Assignment #3

1-9. Design a non-inverting amplifier with a voltage gain of approximately 12 with an input resistance of 12 kΩ . Use SPICE to confirm the result using a simple model of the OpAmp.

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Solution: The non-inverting amplifier has an input resistance of infinity. Therfore, one alternative is to place a 12k resistor from the positive input terminal of the OpAmp to ground - this yields an input resistance of **12k || (Large OpAmp R_i) ≈ 12k**.

To yield a gain of 12, choose resistor ratio in the branched from the negative terminal of the OpAmp to have a ratio of 11:1 since the non-inverting gain is: $A_v = \left(1 + \frac{R_f}{R_G}\right)$ where R_f is the feedback resistor connecting the output to the negative OpAmp input terminal and R_G is the resistor connecting the negative OpAmp input terminal to ground. Using standard value resistors, I chose **R_G = 2k** and **R_f = 22k**.

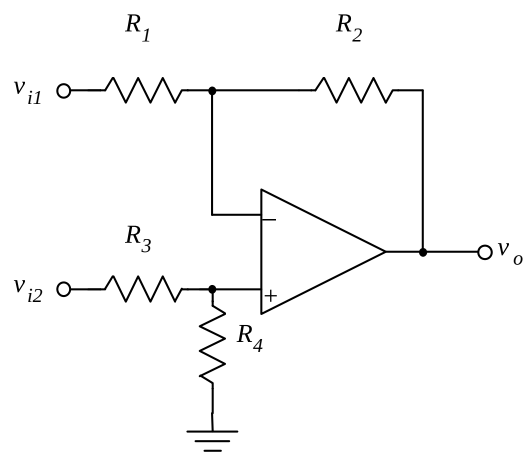
An alternate scheme could be to include a series resistance connected to vs. In order to meet the specified input resistance the sum of that series resistance and a resistor from the positive OpAmp input terminal must equal to R_{in}. Since this resistor network at the source is a voltage divider, the values of R_f and R_g must be altered to meet the voltage gain of 12. I chose the following: **R_{s1} = 6.04k, R_{s2} = 6.04k, R_g = 1k, and R_f = 23.2k**. This yields a gain of approximately 12.

1-12. Design an operational amplifier circuit to meet the following specifications:

- $v_o = 3.0\, v_{i2} - 5.0\, v_{i1}$
- R_{i1} = 15 kΩ (the input resistance seen by source v_{i1})
- R_{i2} = 25 kΩ (the input resistance seen by source v_{i2})

Solution:

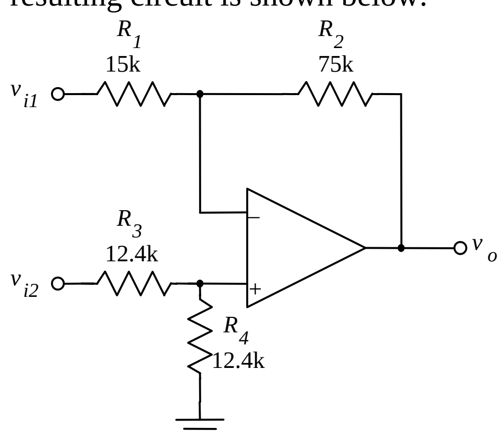
The basic configuration of the difference amp is used:



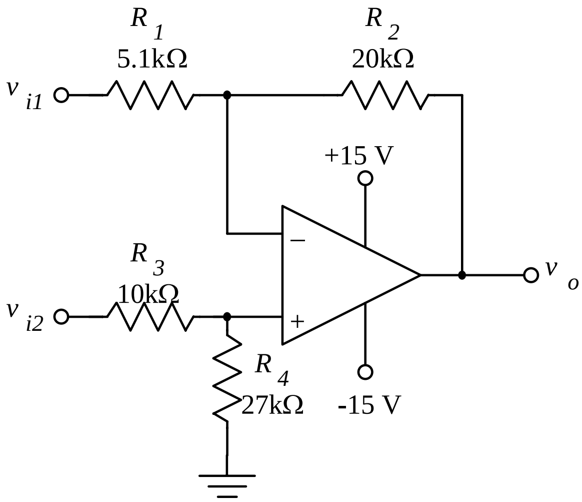
Use superposition to solve for the two signal inputs. The input resistance of the inverting path is $R_1 = R_{i1}$ and the input resistance of the non-inverting path is $(R_3 + R_4) = R_{i2} = 25k$.

In the inverting amplifier path:
$R_{i1} = R_1 = 15k$ so $R_2 = -A_v R_1$ where $A_v = -5.0$, and $R_1 = 15k$ yielding $R_2 = 75k$.

For the non-inverting case: Given the values for R_1 and R_2 the non-inverting gain at the positive OpAmp input terminal is 6.0. However, since $v_o = 3.0\, v_{i2} - 5.0\, v_{i1}$, the non-inverting gain must be 3.0 which is half of 6.0. Therefore, let $R_3 = R_4 = 12.5k \approx 12.4k$. The resulting circuit is shown below.



1-14. What is the expression of the output voltage for the circuit shown for $v_{i1} = cos(\omega_o t)$ and $v_{i2} = 1.5\,cos(\omega_o t + 30°)$?



Use SPICE to confirm the result.

Solution:

By superposition: $v_o = v_{i2}\left(\frac{R_4}{R_3+R_4}\right)\left(1+\frac{R_2}{R_1}\right) - v_{i1}\left(\frac{R_2}{R_1}\right)$. Plugging in the resistor values yields:

$v_o =$ 3.59 v_{i2} – 3.92 v_{i1} . Now substitute v_{i1} and v_{i2} into the previous expression:

$v_o =$ 3.59 [1.5cos($\omega_o t$ +30°)] – 3.92 cos($\omega_o t$) . You can do this by using Euler's equation:

$v_o =$ 3.59 •1.5• 0.5[exp (j($\omega_o t$ +30°))+ exp (– j($\omega_o t$ +30°))] – 3.92• 0.5[exp (j$\omega_o t$)+ exp (– j$\omega_o t$)]

or like me and use my HP48GX in phasor notation to get the result:

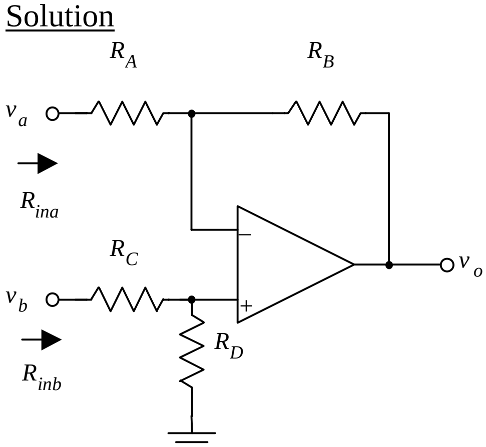
2.79∠74.56° = 2.79cos ($\omega_o t$ +74.56°)

1-23. Design an OpAmp differential amplifier with:

a) a gain of 67 and a minimum input resistance of 22 kΩ for each input.

b) For an OpAmp with CMRR = 67 with a maximum common-mode signal of 0.08V, find the differential input signal for which the differential-mode output is greater than 90 times the common-mode output.

Solution



Let $R_A/R_B = R_C/R_D$; then $v_o = (R_B/R_A)(v_b - v_a)$. Since required gain is 67, let $R_B/R_A = 67$.

Using superposition and Thevenin equivalent analysis for input resistances, we know that
$R_{ina} = R_A$ and $R_{inb} = R_C + R_D$. So let
$R_{ina} = R_A \geq 22k \Rightarrow R_A = 33k$, $R_{inb} = R_C + R_D \geq 22k$
So
$R_B = 67(33k) \approx 2.2M$; let $R_C = 33k$ and $R_D = 2.2M$
$\Rightarrow R_{inb} = 2.233M > 22k$
(b) $A_{DM}v_{DM} > 90A_{CM}v_{CM}$
so $v_{DM} > 90v_{CM}A_{CM}/A_{DM} = \dfrac{90v_{CM}}{10^{CMRR/20}A_{CM}} = \dfrac{90v_{CM}}{10^{CMRR/20}} \Rightarrow v_{DM} > 0.0032\text{V}$