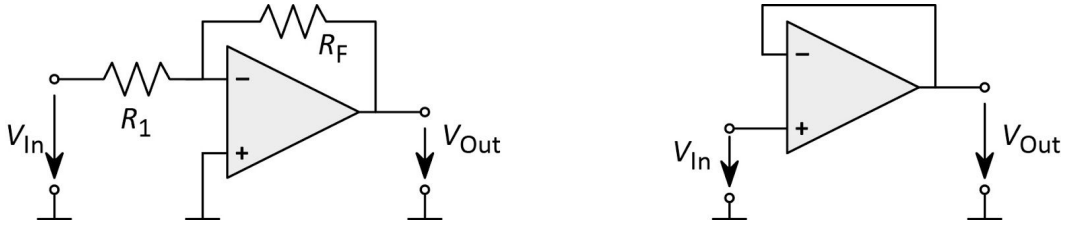
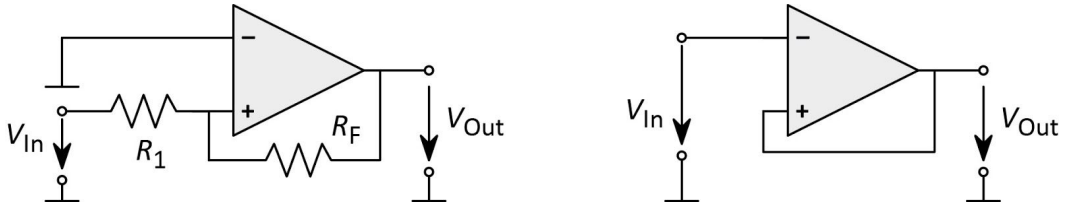
**Homework 02**

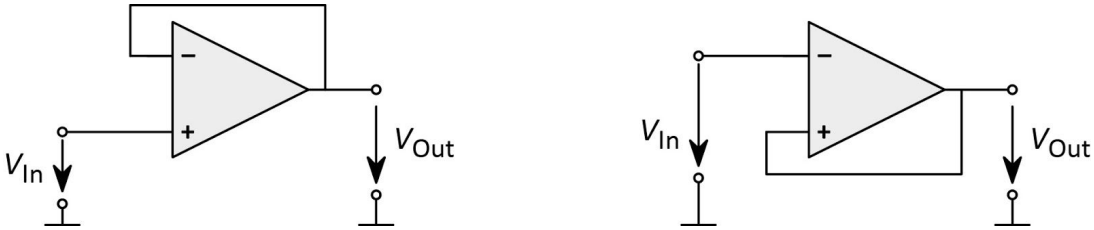
1. Assume that all operational amplifiers (Op Amps) considered in this problem are ideal Op Amps and supplied with a +5 V and –5 V voltage. Op Amp circuits usually have a feedback circuit that feeds back some of the output signal to the input side.
   (a) Sketch an Op Amp circuit that does not have a feedback circuit (e.g. a feedback resistor). Explain the functioning of the circuit. What is the name of such an Op Amp circuit?
   (b) Consider the Op Amp circuits below. Assume $R_1 = R_F = 1$ kOhm. There is a left-hand side (LHS) and a right-hand side (RHS) circuit. Calculate the open-circuit voltage gains ($A_{VOC}$) of the two circuits. Do not neglect minus signs in your calculation.
   (c) Which common feature, relating to feedback circuits, is found in both circuits?



