Operational Amplifier Testing Manual

For LM324 and LM358

Instruction Manual for Test Device and Quality Control

Prepared by: Alireza Rajabi
Approved by: Mr. Moallemi / Mr. Asadghi
Organization: Parlar Electronics – R&D Department
Document Revision: 07
Date: Sunday 20th April, 2025

This document is prepared in accordance with ISO 9001:2015 and IATF 16949 standards.

Important Notice

This manual contains standardized test procedures for verifying key performance parameters of operational amplifiers (LM324, LM358). It is essential to follow all instructions accurately to ensure valid test results. Only qualified personnel should operate the device. Data accuracy and integrity must be maintained throughout the testing process.

1 Input Offset Voltage Measurement (V_{OS})

To measure the input offset voltage of an op-amp, the following circuit is used:

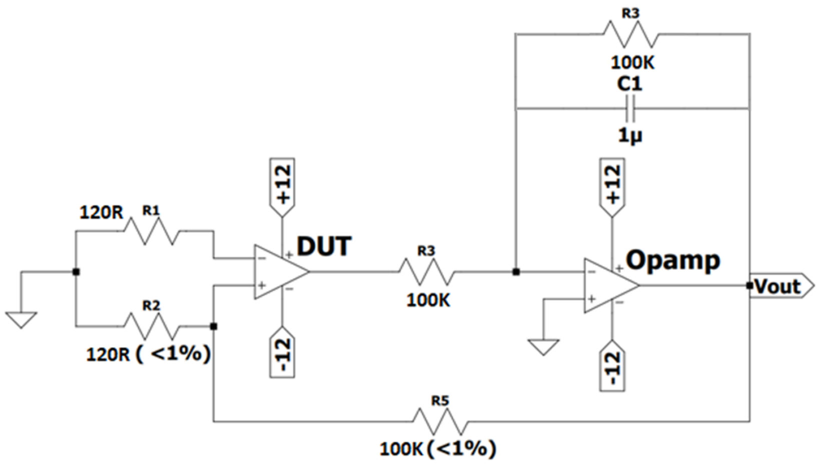

Figure 1: Figure 1: Input Offset Voltage Test Circuit for Op-Amp

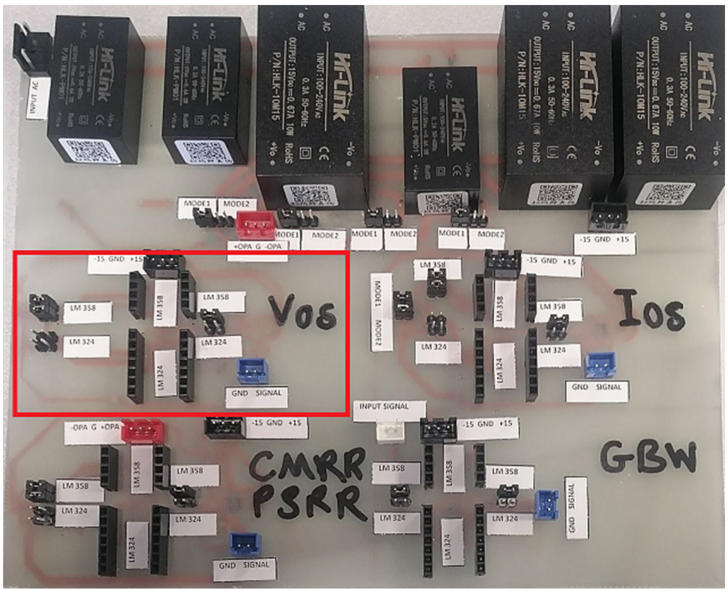

Figure 2: Figure 1: Input Offset Voltage Test Device for Op-Amp

Formula for Calculating V_{OS}

$$V_{OS} = \frac{V_{out(DC)}}{\left(\frac{R_5}{R_2} + 1\right)} \tag{1}$$

Instructions for Using the Test Device to Evaluate Op-Amp Quality

- The op-amp being tested for its offset voltage is referred to as the **DUT (Device Under Test)**.
- The precision of resistors R5 and R2 must be **1% or better**. (If a new board is built, the exact values should be measured using an RLC meter and entered into the software for calibration.)
- The second op-amp used in the circuit, labeled `Opamp`, can be the same type as the DUT or a similar one. In this project, an **LM358** is used.
