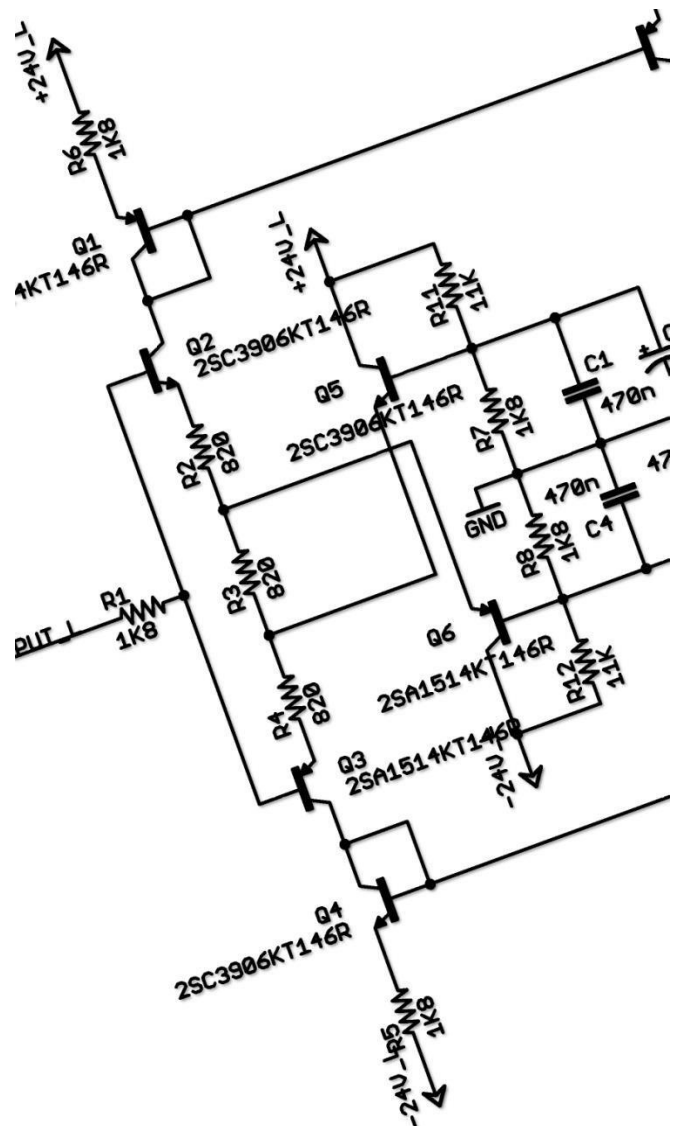




ECE2131

Electrical Circuits Laboratory Notes

2022 Edition



Name:

Student ID:

Email:

Electrical and Computer Systems Engineering, Monash University

2022

7 Introduction to Operational Amplifiers

Operational Amplifiers (op-amps) are a common type of flexible high gain differential input amplifiers. When combined with a couple of discrete components, they can be configured as signal buffers, filters, amplifiers, integrators, differentiators, adders, and more. In the following two labs, we will explore some of these applications. However, this lab aims to introduce op-amps, demonstrate some simple amplifier configurations, and gain some hands on experience in working with these devices. This will be done by:

1. Investigating the basic operating characteristics of an operational amplifier,
2. Verifying the principle of virtual earth analysis and negative feedback,
3. Investigating the behaviour of an inverting operational amplifier circuit,
4. Investigating the behaviour of a non-inverting operational amplifier circuit, and
5. Investigating the operating limits of the TL074 opamp.

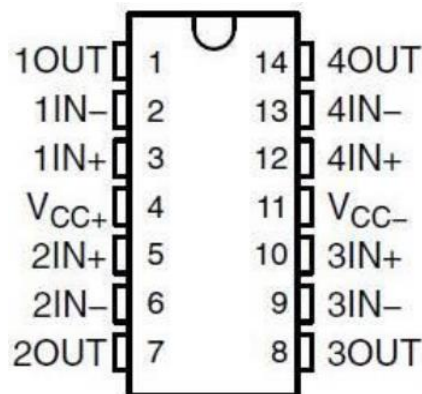
By the end of this lab you should:

- Build and characterise simple inverting and non-inverting amplifiers based on op-amps.
- See what the 'virtual short' concept in negative feedback means in real circuits
- Understand the effect of supply rails and gain-bandwidth product in limiting op-amp outputs

7.2 EQUIPMENT AND COMPONENTS

- Breadboard.
- Opamp TL074.
- Resistors: 10 kOhm, 100 kOhm.
- Capacitors: 100 nF, 100 pF.

