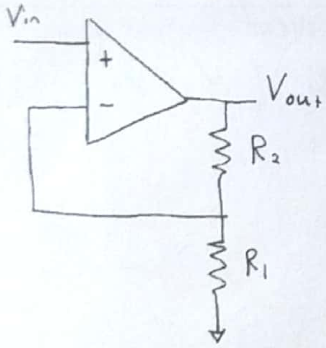
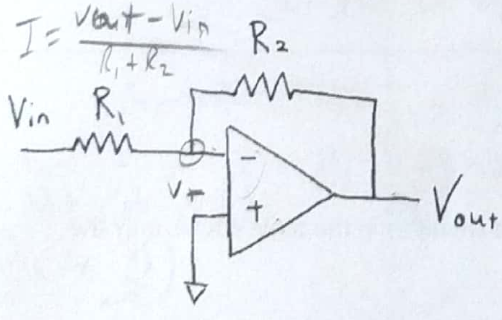
Problem Set: Basic op-amp circuits

For each circuit in the table, write Vout as a function of the input voltage(s) and the resistors in the circuit.

The circuits in the table are all referenced to ground and we will assume the power supply to the op-amp in no way limits the result (this is not true in practice but useful to get started). Use the two rules

- Inputs to the op-amp have zero current.
- V+=V- when we have negative feedback.

To get started, apply these rules and use Ohm's law to figure out the current flow through each resistor. Once you have the currents, a little manipulation will quickly yield an expression for Vout.

	$V_{out} = \frac{R_1+R_2}{R} V_{in}$
$I = \frac{V_{out}-V_{in}}{R_1+R_2}$ 	$V_{out} = \frac{-R_2}{R_1} V_{in}$

$I = \frac{V_{out} - V_{in}}{R_1+R_2} = \frac{V_- - V_{out}}{R_1} = \frac{V_{out} - V_-}{R_2}$

$R_2 V_- - R_2 V_{out} = R_1 V_{out} - R_1 V_-$

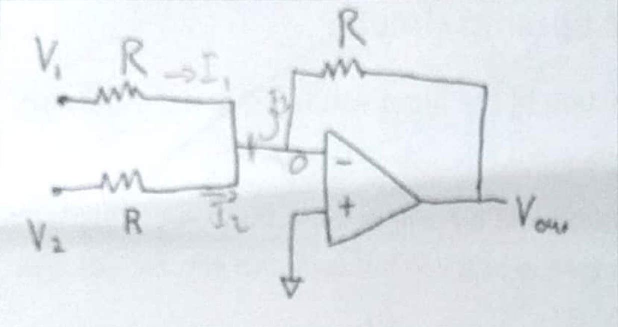
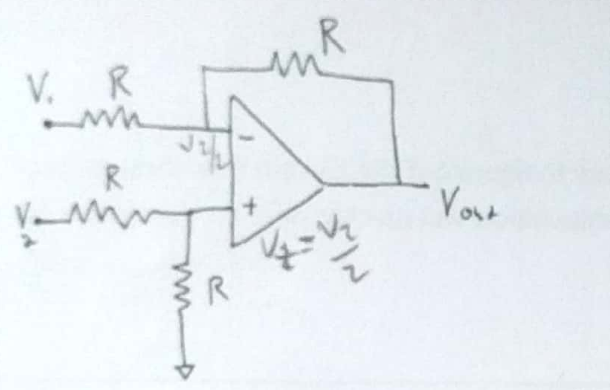
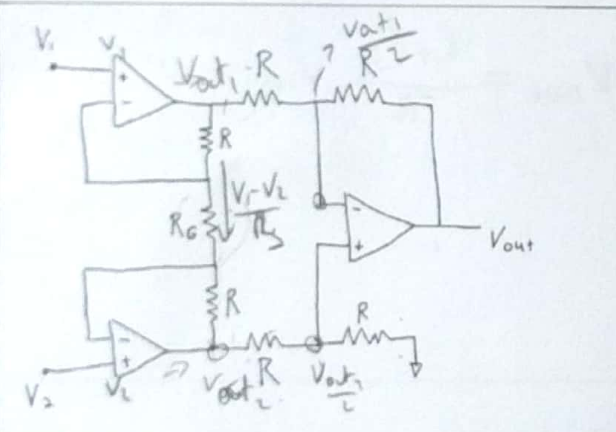
$\cancel{V_{out}}$

$(R_2 + R_1) V_-$

$R_1 (V_{out} - V_{in}) = (R_1+R_2)(V_{in} - V_{out})$

$R_1 V_{out} \cancel{+} \cancel{- R_1 V_{in}} = \cancel{R_1 V_{in}} + R_2 V_{in} - R_1 V_{out} - R_2 V_{out}$

$I_1 = \frac{V_1}{R}$ $I_2 = \frac{V_2}{R}$ $I_3 = \frac{(V_1+V_2)}{R}$ $\frac{V_{out} - V_-}{R}$

	$V_{out} = -(V_1 + V_2)$ $V_1 + V_2 = V_{out}$
	$V_{out} = V_2 - V_1$ $\frac{\frac{V_2}{2} - V_1}{R} = \frac{V_{out} - V_2/2}{R}$ $V_{out} = V_2 - V_1$
	This is the challenge circuit $V_{out} = \left(\frac{2R}{R_g} + 1\right)(V_1 - V_2)$ $\frac{V_1 - V_2}{R_g} = \frac{V_{out_1} - V_{out_2}}{2R + R_G}$

$\frac{(V_1 - V_2)(2R + R_G)}{R_G} = V_{out_1} - V_{out_2}$

$\frac{V_1 2R - V_2 2R}{R_G} + V_1 - V_2 = V_{out_1} - V_{out_2}$

$\frac{2R}{R_G}(V_1 - V_2) + (V_1 - V_2)$

$\left(\frac{2R}{R_G} + 1\right)(V_1 - V_2)$

Testing an amplifier

Build the amplifier circuit shown in Figure 1a. This is the same circuit as in the table above, only the circuit is referenced to 2.5 V instead of ground.

Test the circuit by using the waveform generator and scope on your Analog Discovery. Set the waveform generator to output a **100 mV amplitude sinusoidal signal with an offset of 2.5 volts**. With the scope, measure both the input and the output voltage, referencing Ch1- and Ch2- to ground. Adjust the scope time and volts/div scale so that you can see the signal clearly. Check your observation against what you predicted in the table above (you don't need a plot here).

Switch the connection on R2 to ground instead of 2.5 V as shown in Figure 1b. Leave the input voltage on the waveform generator as it was previously to output a **100 mV amplitude sinusoidal signal with an offset of 2.5 volts.** Check the output of the circuit, referencing Ch1- and Ch2- to ground. Now change the offset of the input signal on W1 to be 0 volts (note, both input signals are shown schematically in Figure 3b). Check the output of the circuit. Work to understand the difference between referencing your circuit to 2.5 volts as in Figure 1a versus ground in Figure 1b. Think about why we will usually use the reference to 2.5V. You do not need to turn in any plots, just test it.

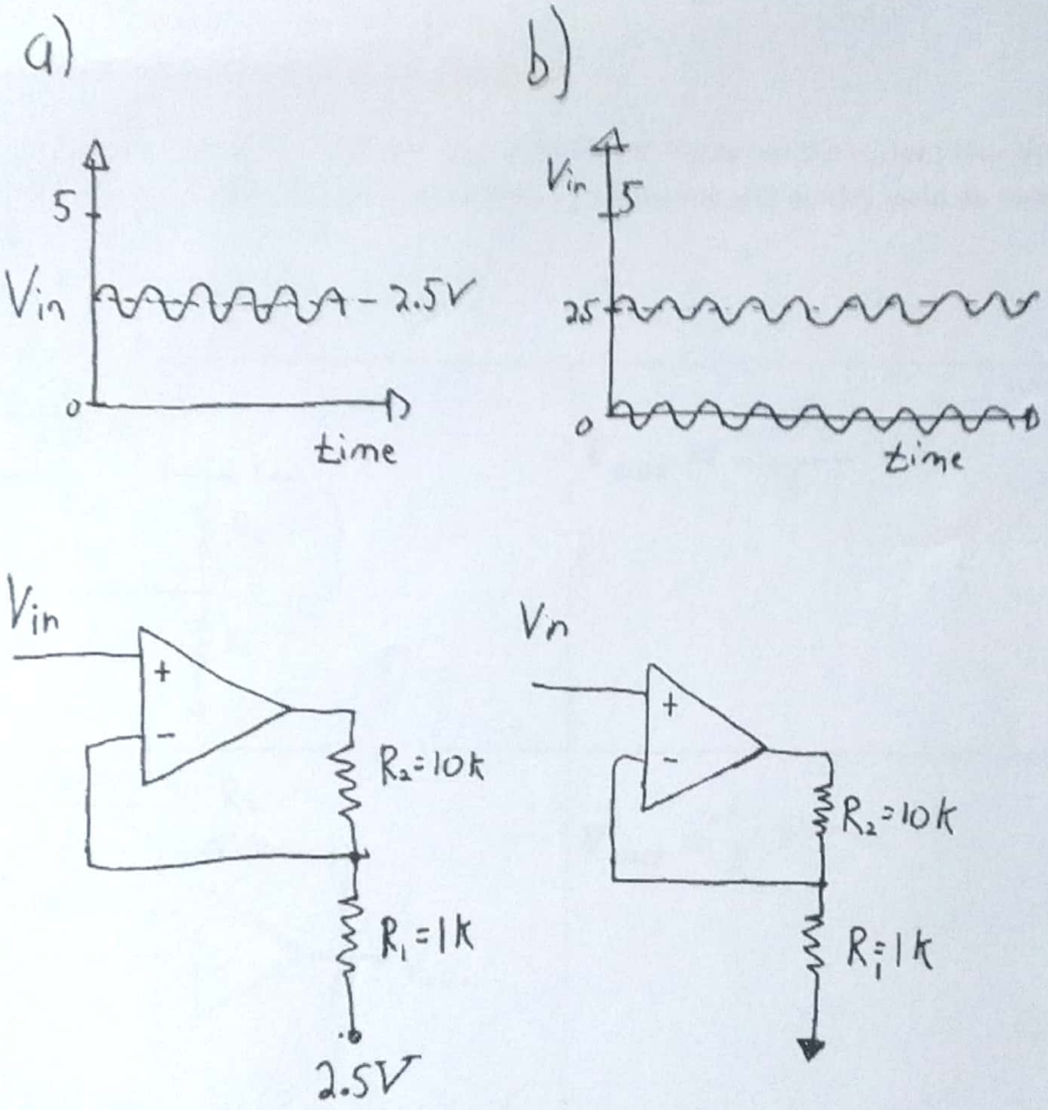


Figure 1: Amplifier circuit with 2.5 and ground reference