オペアンプ試験技術Null法のシミュレーション・実測評価

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1. Research Objective

Accurate and **Fast** measurement of Operational Amplifier

For reliable and low-cost IoT systems

➢ Approach

NULL Method

Minus input voltage of amplifier

→ Zero potential with servo loop

2. Background

Operational Amplifier

Differential inputs → Single-ended output

Extremely high gain

Key device in IoT systems

NULL Method

Measurement time : Long

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Mass production testing : Difficult

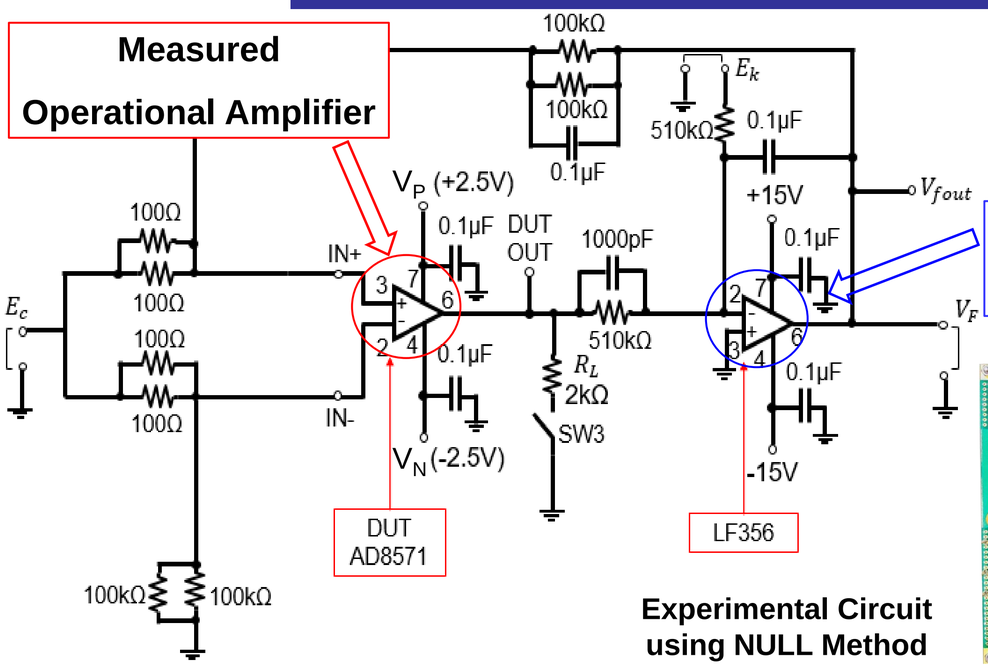
Good capacitor value selection

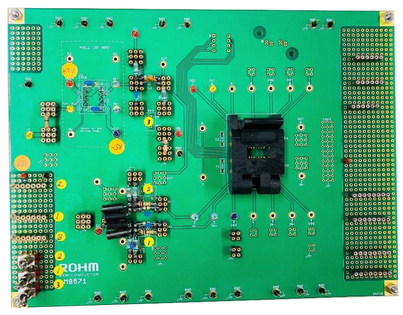
➡ Fast, stable operation

Goal

Apply NULL method to mass production testing

3. NULL Method Prototype



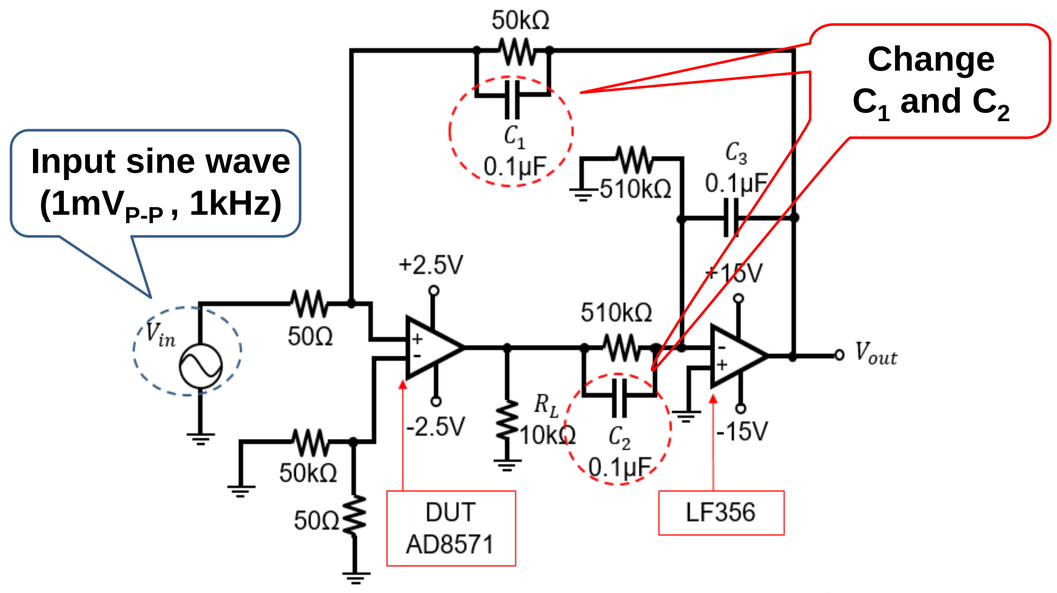


Experimental Circuit using NULL Method

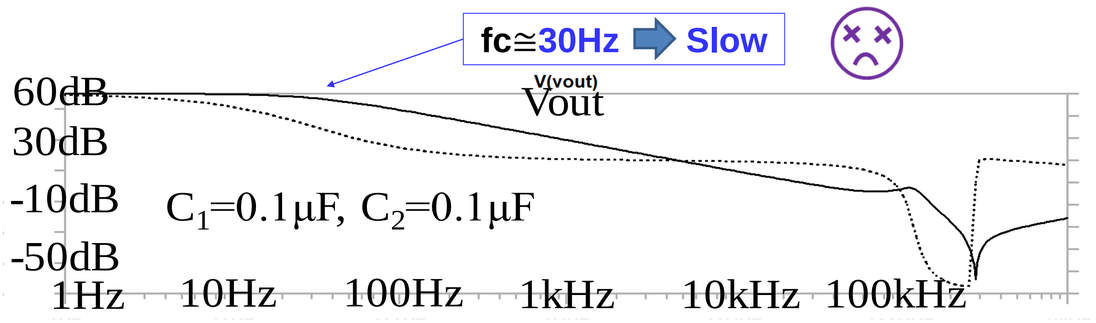
Operational Amplifier :
Vendor provided
SPICE model