- Parameters and specifications should always be checked against the component's **datasheet**, since devices like the LM358 from different manufacturers (e.g., ST, Texas Instruments, Onsemi) may have slight variations.
- As shown in the figure, the test steps are clearly marked with **labels**. For instance, when testing LM324, jumpers should be set to the LM324 position; for LM358, the corresponding jumper setting should be selected.
- Power is supplied from the upper section of the board, clearly labeled. In this test, a supply of $\pm$**15V** is used exclusively.
- During the test, voltages must be **accurately measured** and entered into the software. The results are then exported to an Excel file.
- In the software interface, the relevant parameter (here, `Vof`) is first selected.

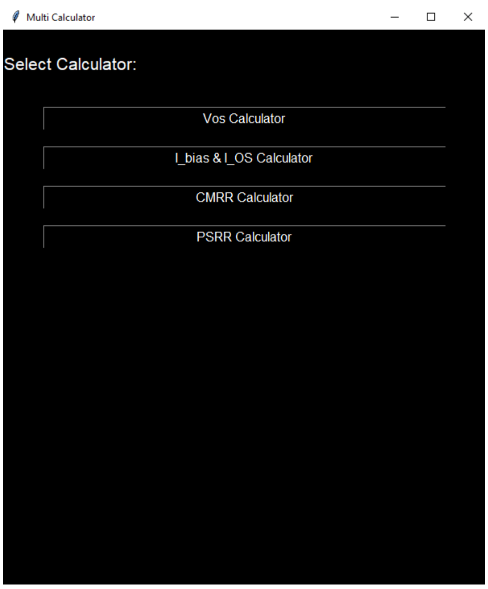

Figure 3: Figure 1: Input Offset Voltage Test Circuit for Op-Amp

- In the next step, the measured values are entered and the results are recorded.

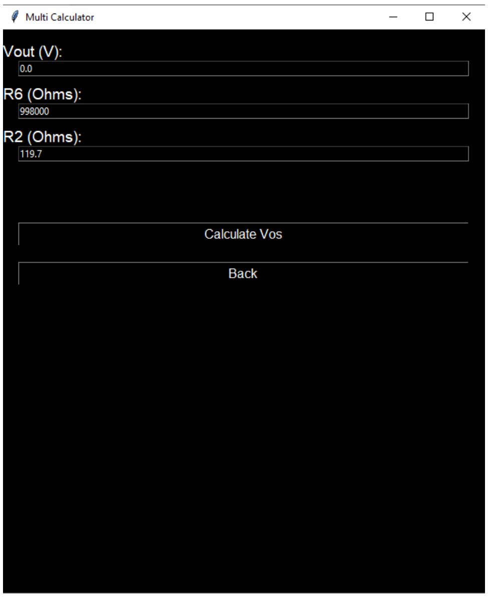

Figure 4: Figure 1: Input Offset Voltage Test Circuit for Op-Amp

Important Notes

- The values of resistors R2 and R5 are **fixed**. Under no circumstances should a new value be entered manually. If entered by mistake, restart the software to restore default values.
- You are only allowed to update resistor values if **a new resistor has been soldered to the board**. In such cases, the new values must be measured with an RLC meter and updated in the software.
- The software interface displays the **units of input and output values**. Ensure all values are entered and recorded using the correct units.

2 Input Offset Current Measurement (I_{OS})

To measure the input offset current of the operational amplifier, the following schematic is used:

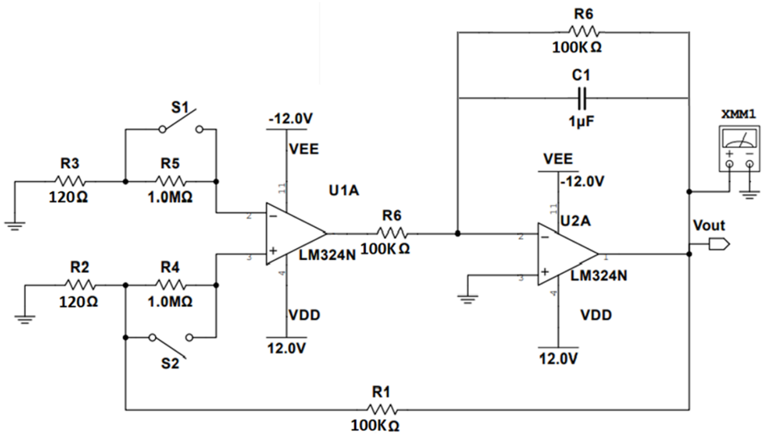

Figure 5: Figure 1: General Setup for Input Offset Current Measurement

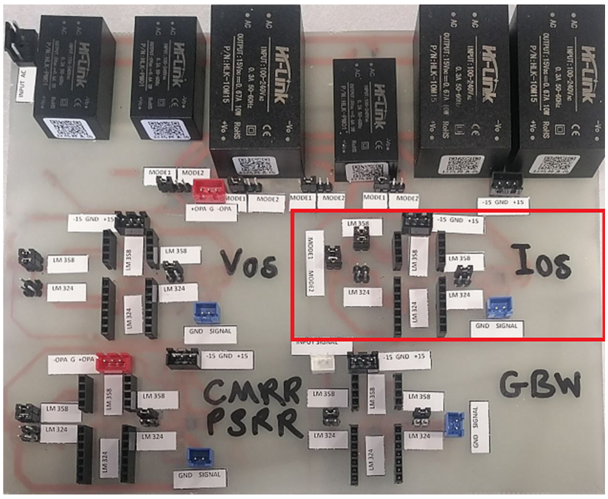

Figure 6: Figure 2: Offset Current Test Schematic

Test Procedure and Recommendations

- Use precision resistors with minimal tolerance preferably $\leq 1\%$ to ensure accurate current measurements.
- If any resistor or the test board is modified or replaced, the resistor values must be remeasured and updated in the software with high precision.

Step-by-Step Test Instructions for I_{OS}

The input offset current is measured in three stages by changing the switch configurations and recording output voltages:

Stage 1: Both switches S1 and S2 are closed

- Short both ends of the resistors by closing S1 and S2.
- Both jumpers `mode1` and `mode2` are connected as per schematic.
- Record the output voltage as V_{outA}.

Stage 2: Open S1 and keep S2 closed

- Disconnect jumper `mode1` and leave `mode2` connected.
- Record the output voltage as V_{outB}.

Stage 3: Close S1 and open S2

- Disconnect jumper `mode2` and keep `mode1` connected.
- Record the output voltage as V_{outC}.

Note: Always consider the polarity (positive or negative) of the voltages $V_{outA}, V_{outB}, V_{outC}$ when entering values.

Hardware and Software Notes

- The secondary op-amp (labeled `Opamp`) can be the same as the DUT or a similar device. In this project, LM358 is used.
- Always verify datasheet specifications for the components used. For instance, LM358 variants from ST, Texas Instruments, and Onsemi may have slight differences.
- Test configuration labels (`Labels`) are clearly shown in the schematic:
  - Set jumpers according to the device type (LM324 or LM358).
- Power is supplied via the top labeled connector on the board. In this test, a supply of $\pm 15V$ is used.
- All voltage readings should be recorded precisely, entered into the software, and finally exported to an Excel sheet.

