

6.301 Solid State Circuits

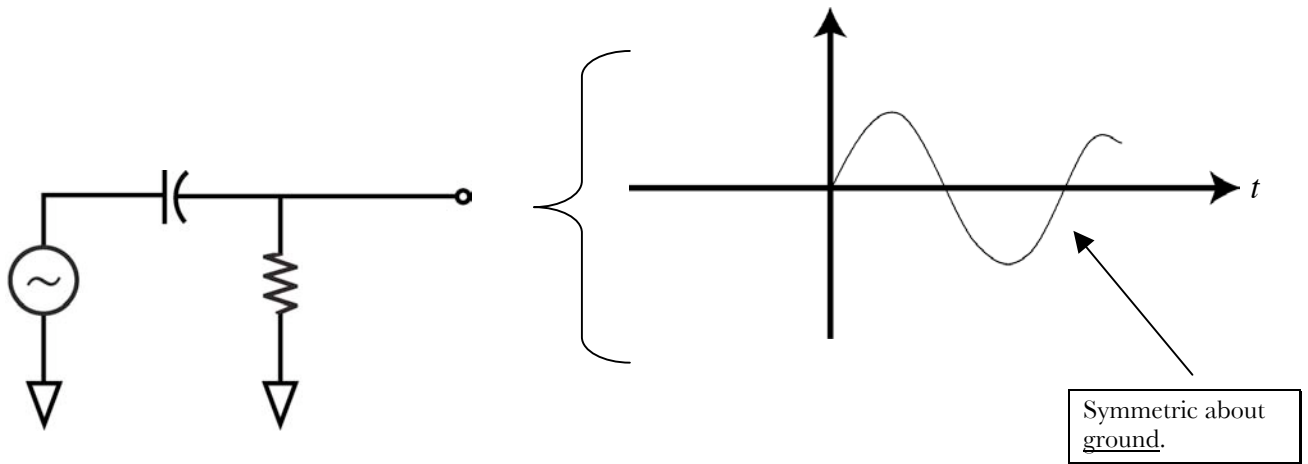
Recitation 10: Op-Amp Applications

Prof. Joel L. Dawson

We're going to treat op-amps in some detail in this class. They are very useful as all-around circuit blocks, as we shall see in the next few lectures. From the standpoint of learning circuit design, though, they are extremely good for sensitizing us to the issues surrounding DC amplification.

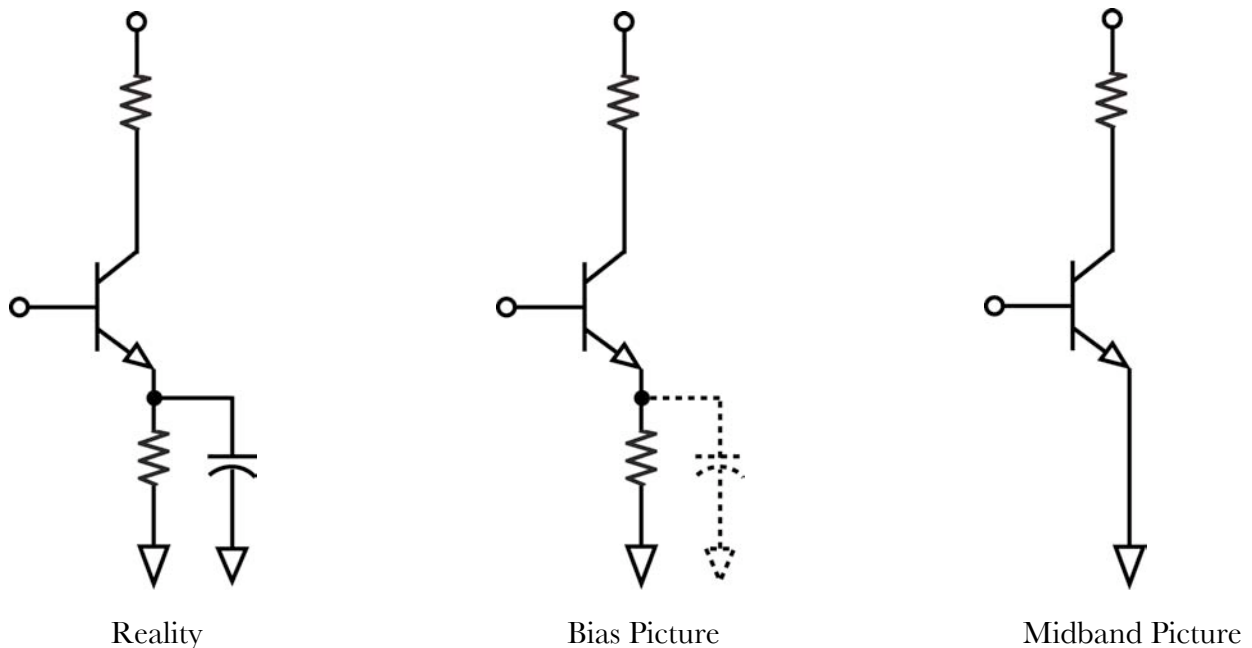
Let's pause and take stock of some of the things that AC coupling has given us.

- (1) We don't worry about what our reference level is:



- (2) DC offsets? What DC offsets?

