

## 1 KVL/KCL Review

Kirchhoff's Circuit Laws are two important laws used for analyzing circuits. Kirchhoff's Current Law (KCL) says that the sum of all currents entering a node must equal 0. For example, in Figure 1, the sum of all currents entering node 1 is  $I_1 - I_2 - I_3 = 0$ . Assuming that  $I_1$  and  $I_3$  are known, we can easily obtain a solvable equation for  $V_x$  by applying Ohm's law:  $I_1 - \frac{V_x}{R_1} - I_3 = 0$ .

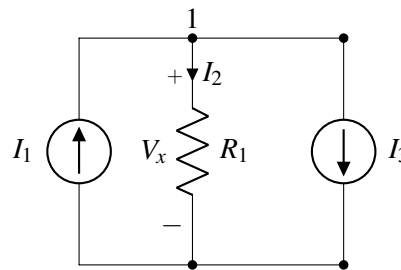


Figure 1: KCL Circuit

Kirchhoff's Voltage Law (KVL) states that the sum of all voltages in a circuit loop must equal 0. To apply KVL to the circuit shown in Figure 2, we can add up voltages in the loop in the counterclockwise direction, which yields  $-V_1 + V_x + V_y = 0$ . Using the relationships  $V_x = i \cdot R_1$  and  $i = I_1$ , we can solve for all unknowns in this circuit. You can use these two laws to solve any circuit that is planar and linear.

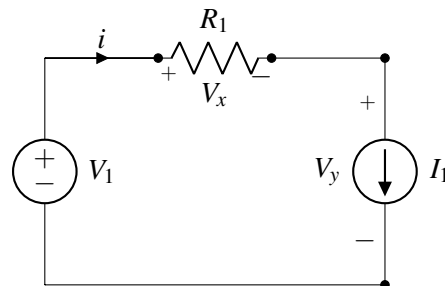


Figure 2: KVL Circuit

If you would like to review these concepts more in-depth, you can check out the EE16A spring 2018 course notes

## 2 Op-amp Review

Figure 3 shows the equivalent model of an op-amp. It is important to note that this is the general model of an op-amp, so our op-amp golden rules cannot be applied to this unless certain conditions are met.

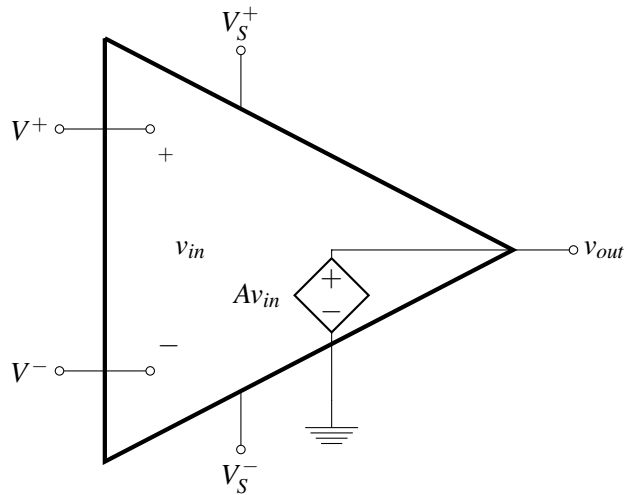


Figure 3: General Op-Amp Model

### Conditions Required for the Golden Rules:

- (a)  $R_{in} \rightarrow \infty$
- (b)  $R_{out} \rightarrow 0$
- (c)  $A \rightarrow \infty$
- (d) The op-amp must be operated in negative feedback.

When conditions 1-3 are met, the op-amp is considered ideal. Figure 4 shows an ideal op-amp in negative feedback, which can be analyzed using the Golden Rules.

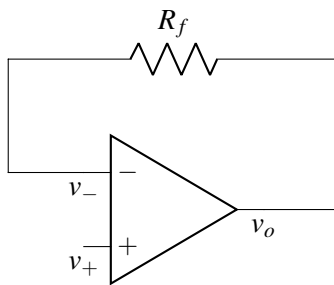


Figure 4: Ideal Op-Amp in Negative Feedback

### Golden Rules of ideal op-amps in negative feedback:

- (a) No current can flow into the input terminals ( $I_- = 0$  and  $I_+ = 0$ ).
- (b) The (+) and (-) terminals are at the same voltage ( $V_+ = V_-$ ).

If you would like to review these concepts more in-depth, you can check out op-amp introduction and op-amp negative feedback from the EE16A spring 2018 course notes.

## 1. KVL/KCL Review

Use Kirchhoff's Laws on the circuit below to find  $V_x$  in terms of  $V_{in}, R_1, R_2, R_3$ .

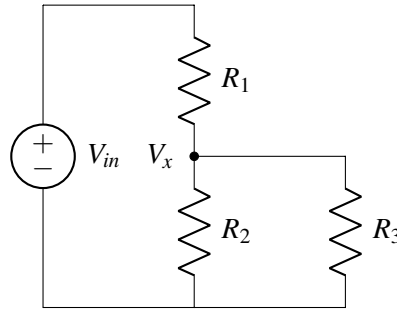


Figure 5: Example Circuit

- (a) What is  $V_x$ ?
- (b) As  $R_3 \rightarrow \infty$ , what is  $V_x$ ? What is the name we used for this type of circuit?

## 2. Op-Amp Summer

Consider the following circuit:

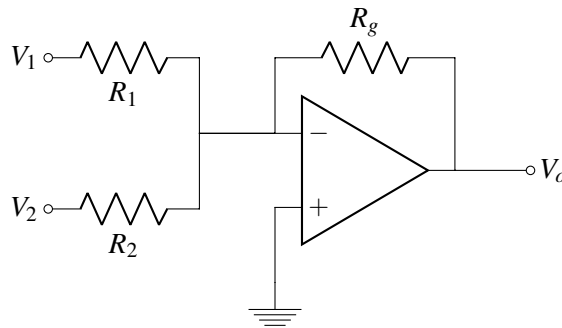


Figure 6: Op-amp Summer

What is the output  $V_o$  in terms of  $V_1$  and  $V_2$ ? You may assume that  $R_1$ ,  $R_2$ , and  $R_g$  are known.