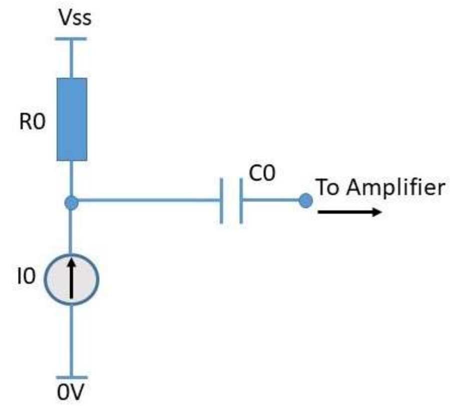
Designing the Microphone Circuit

Read the microphone datasheet:

- Your first task is to work out the microphone circuit as below
- Assume the Microphone (E.C.M. Unit and the FET amplifier) act as an ideal current source



<u>Questions:</u>

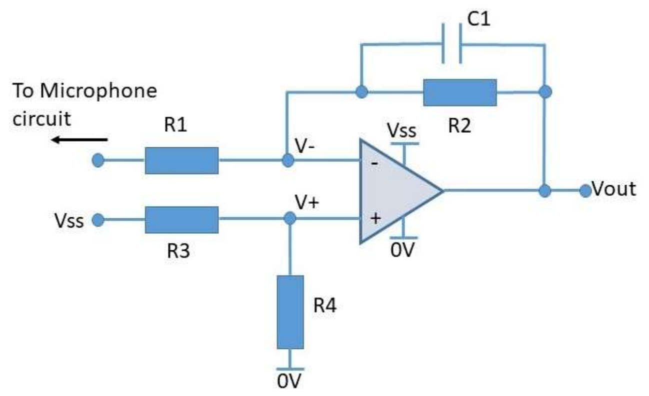
- What is the Current I0 (DC and AC terms)?
- What is the Resistance R0 ?
- What is the Capacitance C0 ?

Operational Amplifier Circuit

- The op-amp design uses the differential amplifier shown below
- The –ve input will take the **AC signal** from the microphone and act as an **inverting amplifier**
- Our ears are not sensitive to the phase of a audio signal, so we can use an inverting amplifier in this case
- The +ve input will take the **DC Power Supply** (Vss = 3.3V) and set a suitable DC level for the amplified AC signal at the output

AC Input

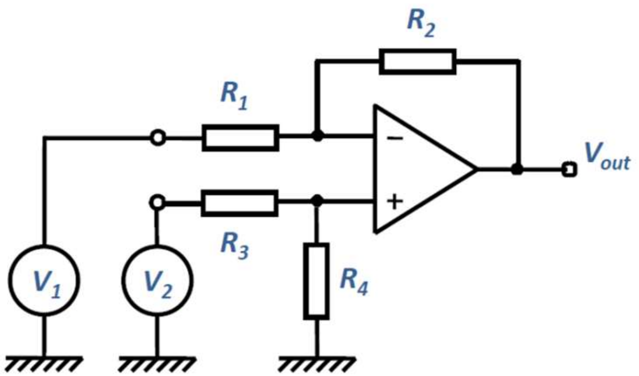
DC Input



Amplifier Design

- We will review how to design this circuit using **principle of superposition** (Revision from 1st year Engineering)

Superposition Theorem



$$V_{out} = V_{out(1)} + V_{out(2)}$$

V_{out} when $V_2 = 0$

V_{out} when $V_1 = 0$

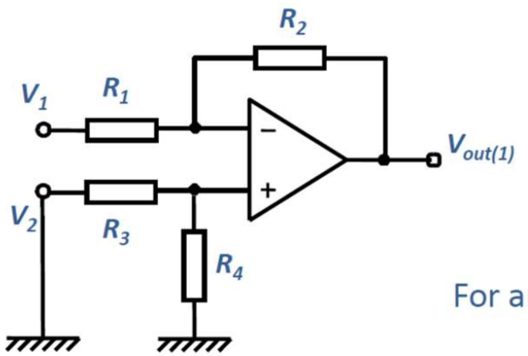
For us:

V1 is the AC input (microphone)

V2 is the DC input (power supply Vss)

Amplifier: AC Analysis for V1

Calculating $V_{out(1)}$



For us:

This will help us work out the gain for audio frequencies

For an inverting amplifier:

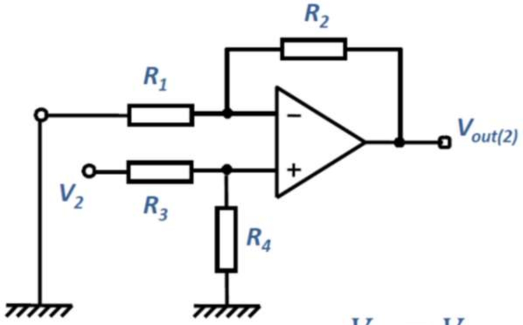
$$V_{out(1)} = -V_1 \frac{R_2}{R_1}$$

Things to Watch Out for:

- R1 includes capacitor **C0** from microphone circuit: for **AC** frequencies it has impedance ~ 0 Ω (acts as a wire)
- Note that the bias resistor **R0** in the microphone circuit will also affect the input impedance to the op-amp

