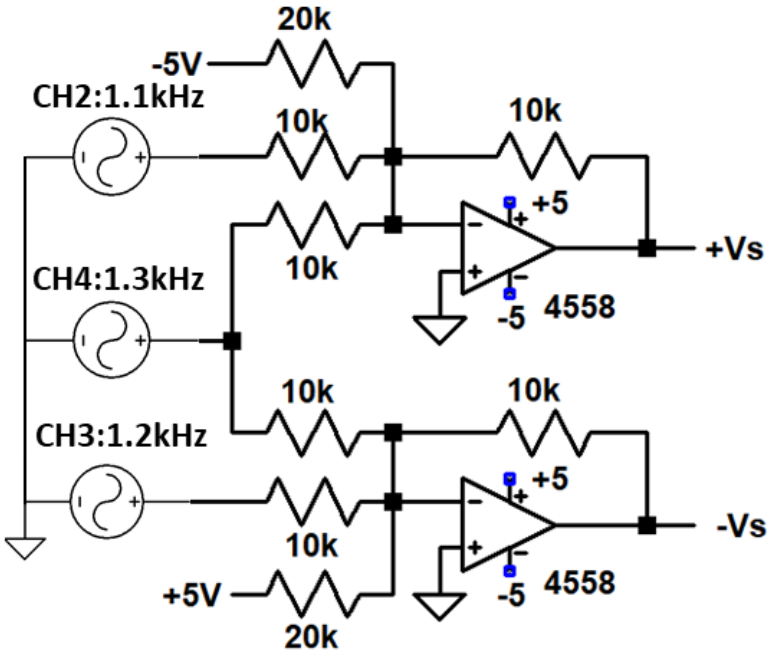
AC Input Signal Level

PSRR, CMRR : 100mVrms
AOL : 10mVrms

4 Input Signals

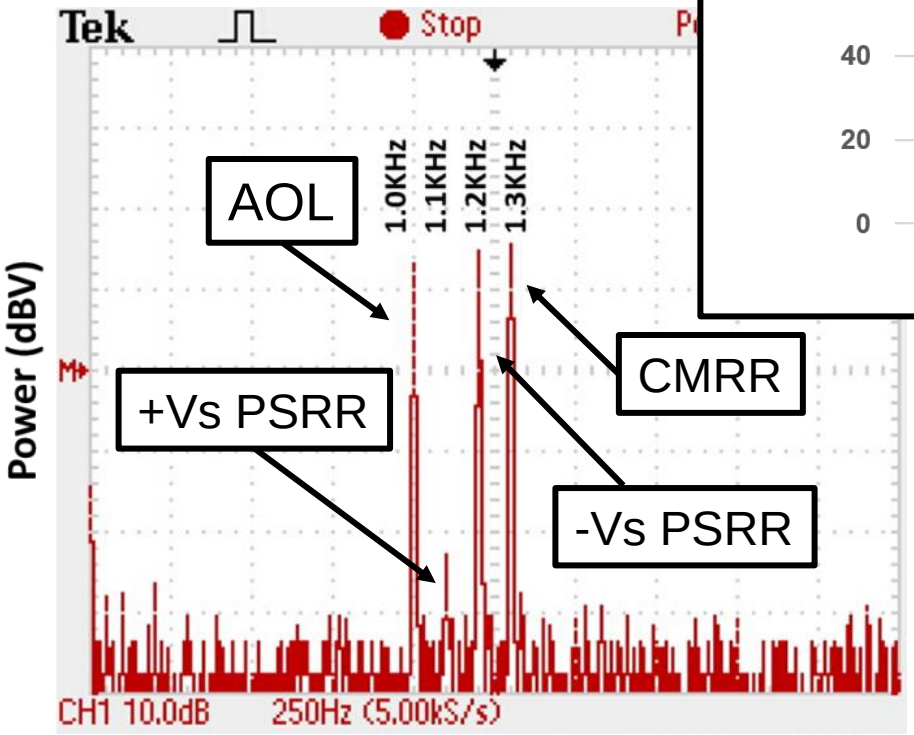
CH1(1.0kHz) : AOL
CH2(1.1kHz) : +Vs PSRR
CH3(1.2kHz) : -Vs PSRR
CH4(1.3kHz) : CMRR

