Today, we will:
- Do some more example problems and discussion about op-amp circuits
- Finish reviewing the pdf module: op-amps (miscellaneous properties: GBP, CMRR)

Example: Op-amp circuits
Given: Consider the circuit shown.

(a) To do: What kind of circuit is this?

(b) To do: Calculate the output voltage $V_{\text{out}}$ when the input voltage is 2.0 V DC.

(c) To do: Calculate the amplitude of the output voltage $V_{\text{out}}$ when the input voltage is a pure sine wave with amplitude 1.0 V and frequency 200 Hz.
Recall, from last lecture:
In general, we desire our electronic circuits to have very low output impedance and very high input impedance.

The input impedance of an inverting amplifier op-amp circuit is approximately \( R_1 \).
That is one reason why we generally want \( R_1 \) to be large (> 1 kΩ as an absolute lower limit).

The output impedance of an inverting amplifier op-amp circuit is small, on the order of 1 Ω.

What about a noninverting amplifier? What are the input and output impedances?

**Inverting Amplifier:**

**Noninverting Amplifier:**
Let’s compare the amplification of common mode noise for inverting and noninverting amplifiers (common mode noise amplification).

**Inverting Amplifier:**

- \( V_{in} \)
- \( V_{p} \)
- \( V_{o} \)
- \( R_1 \)
- \( R_2 \)
- \( V_{out} \)

**Noninverting Amplifier:**

- \( V_{in} \)
- \( V_{p} \)
- \( V_{o} \)
- \( R_1 \)
- \( R_2 \)
- \( V_{out} \)

**Bottom Line:**
- If input loading is of primary concern, noninverting amplifiers should be used.
- If noise reduction and signal-to-noise issues are of primary concern, inverting amplifiers should be used.
**Example: Op-amp circuits with GBP effects**

**Given:** We need to amplify the output of a microphone (music converted into voltage) by a factor of 1000. We construct a noninverting amplifier as sketched, with:

- $R_1 = 1 \text{k}\Omega$
- $R_2 = 999 \text{k}\Omega$

**To do:**

(a) Calculate the *theoretical* gain of the circuit (at any frequency) if the op-amp were ideal.

(b) Calculate the *actual* gain for a type 741 op-amp, with GBP = 1.0 MHz at the following frequencies of the music:

- $f = 20 \text{ Hz} $ (lower limit of human hearing)
- $f = 261.63 \text{ Hz} $ (middle C)
- $f = 4000 \text{ Hz} = 4 \text{ kHz} $ (a fairly high note)
- $f = 20 \text{ kHz} $ (upper limit of human hearing)

(c) Suggest a better circuit.

**Solution:**
Example: Op-amp circuits

Given: We need to build an amplifier with a theoretical gain of 25 (or -25 – sign does not matter). We use a 741 op-amp with GBP = 1.0 MHz (1000 kHz). The resistors we have on hand are 5 kΩ, 10 kΩ, 20 kΩ, 50 kΩ, 100 kΩ, and 200 kΩ (we have several of each).

(a) To do: Draw an electrical circuit that will generate the required gain using a non-inverting amplifier. Repeat for an inverting amplifier.

Solution:

Non-inverting:

Inverting:
(b) To do: For the non-inverting case, calculate the overall gain of the amplifier if the signal being amplified has a frequency of 20 kHz. Repeat for the inverting amplifier.

Solution:

Non-inverting:

Inverting:
(c) To do: For the inverting case, suppose we split up the gain into two stages to reduce the effect of the GBP-filtering. Calculate the overall gain of the amplifier if the signal being amplified has a frequency of 20 kHz.

Solution: