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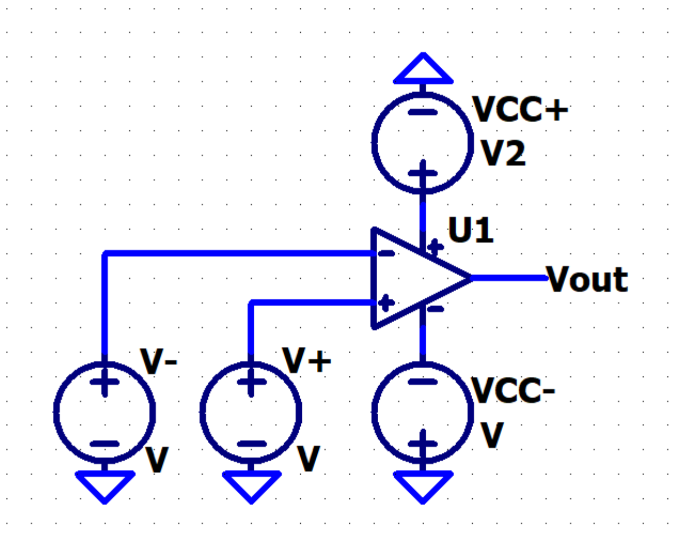
IE HW2

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?

A comparator will output VCC+ if V+ > V- and VCC- if V- > V+.




   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.

Gain of the left hand circuit is -1, gain of the right hand circuit is 1.

   c) Which common feature, relating to feedback circuits, is found in both circuits?

Negative feedback

   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.)

Both have infinite gain.

   e) Given the configuration of the feedback circuit, are these Op Amp circuits useful for amplification of common signals, e.g. a sinusoidal signal?

No, they give digital outputs of VCC+ or VCC-

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?

If Vin = +1uV, Vout will go to VCC+ only if Vout > -1uV * RF/R1, but it will go to VCC- otherwise.
If Vin = -1uV, Vout will go to VCC- only if Vout < 1uV * RF/R1, but it will go to VCC+ otherwise.

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?

If Vin = +1uV, Vout will go to VCC- only if Vout < +1uV, but it will go to VCC+ otherwise.
If Vin = -1uV, Vout will go to VCC+ only if Vout > -1uV, but it will go to VCC- otherwise.

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?

The left hand circuit is a voltage follower with gain of 1. The right hand circuit has infinite gain.

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?

The superposition theory allows you to analyze a circuit of multiple sources by analyzing the circuit with one source at a time and summing them all together. The condition is that it's a linear circuit, which this is.

    b) Use the Superposition Theorem to calculate the output voltage of the Op Amp.

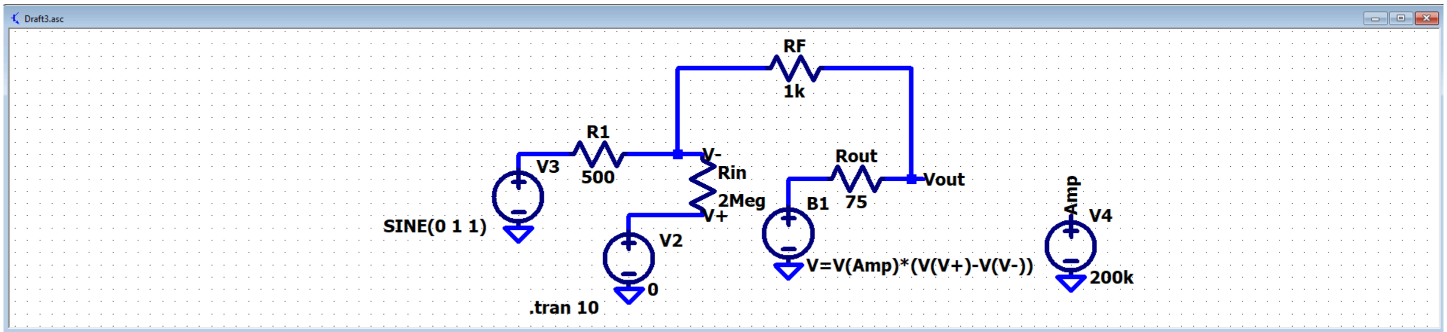
V-=V1+(Vout-V1)*R1/(R1+RF)
V+=V2*RG/(RG+R2)
V-=V+
V1+(Vout-V1)*R1/(R1+RF) = V2*RG/(RG+R2)
(Vout-V1)*R1/(R1+RF) = V2*RG/(RG+R2) - V1
Vout-V1 = (R1+RF)*V2*RG/(R1(RG+R2)) - V1(R1+RF)/R1
Vout = ((R1+RF)*V2*RG/(R1(RG+R2)) -V1(R1+RF)/R1) + V1
Vout=(V2*RG*(R1+RF)-V1*RF*(R2+RG))/(R1*(R2+RG))