DUT Power Supply

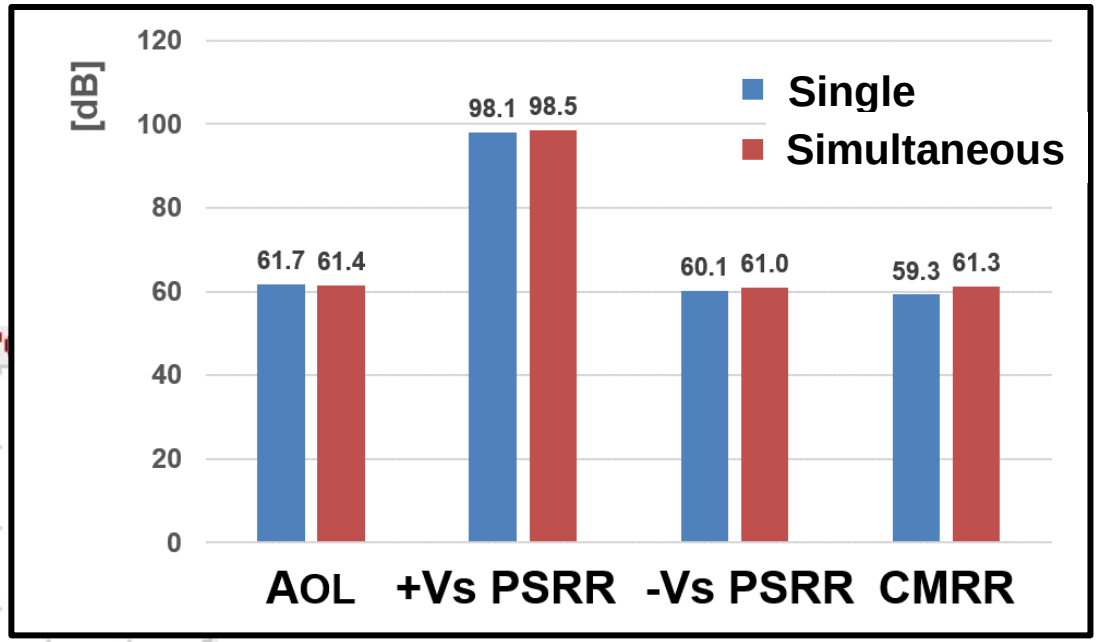


Results of Multiple ACs

AOL : -41.7dBV
+Vs PSRR : -78.1dBV
-Vs PSRR : -40.1dBV
CMRR : -39.3dBV

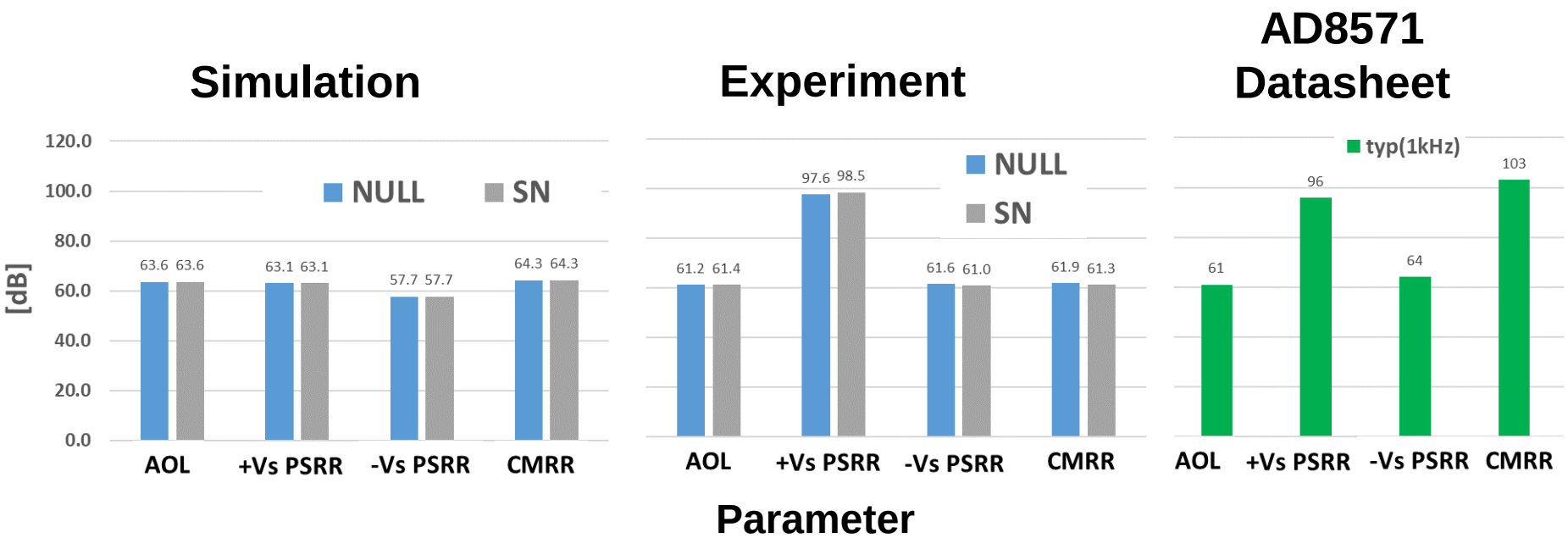


Single and Simultaneous Measurement



Difference is about 1dB

Measurement Result Overview



1. **Accuracy: As good as Null**
2. **Simultaneous measurement of AC characteristics**

✓ **Summing Node Method is**

- Accurate

- (equivalently) Fast

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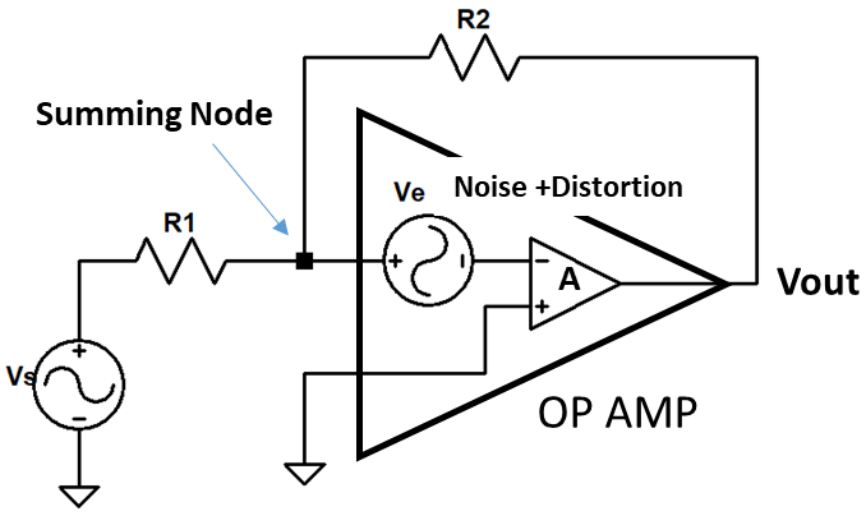
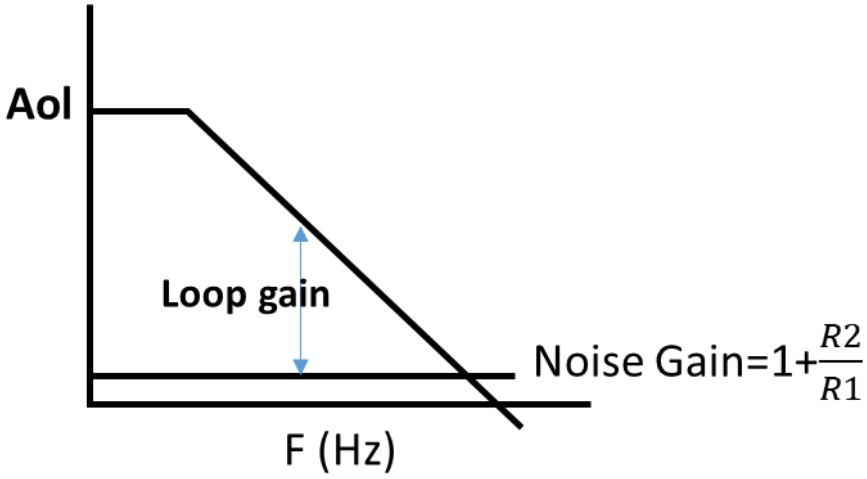
Noise & Distortion Measurement by SN