TL074 Connection Diagram



7.3 EXPERIMENTAL PROCEDURE FOR LABS 7-9

The circuits are constructed on a prototype board using fixed value discrete components. Power your operational amplifier circuits using a fixed $\pm 15\text{V}$ DC supply source. However, if you are using Adalm and Scopy, the DC power supply is limited to $\pm 5\text{V}$ DC. Remember this!!!

When constructing your operational amplifier circuit, take care to make sure you connect the supply voltages with the correct polarity – reversing the supply voltage connections across the operational amplifier will most likely cause device failure. It is good practice (and helps semiconductor devices not to fail), if you only make circuit changes, plug in components, etc, when the circuit is de-energized. Get into the habit of turning the power supplies OFF before making any circuit changes.

The easiest way to construct your circuit is to do so in stages. Before you plug in your op-amp, measure the voltages supplied to the TL074 pins 4 and 11. Then turn off the power supplies, insert the op amp, and quickly check basic circuit operation after you turn on the power supply again to try and find any fundamental problems before damaging the device.

When constructing your circuits, make sure the input pins of the unused TL074 amplifier sections are connected to ground. Circuits are to be excited by the signal generator, set to produce a SINE wave. Circuit responses should be measured using the oscilloscope channels.

Where a particular voltage or frequency performance is specified in these notes, do not waste time adjusting your circuit to achieve exactly this result. The reason is simple - the circuit relationships you are exploring hold for any response that is reasonably close to the specified requirements.

7.4 EXPERIMENTAL WORK

7.4.1 PART A – INVERTING OPERATIONAL AMPLIFIER

Construct the following inverting amplifier circuit on the prototype board.

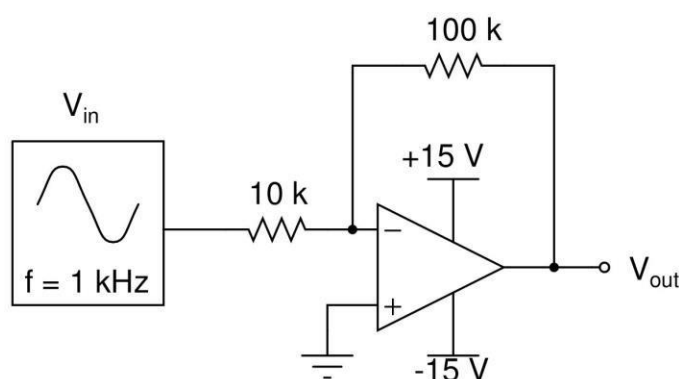


Fig. 1: Inverting amplifier

- 7.4.1.1 Set the signal generator DC offset to 0V, and adjust the signal generator to produce a $600\text{mV}_{\text{p-p}}$ ($\pm 300\text{mV}_{\text{peak}}$) sine wave at frequency of 1kHz. How does the measured gain of the circuit compare with the theoretical value you calculated in the preliminary quiz?

- 7.4.1.2 Is there a phase shift between the signal generator and the output of the opamp? If there is a phase shift, what is this phase shift equal to? Attach a screenshot to clearly show your measurement of the phase shift.

- 7.4.1.3 Measure the opamp output voltage (OUT) with one oscilloscope channel. Connect another oscilloscope channel to the opamp inverting input terminal (IN-).

How do the magnitudes and phase compare?

How does the negative input voltage (IN-) correlate with the “virtual short” concept?

HINT for desktop oscilloscope: You will have to set the CRO probe to X1 gain to measure the opamp negative input voltage, since it is very small. Make sure you reset the probe to X10 and readjust the CRO channel setup accordingly after this test.