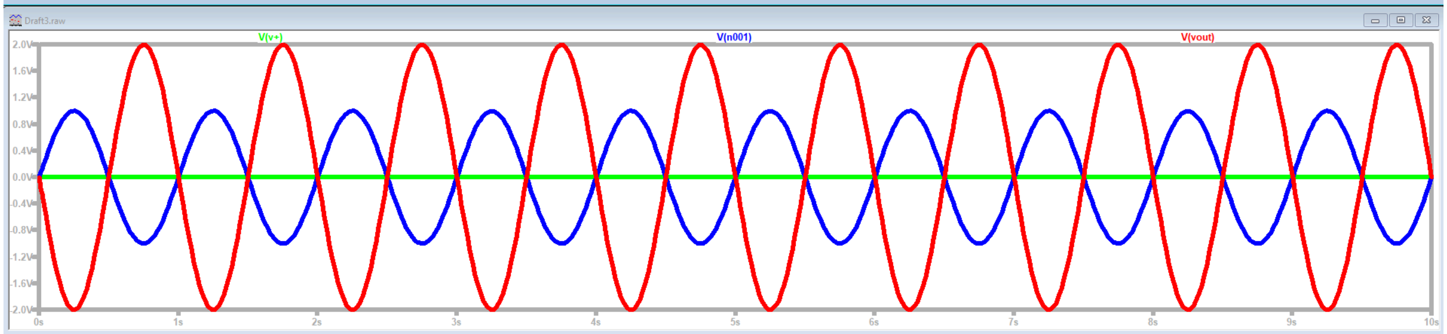
    c) Calculate $V_{Out}$ for $R_1 = R_F = R_2 = 1\ k\Omega$ and $R_G = 100\ \Omega$.

Vout = (V2*100*(1000+1000)-V1*1000*(1000+100))/(1000*(1000+100))
Vout = V2 *2/11 - V1

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.

(With surrounding circuit for inverting amplifier)

Rin: Input impedance, very high, for the LM741, 2M Ohm

Rout: Output impedance, relatively small, for the LM741, about 75 Ohm

B1: Dependent voltage source, gives open loop amplification * difference between V+ and V-. Open loop amplification is large, for the LM741, 200k.

Note: I usually strongly dislike how op amps are just explained as a magical black box, very few of my peers actually understand the differences between the two inputs and what effect they have on the output, they just know how to solve for a steady state assuming V+=V-, but they don't know *why* V+=V- or how negative feedback makes that true, they just assume V+ and V- are actually connected to each other somehow.

This model takes the explanation I usually give and puts it in a really easy to understand dependent source circuit form. Definitely my new favorite explanation!

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 – ) of Stage 1.

The node Vout1 is driven by Op Amp1, and as it’s an ideal source, nothing will change that. The only other thing connected to the inverting input of stage one is Vin, so it’s impossible for V2 or V3 to affect the inputs 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 .

Inverting input:
VM = -Vin
Comparator:
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Vout = {(VM+V2)/2 > 1,  VCC-
       {(VM+V2)/2 < 1,  VCC+
```
Total:
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Vout = {-Vin/2 > 1,  -5V
       {-Vin/2 < 1,  +5V
```
Simplified:
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Vout = {Vin < -2,  -5V
       {Vin > -2,  +5V
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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”.

True. An op amp is called a differential amp because it uses the difference between V+ and V- to determine the gain of the amp (positive if V+>V- and vise versa). This combined with a bit of feedback and voltage dividers is all you need to carry out just about any basic math operation you could ever need, so it’s also called an 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.

True. An ideal op amp is an ideal voltage source, and ideally shorting an ideal voltage source to an ideal ground will give a voltage difference over 0 ohms, I=V/R=1.5/0=infinity.