Noise & Distortion appear in Summing Node as Ve



Configuration

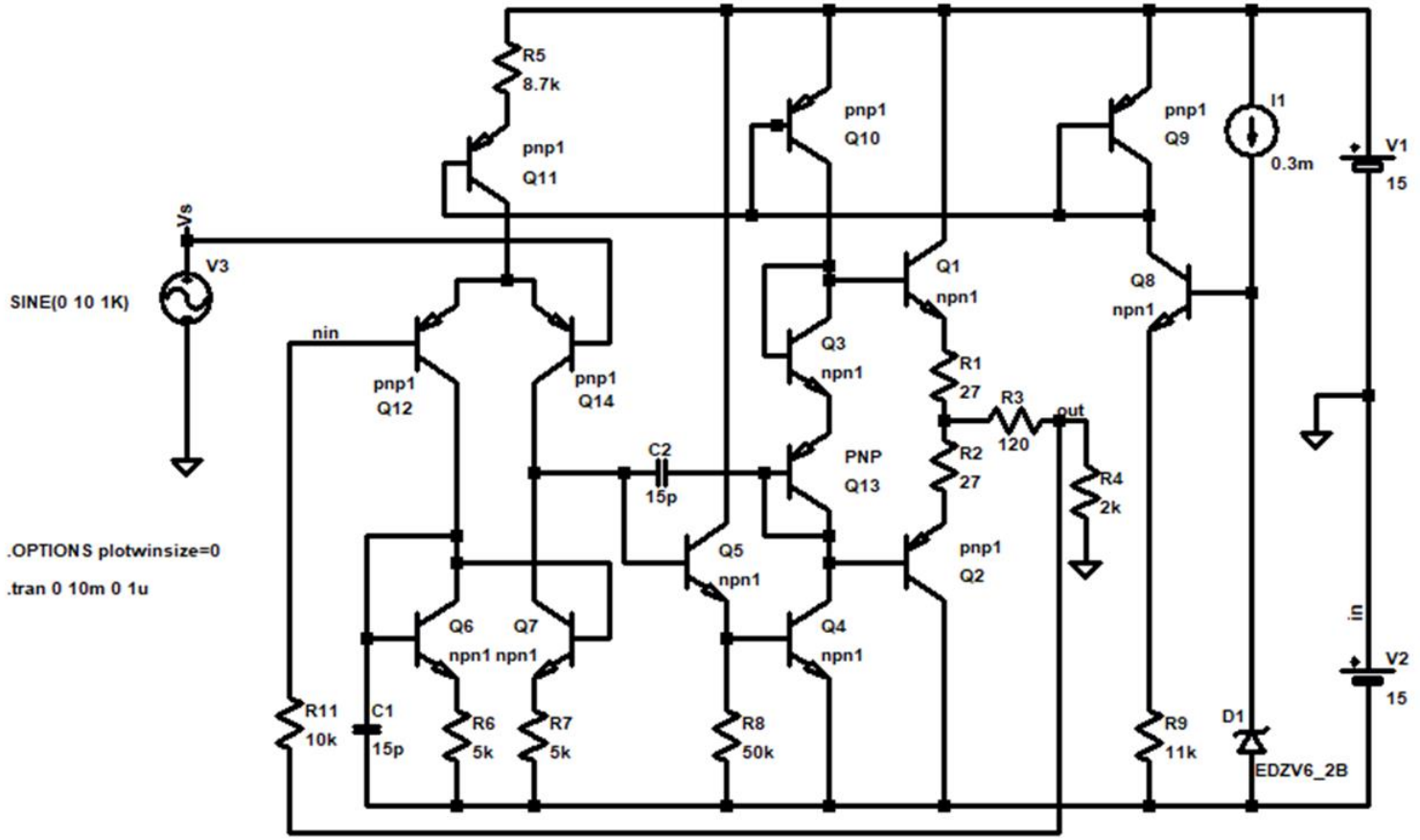


Aol Characteristics

- ✓ **Observation of effective distortion in Summing Node**
- ✓ **No need for high-purity signal sources**

SPICE Simulation with Device Model

Reproduce distortion with device model provided by the manufacturer

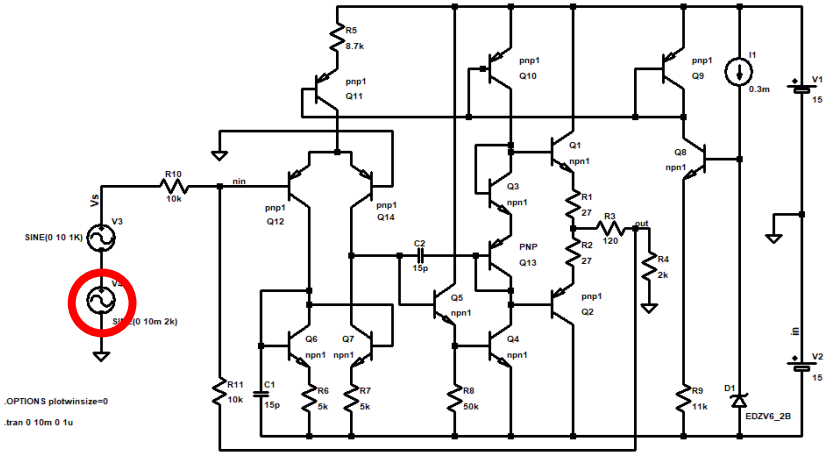


Circuit model:4558 General Purpose Op Amp
(BJT Model: Uniquely model)

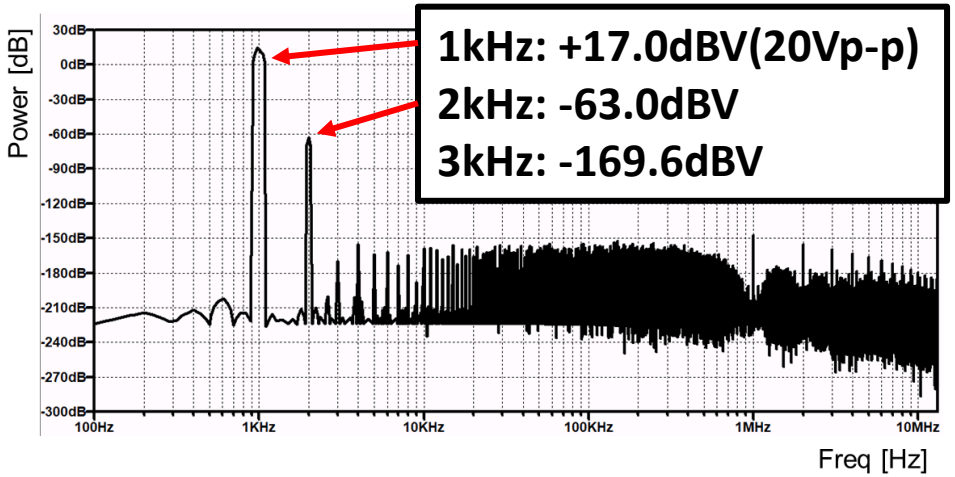
Signal Source with Distortion

Simulation of Signal Source Distortion

Fundamental: 1kHz, 20Vp-p, 2nd-order Distortion: 2kHz, 2mVp-p



2nd-order Distortion Applied

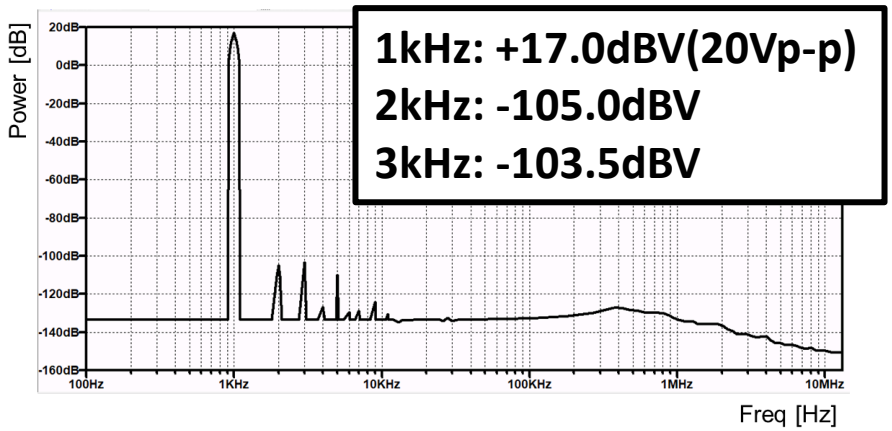


Signal Source Level

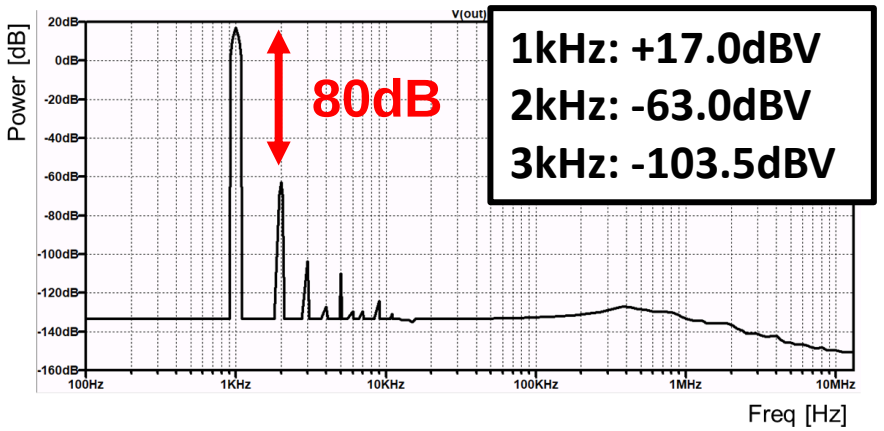
Assuming -80dB (0.01%) HD2 from fundamental wave.