Amplifier: DC Analysis for V2

Calculating $V_{out(2)}$



$$V_- = V_{out(2)} \frac{R_1}{(R_1 + R_2)}$$

$$V_+ = V_2 \frac{R_4}{(R_3 + R_4)}$$

$$V_+ = V_-$$

$$V_{out(2)} = V_2 \frac{R_4}{(R_3 + R_4)} \frac{(R_1 + R_2)}{R_1}$$

For us:

This will help us work out the best DC level for the analogue-to-digital converter

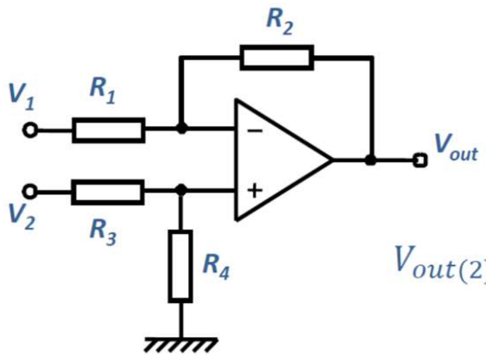
Things to Watch Out for:

- R1 includes capacitor **C0**: at DC frequency, impedance $\sim \infty\ \Omega$ (acts as an open circuit)
- So what happens to the term { (R1+R2)/R1 } ?

Amplifier: Summing Up

The total op-amp output is the sum of **Vout(1)** and **Vout(2)**, the AC and DC terms respectively:

Differential Amplifier



$$V_{out(1)} = -V_1 \frac{R_2}{R_1}$$

$$V_{out(2)} = V_2 \frac{R_4}{(R_3 + R_4)} \frac{(R_1 + R_2)}{R_1}$$

$$\boldsymbol{V_{out} = V_2 \frac{R_4}{(R_3 + R_4)} \frac{(R_1 + R_2)}{R_1} - V_1 \frac{R_2}{R_1}}$$

Output is proportional to the difference between the input voltages

Influence of the DC Level and Capacitors

The Analogue-to-Digital Converter can record any signal between 0V and Vcc (3.3V)

- What is the best DC level to use here?

Our circuit contains two capacitors:

- **Microphone circuit** - **C0** acts like a **high-pass filter**:
  - Blocks the microphone DC current from entering the amplifier
  - Amplifies the AC microphone signal (speech) above 300 Hz

- **Amplifier circuit** – **C1** acts like a **low-pass filter**:
  - Allows the amplified speech to pass to the digitiser
  - Can filter out frequencies above 3 kHz to remove unwanted signals

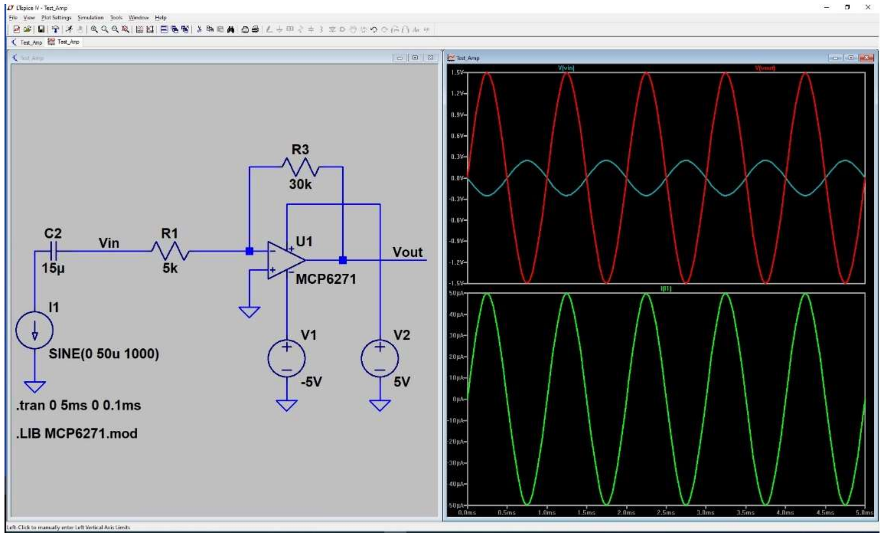
- Calculate cutoff frequencies and check audio is not affected

Designing and Simulating the Circuit

- Please review the slides above and make an initial estimate of the component values you plan to use: **record in your lab book!**
- You can then use LT-Spice to simulate the circuit and check that it behaves as expected and fix any mistakes/problems
- There is a summary guide for LT-Spice to remind you of what to do and a ZIP file to install the MCP6271 op-amp we will use

LT-Spice Opamp Screenshot

NB – your circuit will be different to this one!



Amplifier Specification

- You will use an electet microphone (see datasheet)
- The output will be amplified by the op-amp circuit:
  - You need to achieve at least **1.1V peak-to-peak output** for good audibility
- The op-amp output will be connected to an analogue-to-digital converter on the STM32 Board
- Available Power Supplies: 0V and 3.3V only
- **Available Component Values: as per your component pack**
- You should use capacitors **C0** and **C1** to reduce the gain outside speech range 300 Hz - 3 kHz
- You should make sure that you record in your lab book your key findings, including the following values:
  1. Resistance values **R0-R4**, Capacitor values **C0** and **C1**.
  2. The output voltage achieved at **1 kHz** and the lower and upper cutoff-frequencies of your circuit.