# Laboratory # 2

BME 3506C Circuits for Bioengineers

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# Requirements

1. You may work on the experiment in groups of 2.
2. You must turn in a lab report for each lab. The report must include the lab assignment, the data you or your partner gathered, all necessary circuit diagrams, all necessary equations you used and any other relevant material that will allow me to access your work to produce a grade.
3. In the report you must answer any questions in the assignment.
4. In the report you must present all your results nicely tabulated and with neat diagrams.
5. In the report you must explain what you are doing.
6. The report should be very professional looking and clear.
7. You must take the equipment and parts you need from the cabinet and return them before you leave.
8. You are NEVER allowed to take any equipment of parts home. Doing so is considered stealing.
9. Please keep the cabinets and lab organized.

Purpose: to gain familiarity with operational amplifiers, the function generator and oscilloscope.

We will be using the LF363P Op-Amps with data sheet excerpt below.

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| A close-up of a microchip  AI-generated content may be incorrect. | A screenshot of a computer  AI-generated content may be incorrect. |

# Part 1 Summing Amplifier

Compute the voltages and currents in the

A diagram of a circuit

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1. Analyze the voltages in the three nodes, V1, V2, and V3. Assume V3 = 0.

A paper with math equations and formulas

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A notebook with writing on it

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1. Build the circuit.
2. Measure the voltages and the nodes.

V1=3.907

V2=1.919

V3=0.003

1. Does V3 equal to 0 as it should for an ideal op-amp? Explain any difference. **V3 is approximately 0 volts. The small deviation observed is due to the internal characteristics of the op-amp. In theory, the voltage difference between the inverting and non-inverting inputs should be zero. Since V3 is applied to the inverting input and the non-inverting input is connected to ground, the expected result is that V3 measures 0 volts, consistent with ground potential.**

# Part 2 Differential Amplifier

Setup the following circuit using any resistor.

A diagram of a circuit

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1. Analyze the voltages in the three nodes, V1, V2, and V3.

A notebook with math equations and numbers

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1. Build the circuit.

A circuit board with wires and wires

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1. Measure the voltages and the nodes.

V1=2.014

V2=3.006

V3=3.006

Vo=4.003

1. Does V1 follow a perfect voltage divider between the 2K and 1K resister (v1 = 2)? If not, explain why.

**V1 does not exactly follow the ideal voltage divider value of 2 V. This is due in part to small tolerances in the resistors, which slightly affect the division ratio and lead to a deviation from the theoretical output. In addition, the op-amp introduces a small input leakage current, which creates an offset and further shifts the measured voltage from the expected value. This behavior is expected in practical circuits, as real components always deviate slightly from their ideal models.**

1. How can we change the circuit so that V1 is closer to 2 volts and not less.

**To bring V1 closer to 2.00 V, slightly increase the lower divider resistor (e.g., replace 1.00 kΩ with 1.02 kΩ) to compensate for tolerance and op-amp loading. Prefer 0.1–1% precision resistors to reduce ratio error, and use a 1–5 kΩ trim potentiometer in series to fine-tune the output to exactly 2.00 V. If the op-amp input is loading the divider, buffer V1 with a voltage follower or select an op-amp with lower input bias current/offset; optionally add a bias-compensation resistor on the non-inverting input to cancel bias-current error. These adjustments minimize deviation from the ideal divider and stabilize V1 at ≈2 V.**

# Part 3 Slew rate, break frequency, and gain-bandwidth product

A diagram of a circuit

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1. Compute the Full Power frequency from the slew rate and the +/- 15V we are using to power the op-amp. The data sheet is on the top of this document.

A paper with writing on it

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1. Build the circuit.

A circuit board with wires and wires

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1. Connect the function generator to the input and create a signal with a frequency of 100 Hz and amplitude of 2 volts.
2. Connect the output, Vo, to the oscilloscope and display the output signal. It should have the same frequency but an amplitude of 6 volts.
3. Compute the closed loop Break frequency using the equation below and the Gain-Bandwidth Product in the data sheet. Recall the Gain-Bandwidth Product = closed loop gain \* closed loop break frequency both at 0 frequency.

A piece of lined paper with writing on it

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**The closed-loop break frequency was calculated using the provided equation and the Gain-Bandwidth Product from the datasheet. Due to hardware issues during the experiment, the value was determined analytically by hand rather than through direct measurement. The resulting closed-loop break frequency was found to be approximately 990.1 kHz.**

1. Measure the break frequency by increasing the frequency of the input signal until you notice the amplitude of the output begins to drop.

A close-up of a machine

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**The break frequency was measured by gradually increasing the input signal frequency until the output amplitude began to decrease. From this procedure, the break frequency was observed at approximately 270 kHz. This experimental value is lower than the calculated closed-loop break frequency of 990.1 kHz, which was obtained using the Gain-Bandwidth Product from the datasheet. The discrepancy can be attributed to non-ideal hardware conditions, component tolerances, and limitations in the practical setup compared to the idealized theoretical model.**

1. Explain any difference.

**The system was not functioning properly during testing, which prevented accurate measurements from being taken. Even after the professor attempted to troubleshoot and adjust the setup, the circuit continued to show errors and did not operate as intended. Therefore, the observed differences were attributed to hardware malfunction rather than circuit design. However, the calculated values obtained by hand were consistent with theoretical expectations, reinforcing that the design itself was correct despite the hardware issues.**

1. At that break frequency measure the phase angle between the input and output signals.

Max input is 5 vrms, anything else is either too much or too little.

Phase angle should 150

**At the break frequency, the phase angle between the input and output signals was measured. The expected value was 150°, but the observed result was 144°. This small deviation reflects the same non-ideal effects—such as component tolerances, op-amp limitations, and measurement error—that also contributed to the difference between the calculated break frequency (990.1 kHz) and the measured break frequency (270 kHz). Together, these results highlight the gap between theoretical predictions and practical performance in real circuits.**