Simulation Results: DUT Output

Presence or Absence of HD2 at DUT out



DUT Out
(Signal Source Distortion OFF)

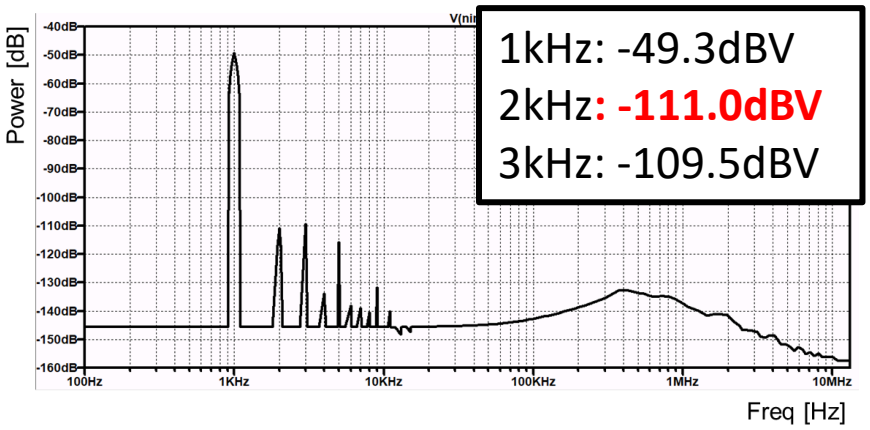


DUT Out
(Signal Source Distortion ON)

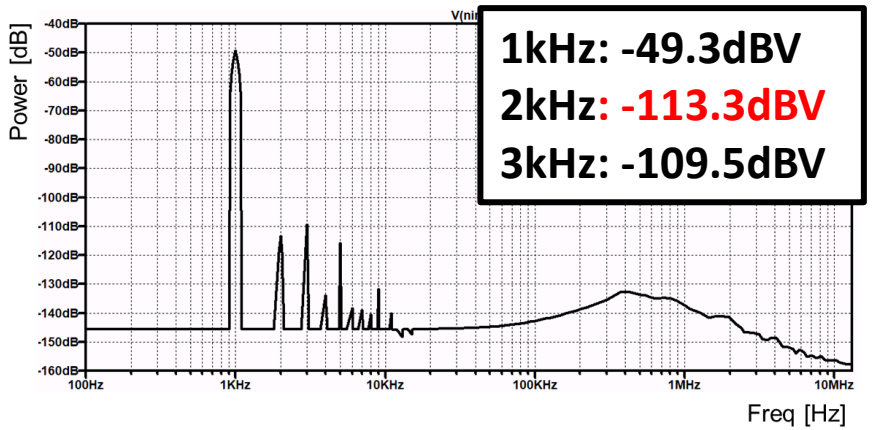
Appearance of HD2 on DUT out

Simulation Results: Summing Node

Presence or Absence of HD2 at Summing Node



Summing Node
(Signal Source Distortion OFF)

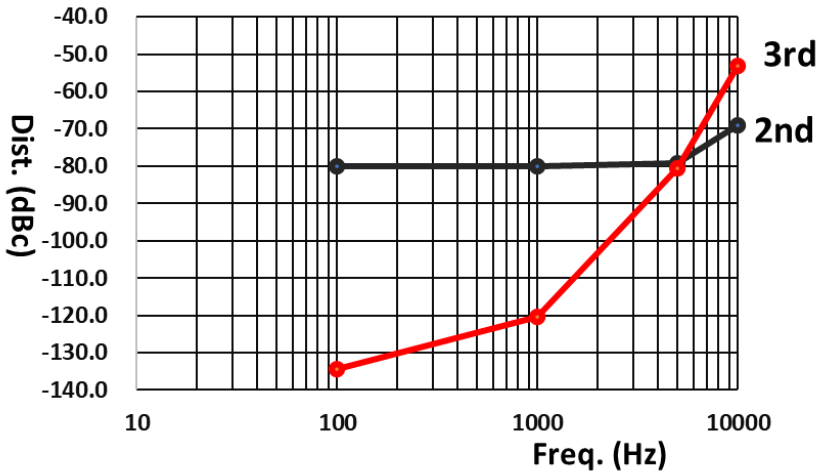


Summing Node
(Signal Source Distortion ON)

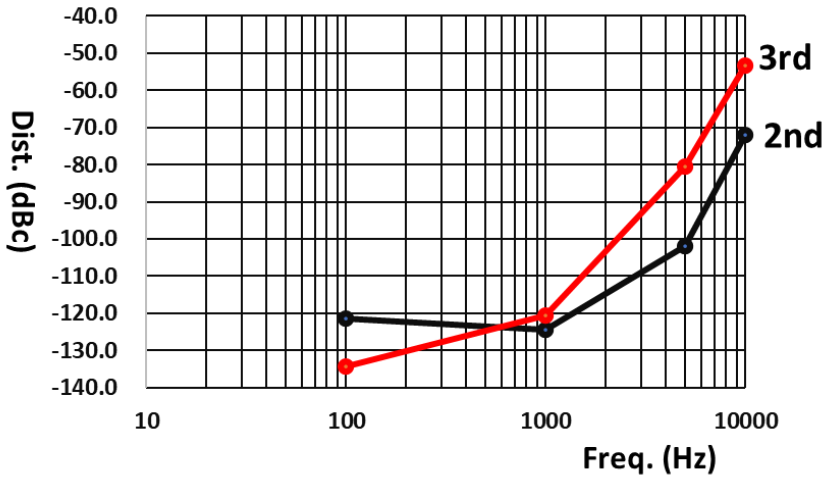
- ✓**No HD2 appears**
- ✓**Only distortion of Op Amp (DUT)**

Effect of Signal Source Distortion

Difference between DUT Out and Summing Node



DUT Out
(Signal Source Distortion ON)