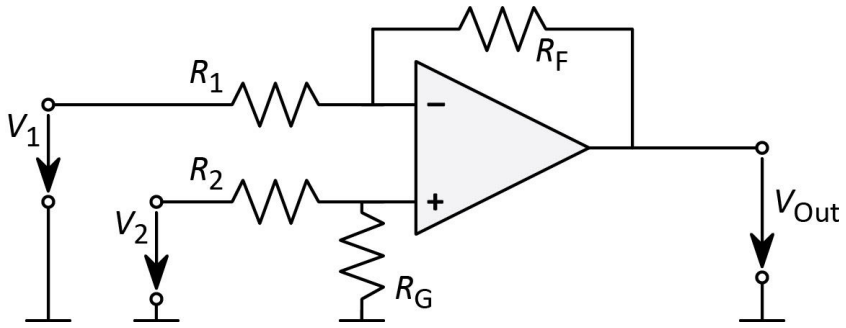

   (d) Consider the Op Amp circuits below. There is a LHS and a RHS circuit. Determine the voltage gains of the two circuits. (Note: Be prepared that these are unusual circuits.)
   (e) Given the configuration of the feedback circuit, are these Op Amp circuits useful for amplification of common signals, e.g. a sinusoidal signal?
   (f) Assume for the LHS circuit that $V_{In} = +1$ µV. What is the output voltage? Assume for the LHS circuit that $V_{In} = -1$ µV. What is the output voltage?
   (g) Assume for the RHS circuit $V_{In} = +1$ µV. What is the output voltage? Assume for the RHS circuit $V_{In} = -1$ µV. What is the output voltage?




   (h) Consider the Op Amp circuits below. There is a LHS circuit and a RHS circuit. Calculate the voltage gains of the two circuits. One of the circuits may be called a voltage-follower. Which one?



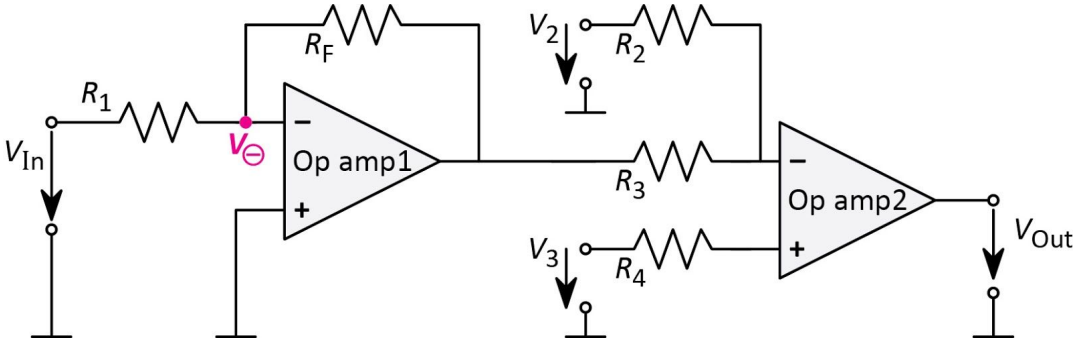
2. Consider an operational amplifier (Op Amp) circuit as shown below.




   (a) The Op Amp has two input voltages. $V_1$ and $V_2$. Articulate the Superposition Theorem in your own words. Under which conditions are we permitted to use the theorem? Are these conditions met?
   (b) Use the Superposition Theorem to calculate the output voltage of the Op Amp.
   (c) Calculate $V_{Out}$ for $R_1 = R_F = R_2 = 1\ \text{k}\Omega$ and $R_G = 100\ \Omega$.

3. A differential amplifier (operational amplifier) can be considered as a black box (as illustrated by the triangular Op Amp symbol) or, alternatively, by an equivalent circuit.
   (a) Draw the equivalent circuit of an ideal operational amplifier.
   (b) Explain all circuit elements and give the numerical values of the circuit elements.

4. Consider a two-stage amplifier having Stage 1 and Stage 2, as shown below. The purpose of this problem is to show that we can consider the stages sequentially and do not need to consider any feedback from Stage 2 onto Stage 1.




   (a) Assume that Op Amp 1 and 2 are ideal Op Amps. Show by superposition of sources that the voltages $V_2$ and $V_3$ do not influence the voltage at the inverting input ($V_\ominus$) of Stage 1.
   (b) Accordingly, a multi-stage amplifier can be analyzed by sequentially considering the operation of each stage. For $V_2 = 0$, $V_3 = 1$ V, $R_F = R_1$, $R_2 = R_3$, $+V_{cc} = +5$ V, and $-V_{cc} = -5$ V, calculate and draw the transfer function $V_{Out}$-versus-$V_{In}$.

5. Are the following statements ***True*** or ***False***? Explain your answer with one or two sentences.
   (a) "Differential amplifier" is synonymous (or very similar) to "operational amplifier".
   (b) Assume that the output voltage of an ideal Op Amp is 1.5 V. If we short the output terminal of the ideal Op Amp to GND, then the output current will be infinite.