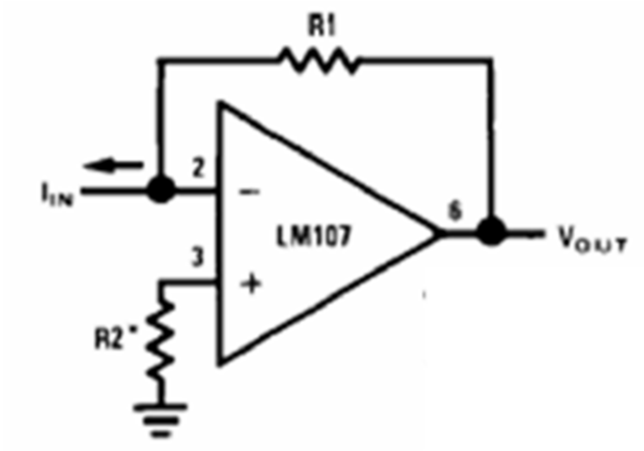
Problem 1(a)



From Golden Rule #2, no current flows into or out of terminal V+. Then we know the voltage drop across R2 is zero. In turn, we know V+ = 0.

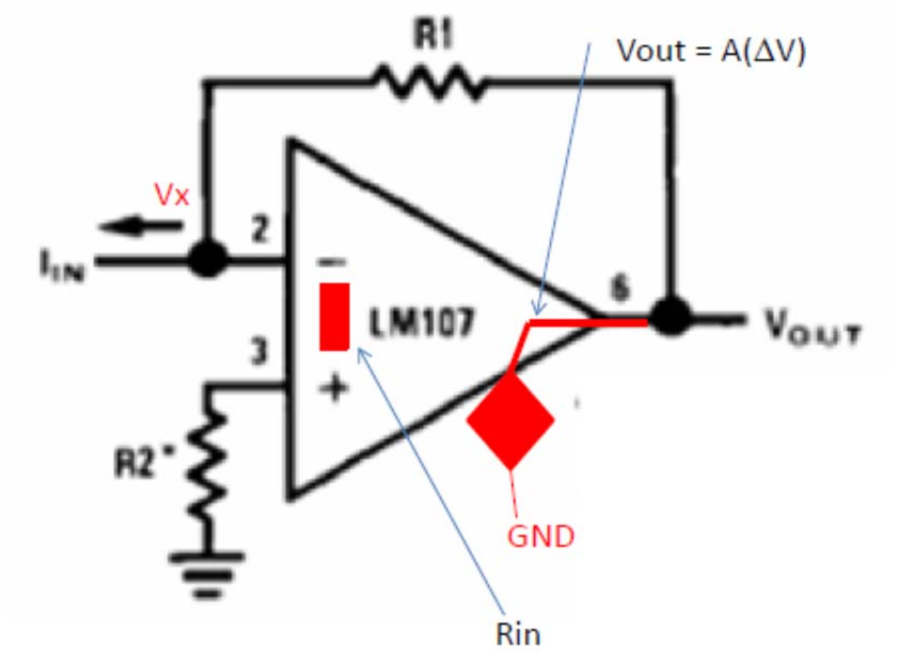
From Golden Rule #1, V- = V+ = 0.

KCL @ V-: $-I_{IN} + 0 + \frac{(Vout-0)}{R1} = 0$

Then, we know: Vout = $R1*I_{IN}$

Problem 1(b):
No. When R2 is a short circuit, V+ = 0. By Golden Rule #1, V- = V+ = 0. The KCL equation at V- is still the same. Therefore, the answer does not change.