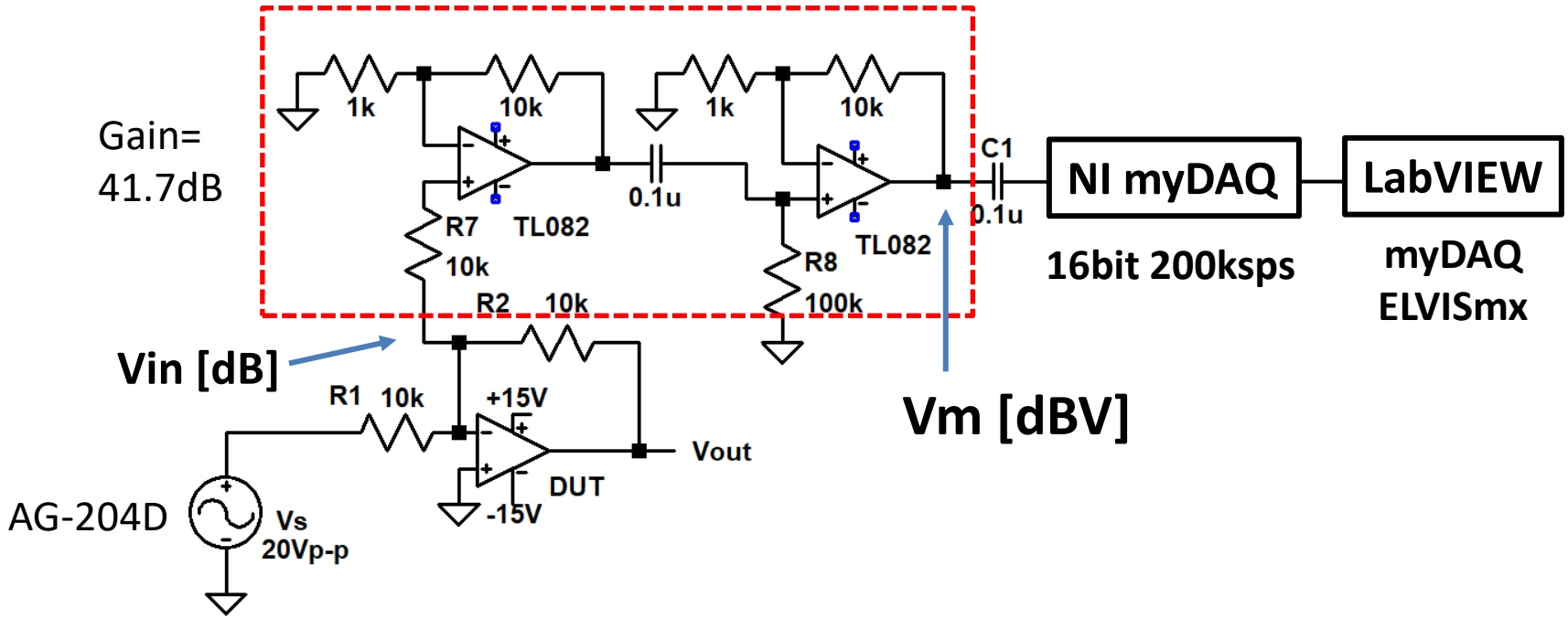


Summing Node
(Signal Source Distortion ON)

- ✓Not affected by signal source distortion
- ✓Only distortion of Op Amp itself

Harmonic Distortion Measurement

Configuration & Operation



Harmonic Distortion[dBc]

= (Vm[dBV] – Gain[dB] + 6[dB]) – Vs[dBV]

HD Measurement Results

Oscilloscope(8bit ADC) and myDAQ (16bit ADC)

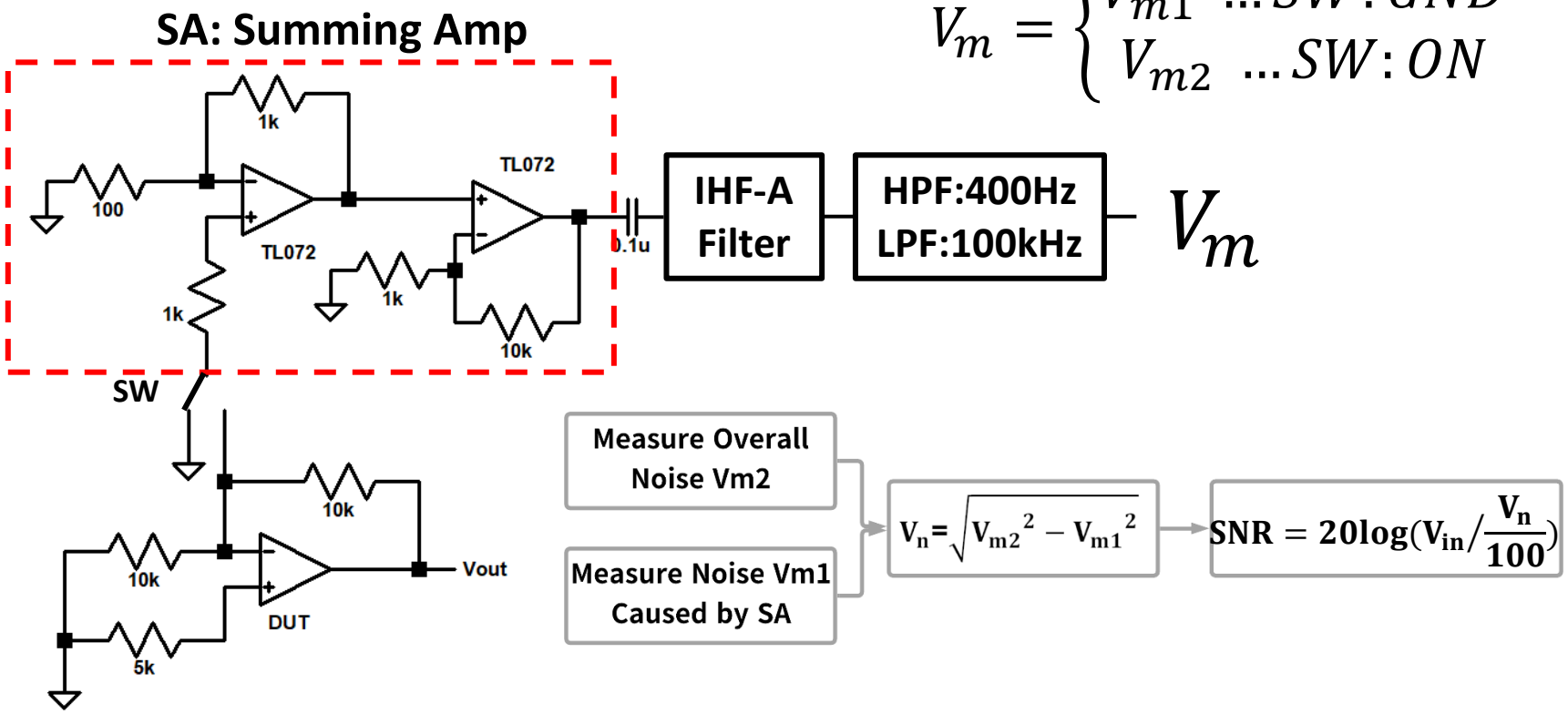
DUT	Fundamental	Order	Distortion	
			Oscilloscope	myDAQ
LF356	1kHz	2nd	-122.9	-123.1
		3rd	-122.9	-135.4
	10kHz	2nd	-92.5	-93.3
		3rd	-102.9	-121.7

- ✓ **Oscilloscope FFT is limited to -120dBc distortion analysis with 1kHz, 20Vp-p Signal**
- ✓ **Confirmed dynamic range of -130dBc or more with 16bit ADC**

SNR Measurement

Configuration & Operation

$$V_m = \begin{cases} V_{m1} & \dots SW: GND \\ V_{m2} & \dots SW: ON \end{cases}$$

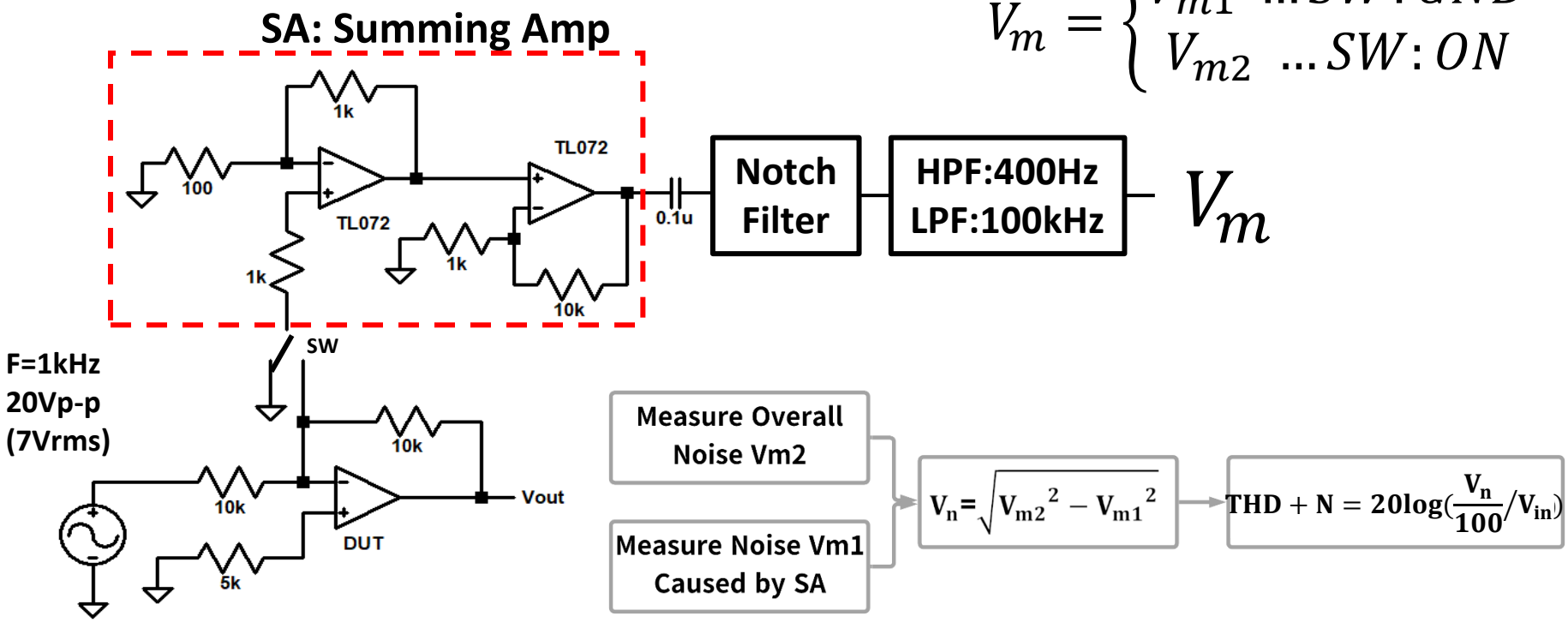


✓Easy to determine SNR from SA output

THD+N Measurement

Configuration & Operation

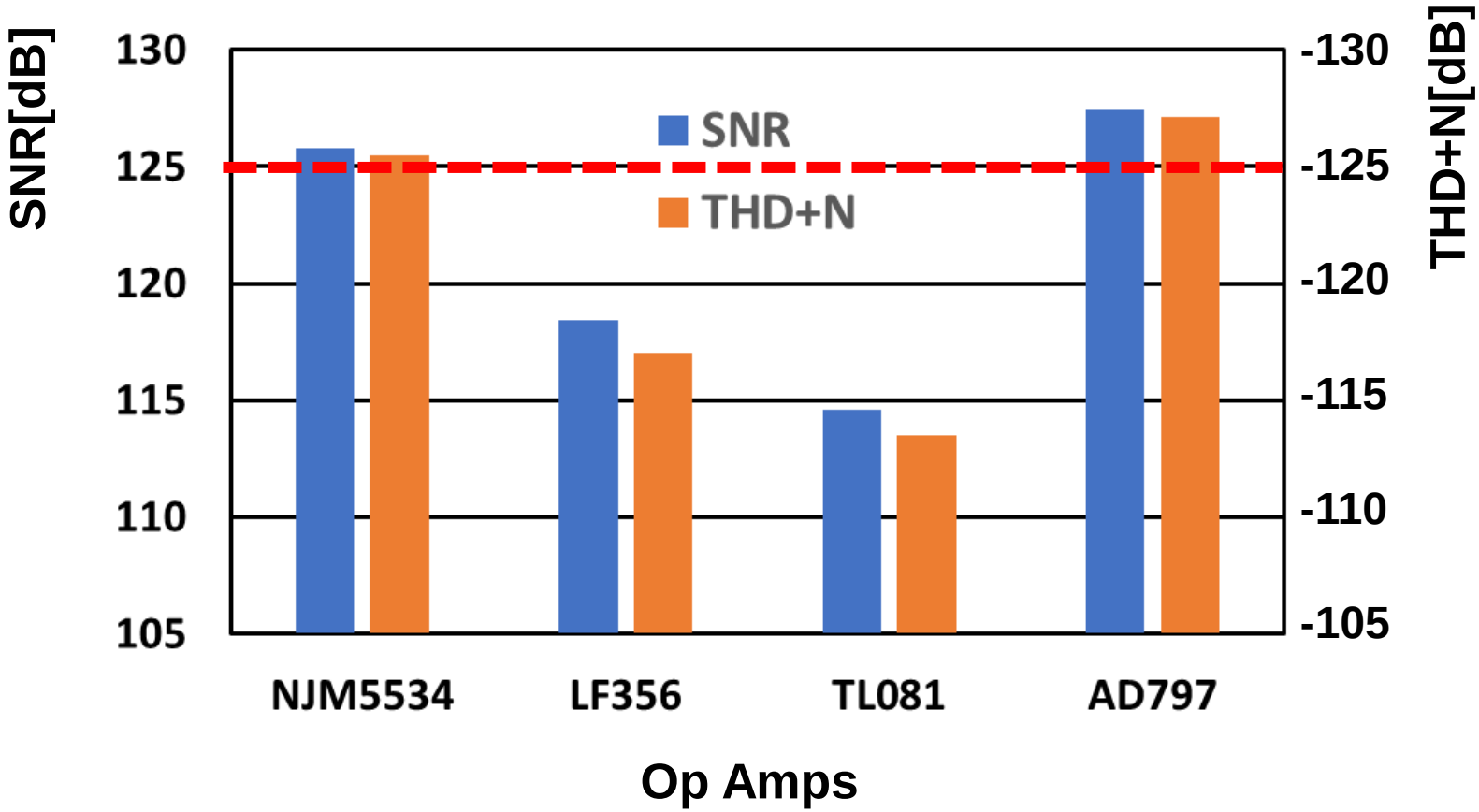
$$V_m = \begin{cases} V_{m1} & \dots SW: GND \\ V_{m2} & \dots SW: ON \end{cases}$$