- 7.4.1.4 Increase the input signal magnitude to 10Vp-p ($\pm 5V_{\text{peak}}$). Measure the V_{in} and opamp output voltages and explain your observations.

- 7.4.1.5 Adjust the input signal magnitude and identify the opamp input signal voltage levels at which the opamp output voltage starts to “clip” at its maximum values, both for positive and negative voltage inputs. Are these maximum output values equal to the supply voltage rails? How do they compare with the maximum output voltage swing as specified in the TL074 data sheet?

- 7.4.1.6 Reset the signal generator output to 600mVp-p ($\pm 300mV_{\text{peak}}$). Increase the signal generator frequency in stages up to 1MHz using the network analyzer and using the input signal as the reference, observe the opamp output voltage response against frequency. Find the frequency at which the output magnitude reduces to $1/\sqrt{2}$ of the output magnitude at low frequency response (1kHz).

- 7.4.1.7 Determine the phase shift between the source and opamp output voltages at this frequency. NOTE: In theory, this frequency should be the “gain-bandwidth” frequency as per the data sheet, divided by the gain of this circuit, and the opamp output should be shifted by 45 degrees. Is this the case in your experiment?

☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here _____

7.4.2 PART B – NON-INVERTING AMPLIFIER

7.4.2.1 Construct the following non-inverting amplifier circuit on the prototype breadboard.

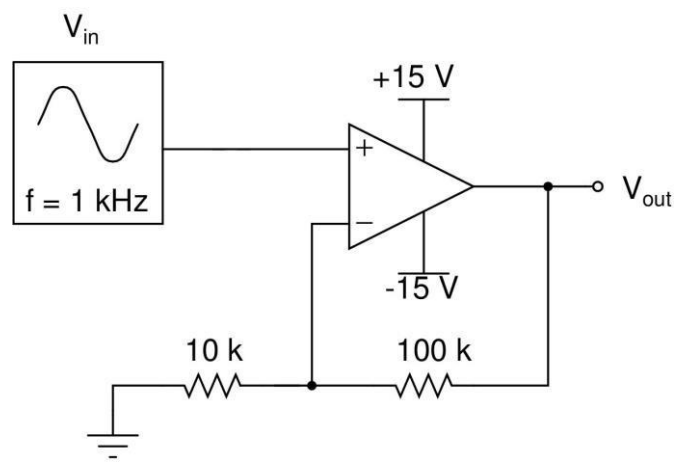


Fig. 3: Non-inverting amplifier with low pass filter function.

7.4.2.2 Set the signal generator DC offset to 0V, and adjust the signal generator to produce a $200\text{mV}_{\text{p-p}}$ ($100\text{mV}_{\text{peak}}$) signal at a frequency of 1 kHz. Observe the output and verify the basic operation of the circuit. What is the theoretical gain of this circuit? Show your circuit analysis of how you obtain this theoretical gain. How does the measured gain of the circuit compare to the theoretical calculations?

7.4.2.3 Is there a phase shift between the signal generator input and the opamp output? If there is phase shift, how much is the phase shift? If there is no phase shift, explain why.

☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here

- 7.4.2.4 Gradually increase the signal generator frequency in stages up to 4 MHz using the network analyzer, and explore the opamp output voltage response as the frequency increases. Find the frequency at which the output magnitude reduces to $1/\sqrt{2}$ of the output magnitude at low frequency response (1kHz).

- 7.4.2.5 Determine the phase shift between the signal generator output and opamp output voltages at this frequency.

☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here

ASSESSMENT

Student Statement:

I have read the university's statement on cheating and plagiarism, as described in the *Student Resource Guide*. This work is original and has not previously been submitted as part of another unit/subject/course. I have taken proper care safeguarding this work and made all reasonable effort to make sure it could not be copied. I understand the consequences for engaging in plagiarism as described in *Statute 4.1 Part III – Academic Misconduct*. **I certify that I have not plagiarized the work of others or engaged in collusion when preparing this submission.**

Student signature: _____ Date: ____/____/____

TOTAL: _____ (/7)

ASSESSOR: _____

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