Problem 1(c):
Considering the non-ideality, we can redraw the circuit:



1. From the amplifier: Vout = A(ΔV) = A (Vp - Vn).

2. KCL @ Vx: $-I_{IN} + \frac{(0-Vn)}{R2+Rin} + \frac{Vout-Vn}{R1} = 0$

3. From voltage division, $\Delta V = Vp - Vn = Vn \cdot \frac{-Rin}{Rin+R2}$

Solving the above system:

$$Vx = \frac{-I_{IN}}{\frac{ARin}{R1(R2+Rin)}+\frac{1}{R1}+\frac{1}{R2+Rin}} = \frac{-I_{IN}(R2+Rin)R1}{ARi+R1+(R2+Rin)}$$

$$Vout = A \cdot \Delta V = A \cdot -Vn\ \frac{Rin}{Rin + R2} = \frac{AI_{IN}R1Rin}{ARin + R1 + (R2 + Rin)}$$

Problem 1(d)

Conceptually, to reduce the effect of Rin on Vout, we should try to reduce the current flowing through Rin. Therefore, we should have as ***LARGE*** R2 as possible.

Mathematically:

From 1(c):

$$\text{Vout} = \frac{\text{AI}_{\text{IN}}\text{R1Rin}}{\text{ARin} - \text{R1} - (\text{R2} + \text{Rin})}$$

The effect of Rin on Vout =

$$\frac{\partial \text{Vout}}{\partial \text{Rin}} = \frac{-\text{AI}_{\text{IN}}\text{R1}\{\text{R1} + \text{R2}\}}{[\text{ARin} - \text{R1} - (\text{R2} + \text{Rin})]^2}$$

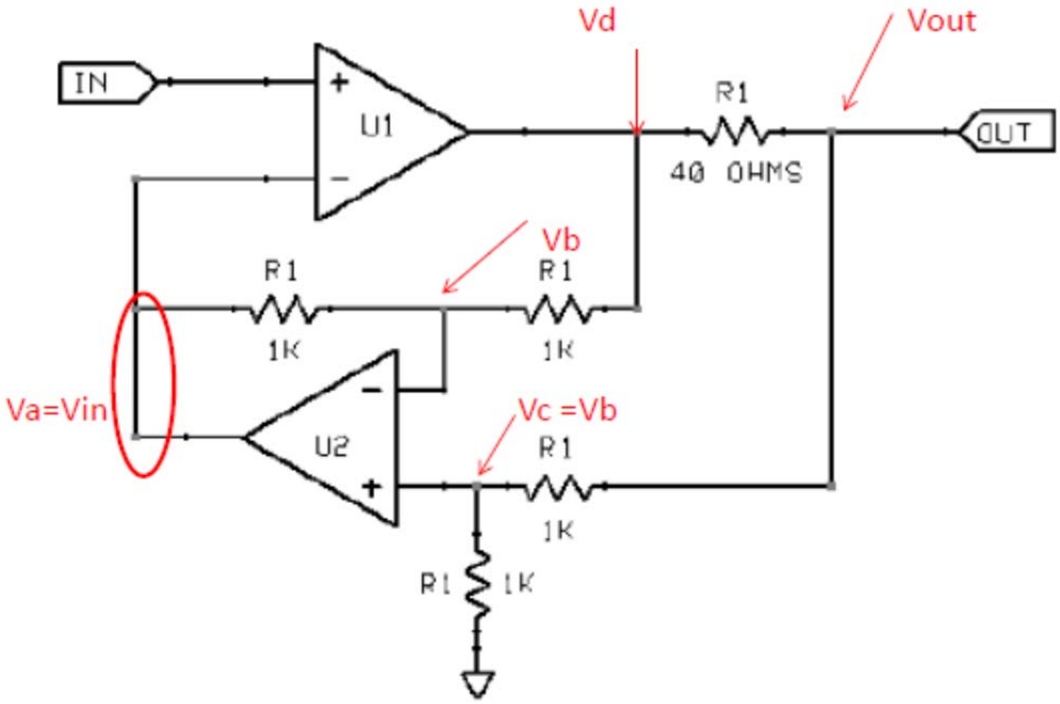
$$= \frac{O(\text{R2})}{O(\text{R2}^2)}$$

(Big O notation, the numerator has R2 in the first order, and the denominator has R2 in the second order.