✓Easy to determine THD+N from SA output

SNR, THD+N Measurement Results

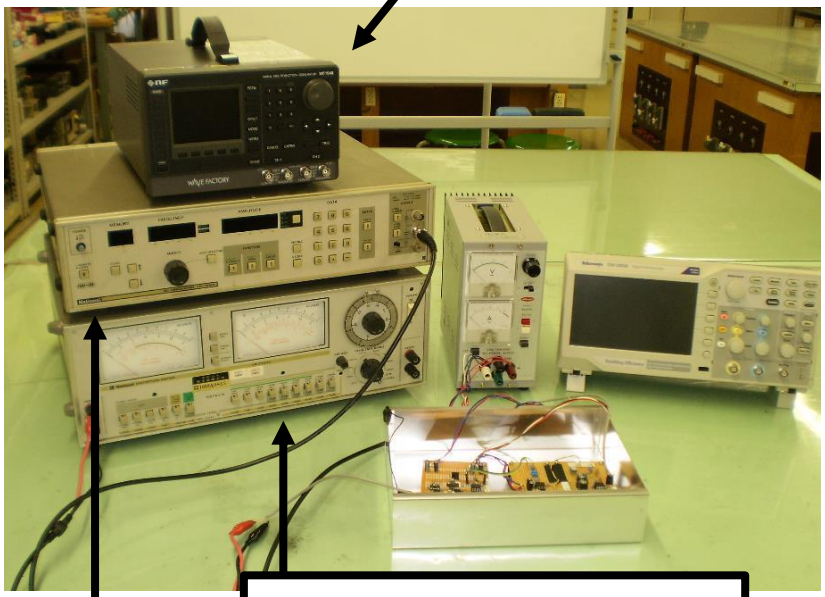
Measurement Results for several Op Amps



✓SNR, THD+N Measurement of 125 dB or more is possible

Actual Experiment Environment

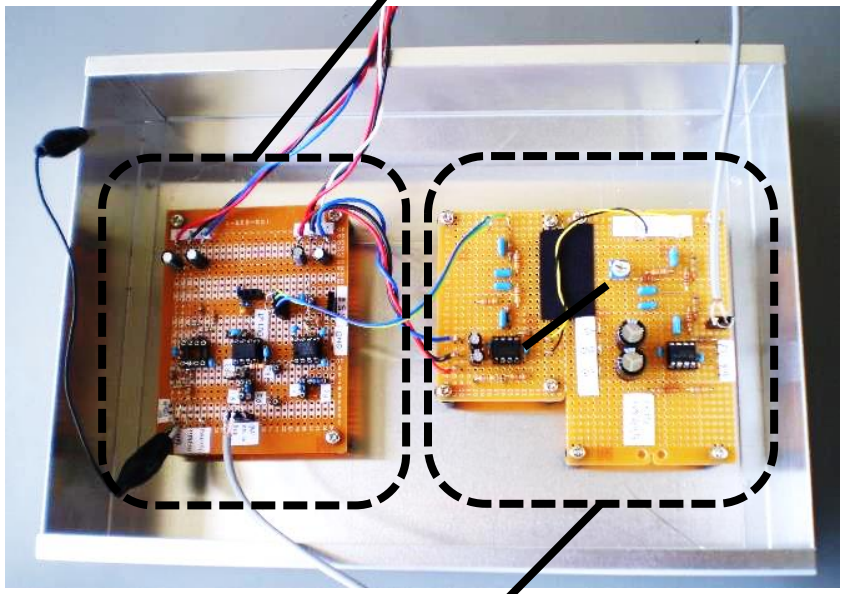
WF1948
Function Generator
(16bit DAC)



VP7702C
Distortion Meter

VP7214A
Low Distortion Oscillator

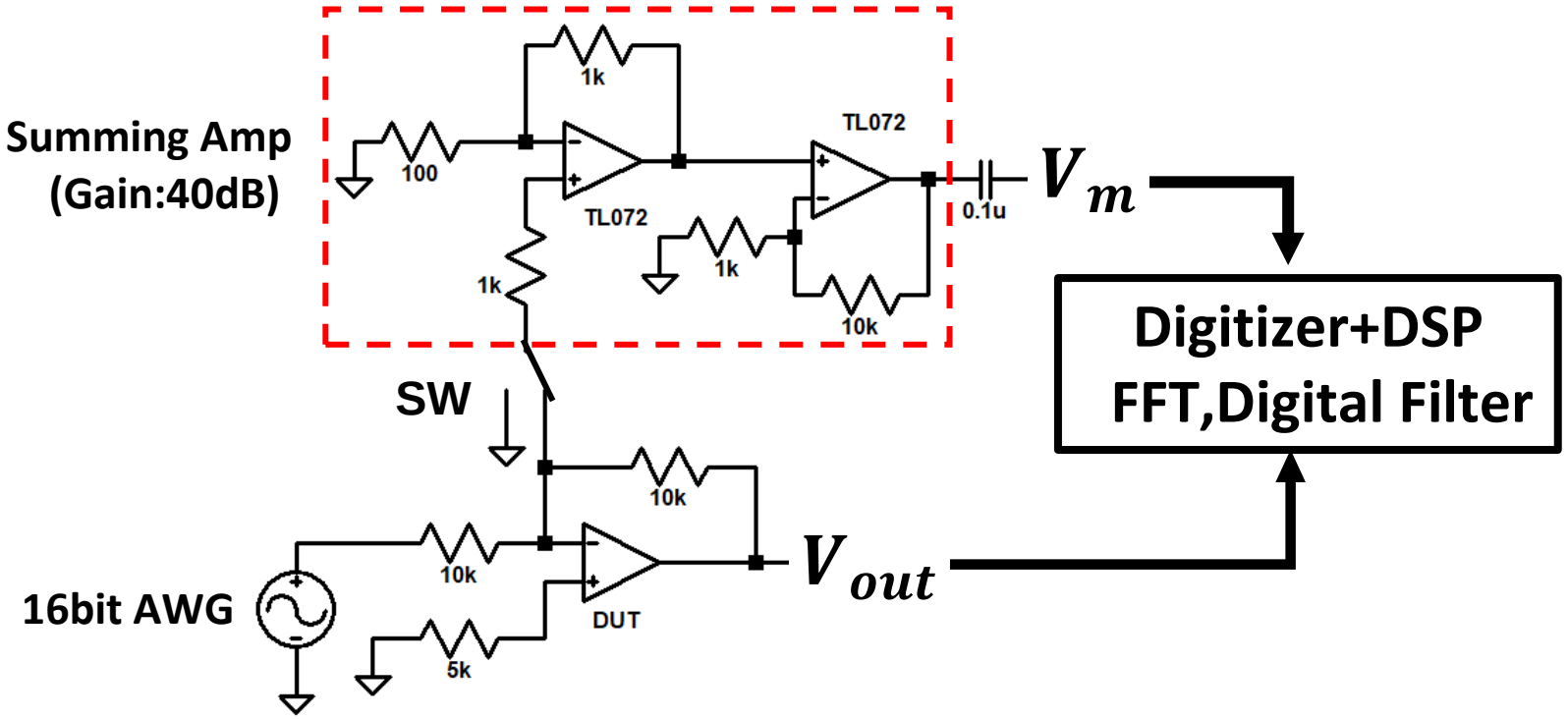
Op Amp (DUT) &
Summing Node Amp



Notch Filter &
IHF-A Characteristic Filter

Integrated Measurement System

Configuration for ATE



✓**Supports Multiple AC Characteristics**

(Aol, PSRR, CMRR, SNR, Harmonic Distortion, THD+N)

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Conclusion

Summing Node Method Proposal for OP Amp testing

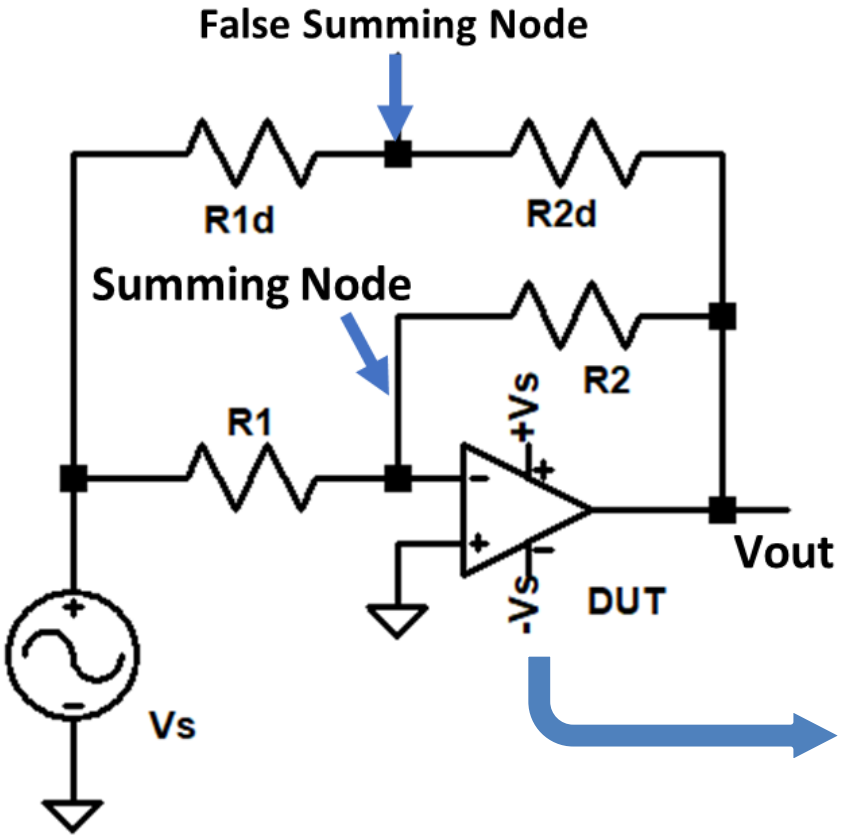
- **Multiple AC Characteristics Measurement**
  such as Open-Loop Gain, PSRR, CMRR, SNR, Harmonic Distortion, THD+N

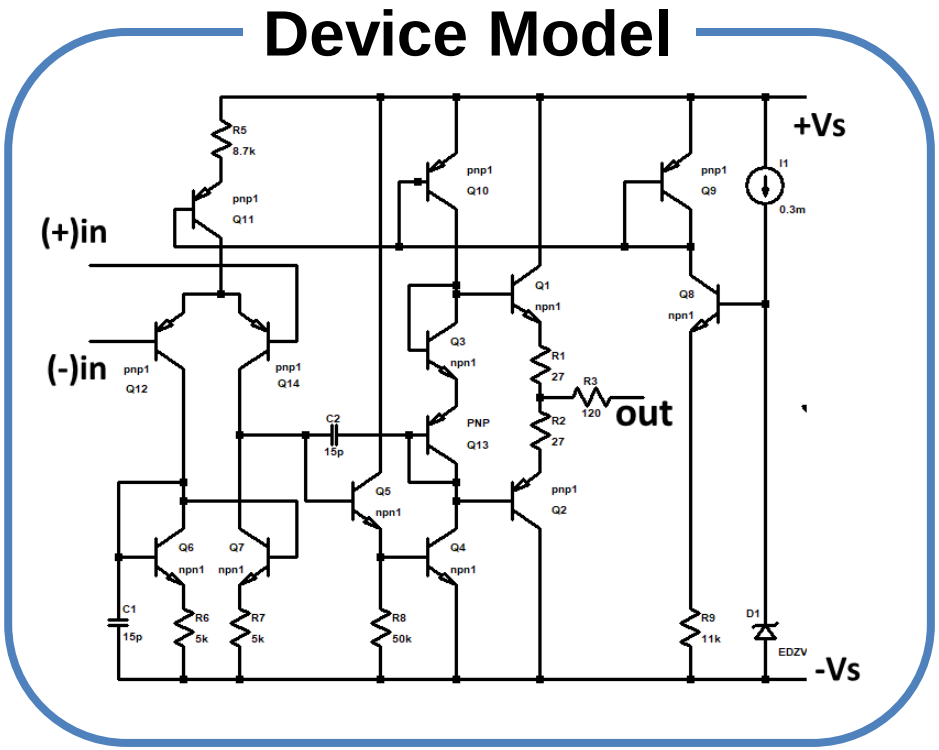
- **Measurement without high-end equipment**
  No need a high-performance signal source or measurement system

✓ **Applicable to fast, accurate, low cost testing of Op Amps without expensive instruments.**

Future Works

Not good to observe Summing Node directly



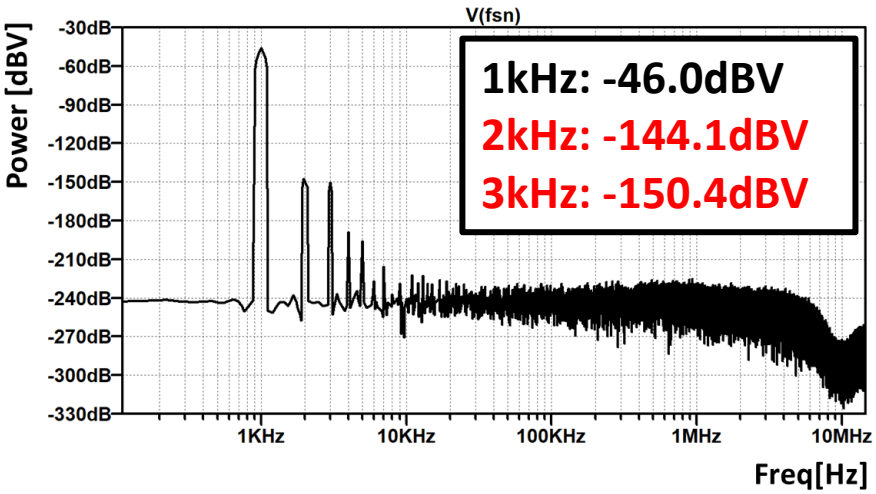


✓ Expectations for **False Summing Node**

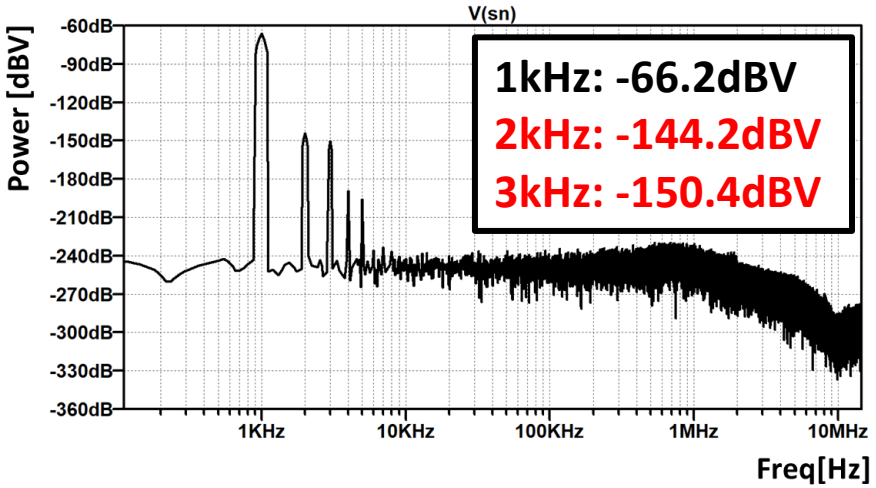
False Summing Node Simulation

Apply resistor mismatch error (+1%)

False Summing Node



Summing Node



- ➢ Fundamental wave is mainly affected
- ➢ Small (negligible) effect to harmonics

✓ **Effective for measuring THD, THD+N, SNR**

Q&A

- Can you scale the PSRR and CMRR using the test -method proposed to another different operating frequencies?
  - ✓ PSRRとCMRRを異なる周波数スケールで測定する実験は行っていないが、複数のDUTの開ループゲインを同時に測定できることを踏まえると可能性は十分にあると考える。

- P.26について、図の1kHz成分が極端に大きいがなぜか。
  - ✓ 実験では、基本波を遮断するなどのフィルター処理をしていないため、1kHz成分に信号源の振幅がそのまま表れている。2kHz, 3kHzにてオペアンプ自体の歪が観測される。