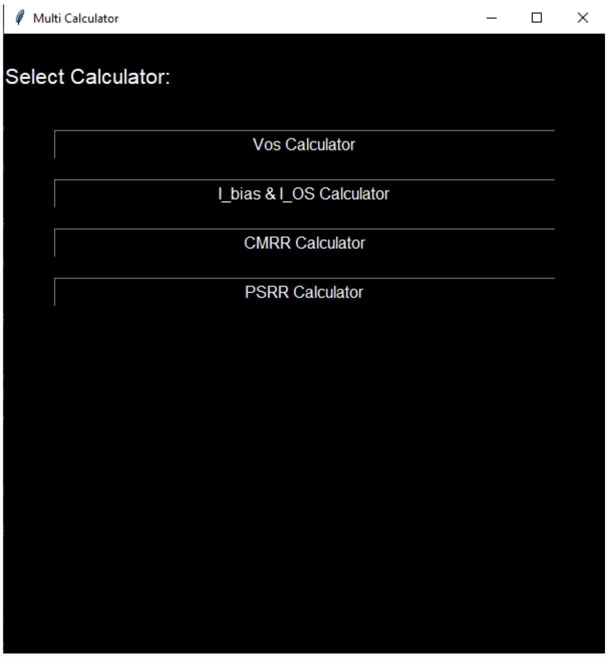

Figure 7: Figure 3: Software Interface – Select Ibias and Ios

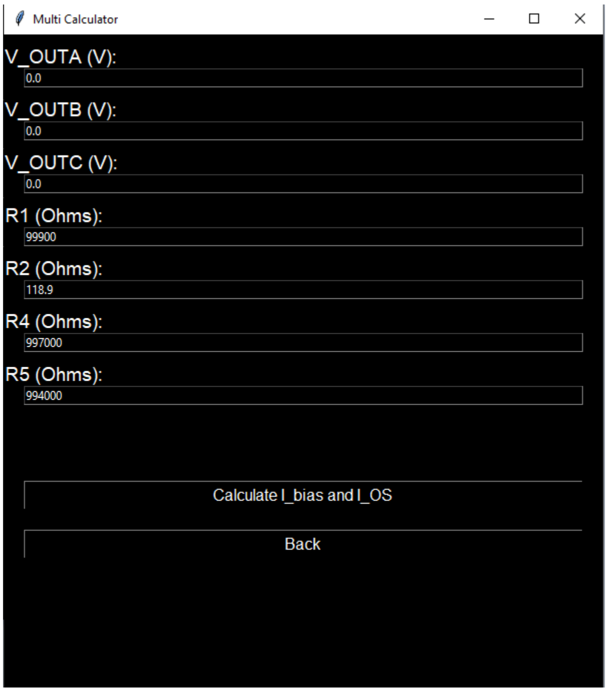

Figure 8: Figure 4: Data Entry and Result Display

Formulas for Bias and Offset Current Calculation

The base bias currents for the inverting and non-inverting inputs are calculated using the following formulas:

$$i_{b-} = \frac{V_{outA} - V_{outB}}{R_5 \left(\frac{R_1+R_2}{R_2} \right)} \tag{2}$$

$$i_{b+} = \frac{V_{outC} - V_{outA}}{R_4 \left(\frac{R_1+R_2}{R_2} \right)} \tag{3}$$

Or simplified:

$$i_{b-} = (V_{outA} - V_{outB}) \times 1.203 \times 10^{-9} \tag{4}$$

$$i_{b+} = (V_{outC} - V_{outA}) \times 1.207 \times 10^{-9} \tag{5}$$

Then:

$$I_{OS} = i_{b+} - i_{b-} \tag{6}$$

$$I_{bias} = \frac{i_{b+} + i_{b-}}{2} \tag{7}$$

Important Notes

- Resistors R_1, R_2, R_4, R_5 are fixed and must not be modified manually. If incorrect values are entered, restart the software to restore default settings.
- Only modify resistor values if new components are mounted on the board. In that case, measure accurately using an RLC meter and update values in the software.
- The software displays the units of all input and output fields. Always confirm that data is recorded using the correct units.

3 Common Mode Rejection Ratio (CMRR) Measurement

To measure the Common Mode Rejection Ratio (CMRR) of an operational amplifier, the following circuit is used:

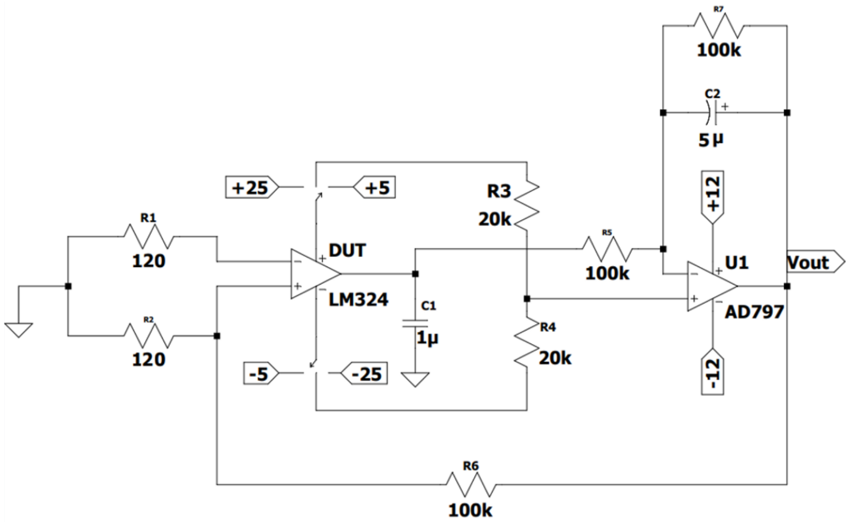

Figure 9: Figure: CMRR Test Circuit

Formula for Calculating CMRR

$$\text{CMRR} = 20 \cdot \log_{10} \left[\left(\frac{R_6}{R_2} + 1 \right) \cdot \frac{20}{\Delta V_{out}} \right] \tag{8}$$

Circuit and Measurement Considerations

- The secondary op-amp (labeled `Opamp` in the schematic) can be the same type as the DUT or a similar one. In this project, LM358 is used due to acceptable accuracy and availability.
- Ideally, the secondary op-amp should have high gain and low input offset voltage to ensure maximum measurement precision.

Op-Amp Datasheet Verification

- Always refer to the official datasheet for component parameters and tolerances.
- Identical models may have slight differences depending on the manufacturer. For example, LM358 is produced by STMicroelectronics, Texas Instruments, and On-semi — each with minor electrical variations.

Test Configuration and Jumper Setup

- The test procedure is clearly marked using `Labels` in the schematic.
- When testing LM324, set the jumpers to the LM324 position.
- When testing LM358, use the appropriate LM358 jumper settings.

Power Supply Setup

- The required power is supplied through the labeled `Power` section on top of the board.
- In this test, a dual power supply of $\pm 15V$ is used.

Measurement Procedure for CMRR

- The op-amp is tested under two different supply conditions:
  - First configuration: $+25V, -5V$; record the output voltage as V_{out1}
  - Second configuration: $+5V, -25V$; record the output voltage as V_{out2}
- Switching between configurations is done via jumper modes (Mode1 $\rightarrow$ Mode2), as clearly marked on the PCB.
- The absolute value of the output voltage difference $|V_{out1} - V_{out2}|$ is used as ΔV_{out} in the CMRR formula.

Software Operation for CMRR Test

- In the software, first select the parameter labeled `CMRR` from the test list.

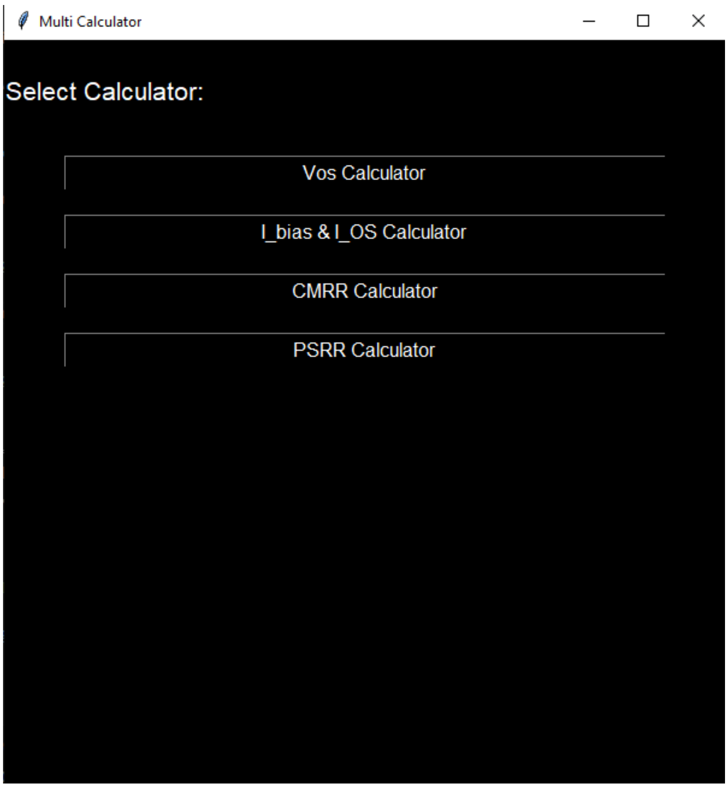

Figure 10: Figure: Selecting CMRR in Software

- Next, input the measured values of V_{out1} and V_{out2}. The software automatically calculates ΔV_{out} and computes the final CMRR value.

- For accurate measurement of small voltages, use the millivolt range of the multimeter.

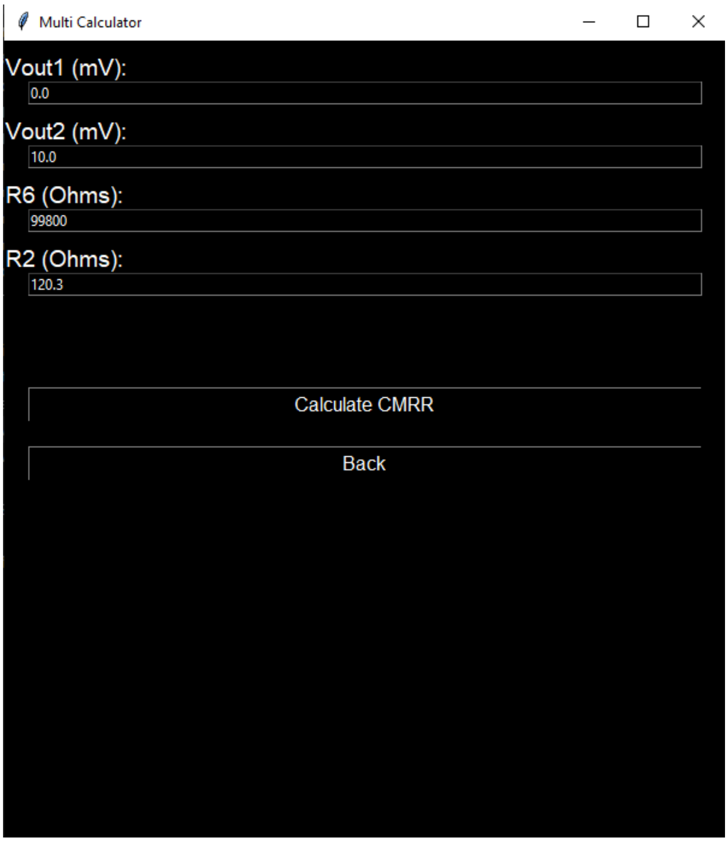

Figure 11: Figure: Voltage Entry for CMRR Calculation

Important Notes

- The resistor values R_2 and R_6 are fixed and must not be manually changed in the software. If new values are entered by mistake, restart the application to restore defaults.
- Only update resistor values if new components have been soldered onto the board. In that case, accurately measure them using an RLC meter and update the software accordingly.
- The software clearly displays the units for all input and output fields. Always confirm that all values are entered and recorded using the correct units.

4 Power Supply Rejection Ratio (PSRR) Measurement

The Power Supply Rejection Ratio (PSRR) is measured using a circuit similar to the one used for CMRR testing. Since the PSRR test range overlaps with the CMRR test conditions, verifying CMRR implicitly confirms the PSRR behavior — hence a separate PSRR calculation is often not necessary.

> **Note**
>
> The following steps are not required for routine testing. They are presented here only for completeness and demonstration purposes.

Power Supply Configuration for PSRR Testing

The test is carried out in two steps by varying the dual power supply:

- **Step 1:** Set the power supply to $\pm 14V$ and measure the output voltage. Record the result as V_{out1}.
- **Step 2:** Set the power supply to $\pm 15V$ and measure the new output voltage. Record the result as V_{out2}.
- Calculate the absolute voltage difference: $\Delta V_{out} = |V_{out1} - V_{out2}|$

Data Entry in the Software

- From the software interface, select the `PSRR` option in the parameter menu.
- Input the measured values for V_{out1} and V_{out2}. The software will automatically calculate ΔV_{out} and compute the PSRR.
- The final result is stored in the PSRR section and exported to an Excel report.