Therefore, when R2 -- > infinity, $\frac{\partial \text{Vout}}{\partial \text{Rin}} = 0$ (changes of Rin has no effect on Vout)

Therefore, we should have as ***LARGE*** R2 as possible.

Problem 2(a)



1) KCL @Vb: $\frac{\text{Vin}-\text{Vb}}{1\text{k}} + \frac{\text{Vd}-\text{Vb}}{1\text{k}} + 0 = 0$

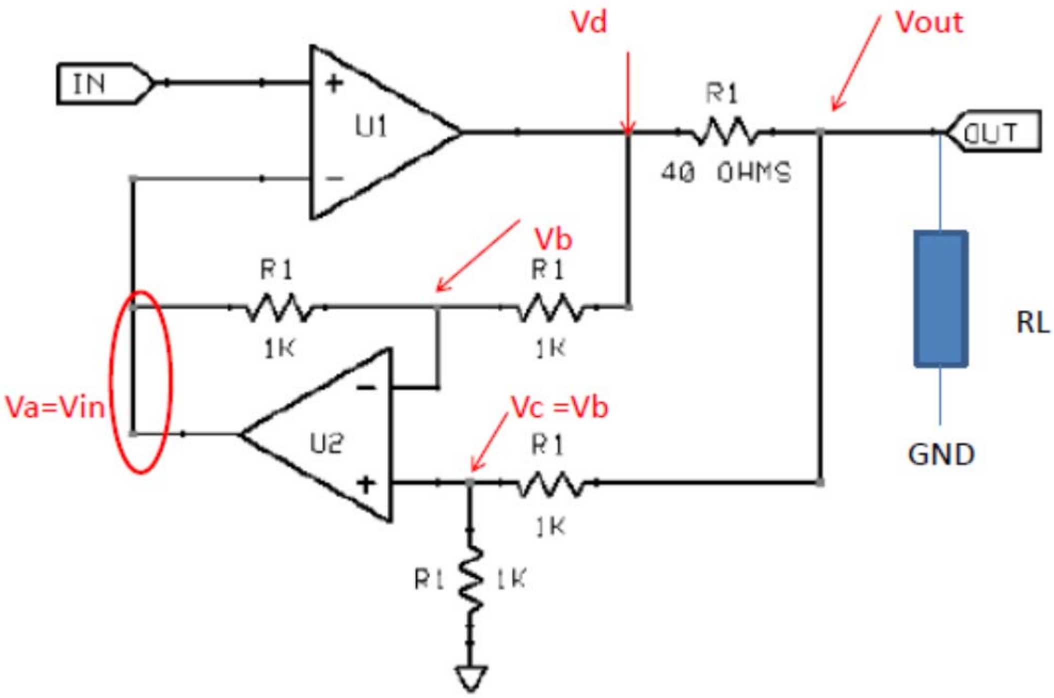
2) KCL @ Vc: 0 + $\frac{0-\text{Vb}}{1\text{k}} + \frac{\text{Vout}-\text{Vb}}{1\text{k}} = 0$

3) KCL @ Vout: $\frac{\text{Vd}-\text{Vout}}{40} + \frac{\text{Vb}-\text{Vout}}{1\text{k}} = 0$

Three unknowns: Vb, Vd, and Vout; three equations.

After solving for the system, we get $\text{Vout} = -50\text{Vin}$

Problem 2(b)



1) KCL @Vb: $\frac{\text{Vin}-\text{Vb}}{1\text{k}} + \frac{\text{Vd}-\text{Vb}}{1\text{k}} + 0 = 0$

2) KCL @ Vc: 0 + $\frac{0-\text{Vb}}{1\text{k}} + \frac{\text{Vout}-\text{Vb}}{1\text{k}} = 0$

3) KCL @ Vout: $\frac{\text{Vd}-\text{Vout}}{40} + \frac{\text{Vb}-\text{Vout}}{1\text{k}} + \frac{0-\text{Vout}}{R_L} = 0$

Three unknowns: Vb, Vd, and Vout; three equations.