4. SPICE Simulation Verification

< Frequency Characteristics >

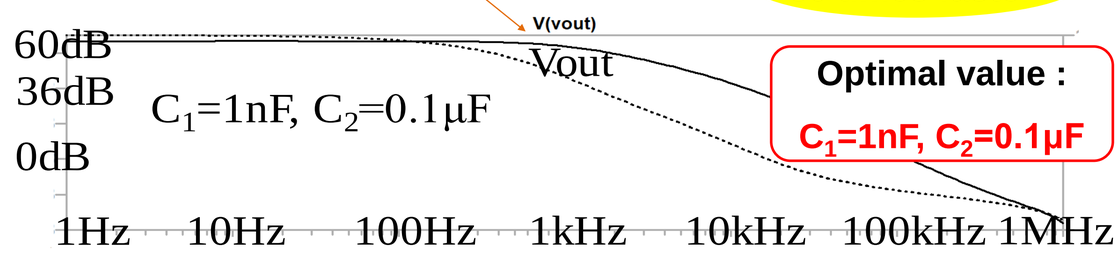


fc≅30Hz ➡ Slow



fc≅1kHz ➡ Fast

30 times faster

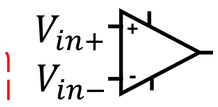


Optimal value :
C_1=1nF, C_2=0.1μF

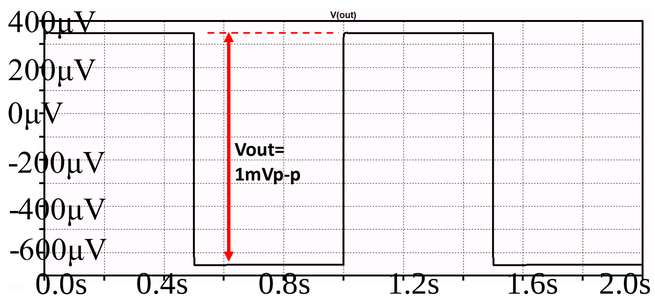
< Offset Voltage >

Ideal $V_{in+} = V_{in-}$

In practice $V_{in+} \neq V_{in-}$

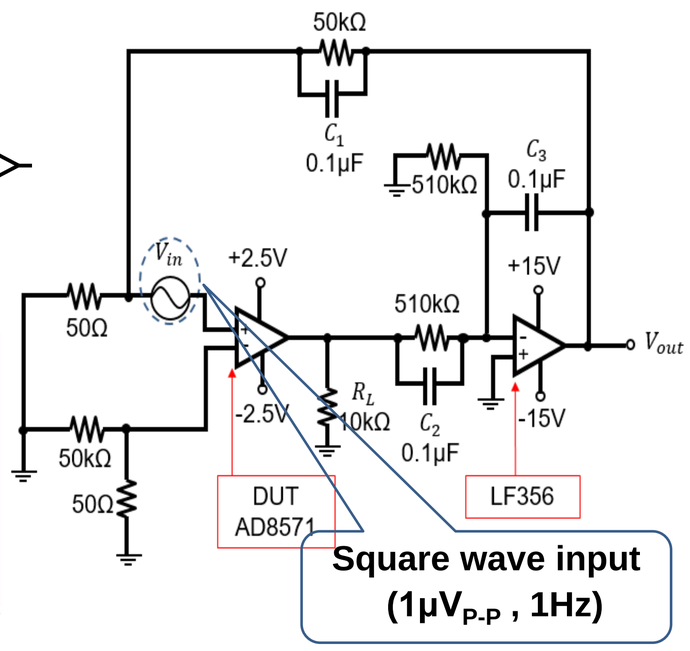


Measure



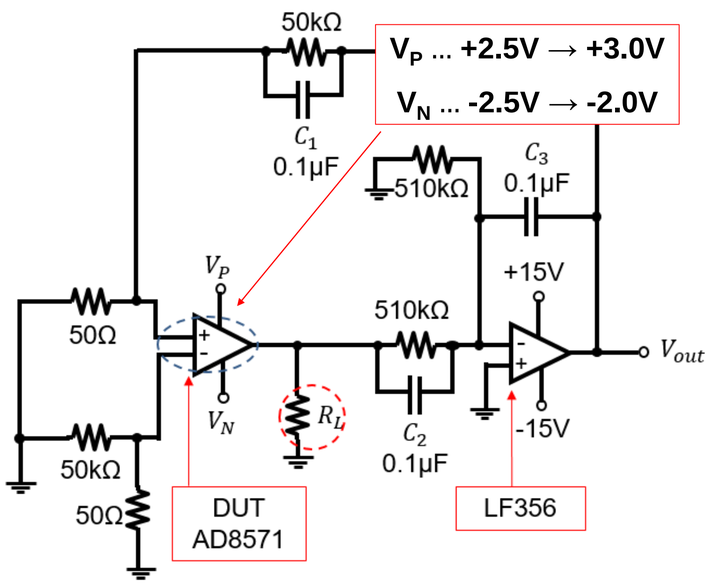
1μV$_{P-P}$ ➡ 1mV$_{P-P}$

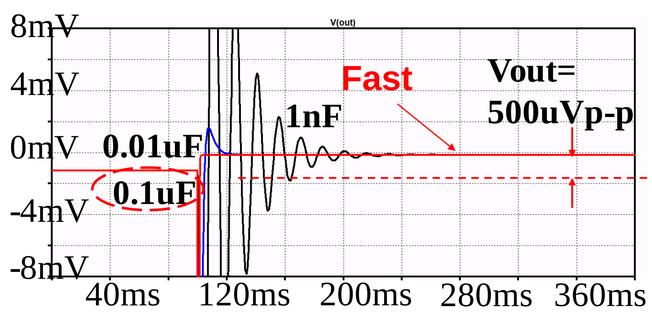
Minute error → ×1,000



➡ Easy Measurement

< CMRR >





When R_L=10kΩ, C_1=1nF, C_2 is varied

R_L → 10kΩ, C_1 → 1nF, C_2 → Large

↓

CMRR → **Fast** response

Experimental results (dB) for R_L=10kΩ

No.1	No.2	No.3	No.4	No.5
131	131	134	115	125

Almost the same

Simulation results

R_L [kΩ]	CMRR [dB]
2	126
10	126
100	126

5. Conclusion

- Optimization of phase compensation constants

  C_1=1nF, C_2=0.1μF

  ➡ NULL Circuit → Fast and Stable

- Switching C_1 and C_2 depending on the measurement item

  ➡ Settling time reduction → ≒ 1/10

References

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[3] K. Blake, “Op Amp Precision Design: PCB Layout Techniques”, Microchip Technology Inc., Tech. Rep. AN1258 (2009).

[4] R. Dopkin, Analog Circuit Design, Linear Technology (2013).

[5] G. Robert, F. Taenzler, M. Burns, An Introduction to Mixed-Signal IC Test & Measurement, 2nd edition, Oxford University Press (2012).

[6] Y. Sasaki, K. Machida, R. Aoki, S. Katayama, T. Nakatani, J. Wang, K. Sato, T. Ishida, T. Okamoto, T. Ichikawa, A. Kuwana, K. Hatayama, H. Kobayashi, "Accurate and Fast Time Testing Technique of Operational Amplifier DC Offset Voltage in μV-order by DC-AC Conversion", IEEE 3rd International Test Conference in Asia, Tokyo (Sept. 2019).