Tip: For improved accuracy in measuring small voltage differences, use the millivolt range of the multimeter.

Formula for Calculating PSRR

$$\mathrm{PSRR} = 20 \cdot \log_{10}\left[\left(\frac{R_6}{R_2} + 1\right) \cdot \frac{1}{\Delta V_{out}}\right] \tag{9}$$

5 Gain Bandwidth Product (GBP) Measurement

To measure the Gain Bandwidth Product (GBP) of the operational amplifier, a signal generator is required.

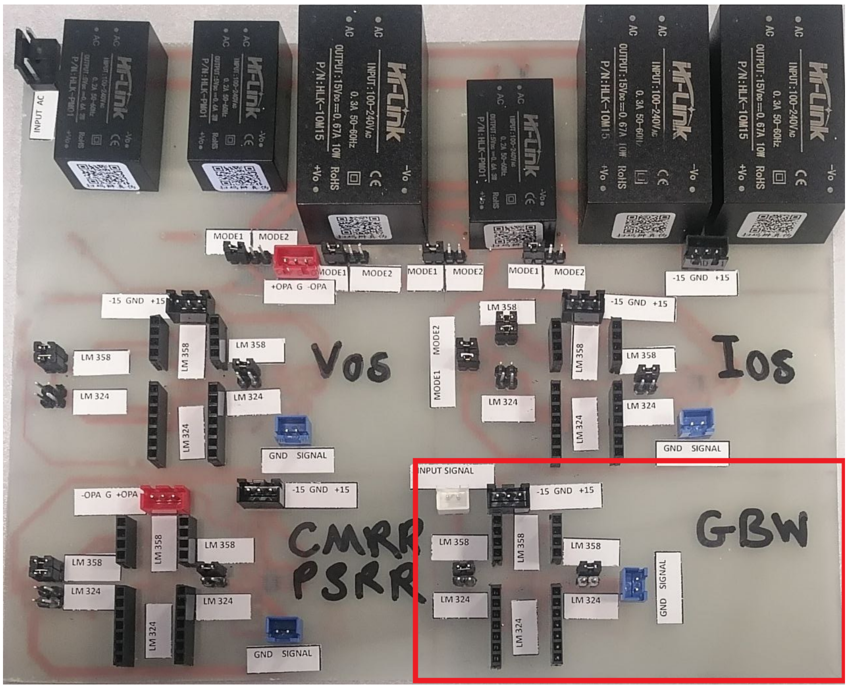

Figure 12: Figure: GBP Test Circuit

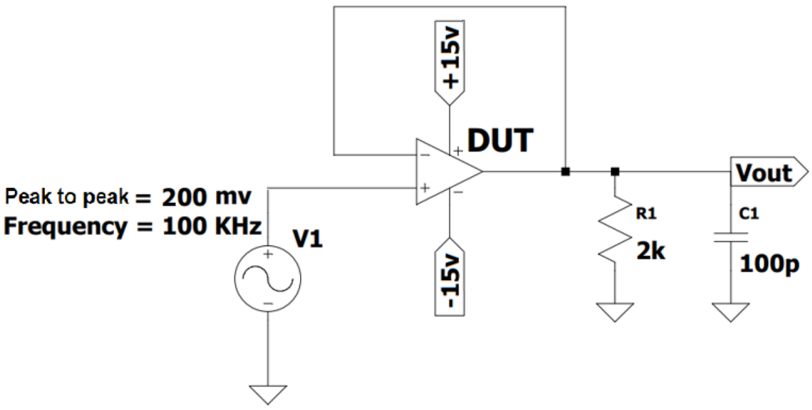

Figure 13: Figure: GBP Test Device

Test Procedure

- Connect the op-amp as shown in the circuit above.
- Gradually increase the input signal frequency using a signal generator.
- Monitor the output waveform on an oscilloscope.
- When the output signal's peak-to-peak amplitude reaches approximately 140 millivolts, record the input frequency.

- This frequency corresponds to the Gain Bandwidth Product (GBP) of the op-amp under test.

Note

This test device is specifically designed for the listed parameters. For other op-amp parameters not included in this document, please refer to the previous test protocols and datasheets.