After solving for the system, we get $\text{Vout} = \text{Vin} \cdot \frac{-50}{1+\frac{2000}{R_L}}$

Then, I_L = Vout / R_L = $\text{Vin} \cdot \frac{-50}{R_L+2000}$

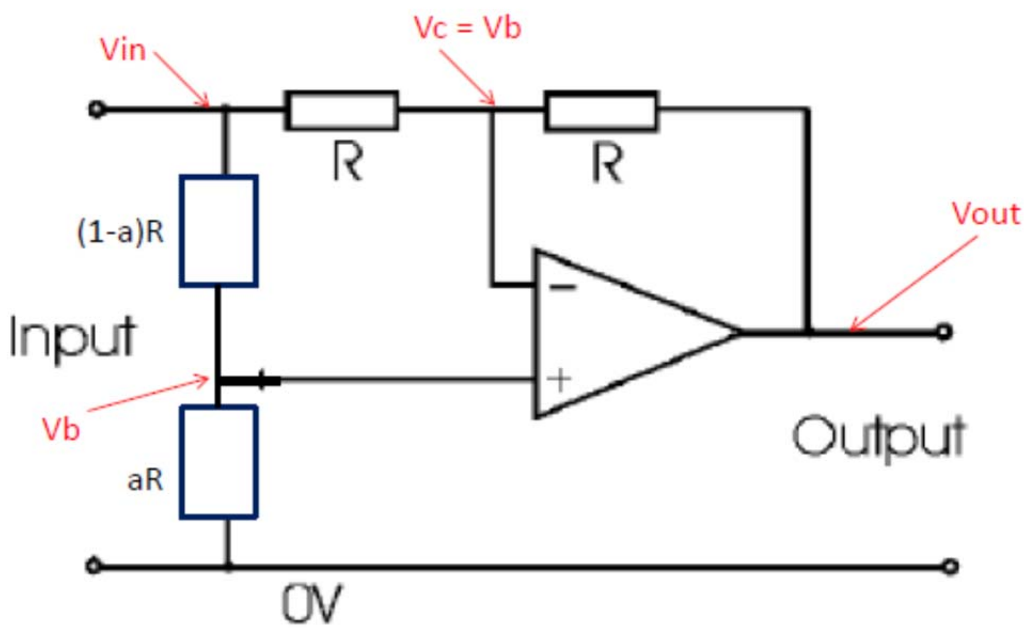
Problem 3(a)
We want to be able to change the gain without changing the internal design of the op-amp. In addition, negative feedback provides stable gain as well.

Problem 3(b)
Amp*100 = 15V. Amp, max = 0.15V. The maximum amplitude without clipping is 0.15V.

Problem 3(c)
When clipping occurs, a pure sinusoidal wave is no longer sinusoidal. The distorted wave now contains waves of some high frequencies (since such clipped waves can be modeled as a combination of numerous sinusoids of multiple frequencies. Because of these additional frequencies, the sound is no longer the same.

Problem 3(d)
dB = 20 log (Gain) = 20 log (100) = 40 dB.

Problem 4



0) Label all the nodes as shown above.

1) From Golden Rule #1, Vc = Vb.

2) KCL @ Vb: $\frac{Vin-Vb}{(1-a)R} + 0 + \frac{0-Vb}{aR} = 0$

3) KCL @ Vc: $\frac{Vin-Vb}{R} + 0 + \frac{Vout-Vb}{R} = 0$

From the two KCL equations, We can solve for Vout.

$Vb = aVin$

$Vout = (2a-1)Vin$

$\frac{Vout}{Vin} = 2a - 1$