- (3) "Bias Picture" vs. "Midband Picture"



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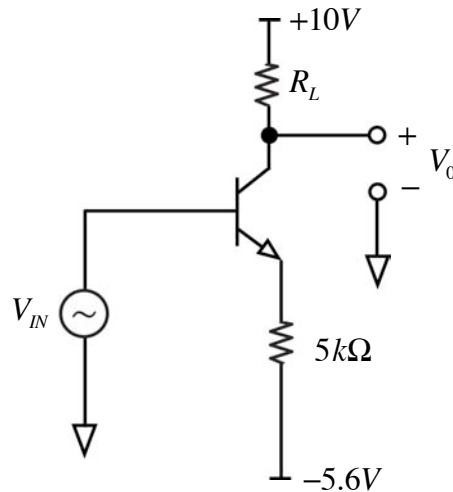
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But suppose our input has a DC component that we care about?

CLASS EXERCISE

Consider the following circuit, for which V_{BE} is 0.6V.



Suppose we have chosen our reference output level to be +2V. That is, when V_{IN} is 0, V_O is 2V.

- (1) Pick R_L to achieve this.
- (2) What range is R_L restricted to if we demand accuracy to within $\pm 1mV$?

(Workspace)

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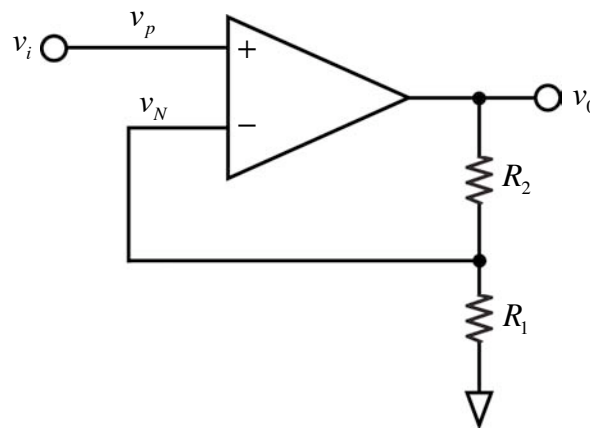
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When we design for DC performance, then, we go to a whole new bag of circuit tricks. Differential structures and op-amps are big parts of that bag...

So what are op-amps useful for? First, recall how to analyze op-amp circuits quickly:

(1) Non-inverting amplifier



Start by making no assumptions about the gain, a , of op-amp.

$$v_N = \frac{R_1}{R_1 + R_2} v_o \quad ; \quad \begin{aligned} v_o &= a(v_p - v_N) \\ v_o &= a\left(v_i - \frac{R_1}{R_1 + R_2} v_o\right) \end{aligned}$$

Solve for V_o :

$$\left(1 + a \frac{R_1}{R_1 + R_2}\right) v_o = a v_i$$

$$\boxed{\frac{v_o}{v_i} = \frac{a}{1 + a \frac{R_1}{R_1 + R_2}}}$$

And of course, if we are lucky enough to have large gain a ,

$$\frac{v_o}{v_i} = 1 + \frac{R_2}{R_1}$$

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Before we leave this, let's go back and look at

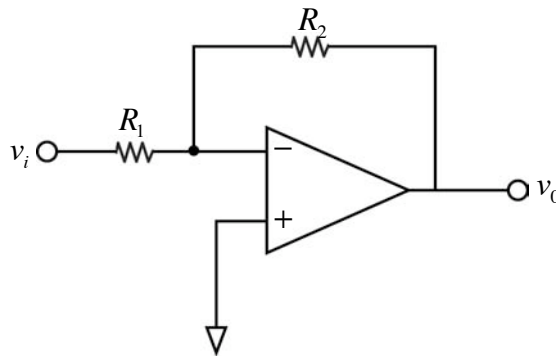
$$v_o = a(v_p - v_n)$$

Notice that infinite gain a , together with finite values v_o , imply $v_p - v_n \rightarrow 0$. Put (yet) another way:

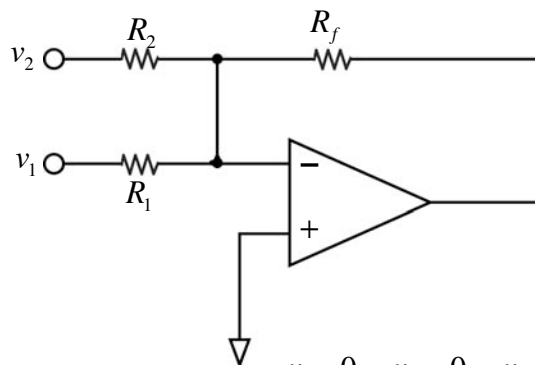
$$v_p - v_n = \frac{v_o}{a} = \frac{1}{1 + a \frac{R_1}{R_1 + R_2}}$$

As a goes to infinity, it must be true that $v_p \approx v_n$.

(2) Inverting amplifier and Summer



$$\frac{v_i - 0}{R_1} = \frac{0 - v_o}{R_2} \Rightarrow \frac{v_o}{v_i} = -\frac{R_2}{R_1}$$



Allows you to perform weighted sum!

$$\frac{v_i - 0}{R_1} + \frac{v_2 - 0}{R_2} + \frac{v_N - 0}{R_N} = \frac{0 - v_o}{R_f}$$

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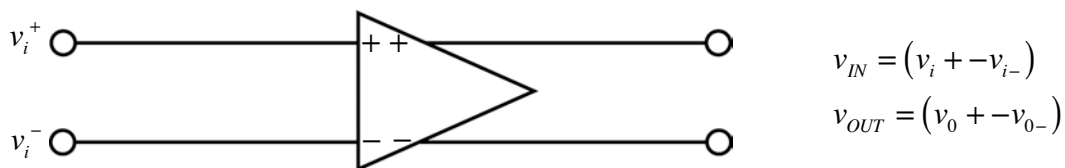
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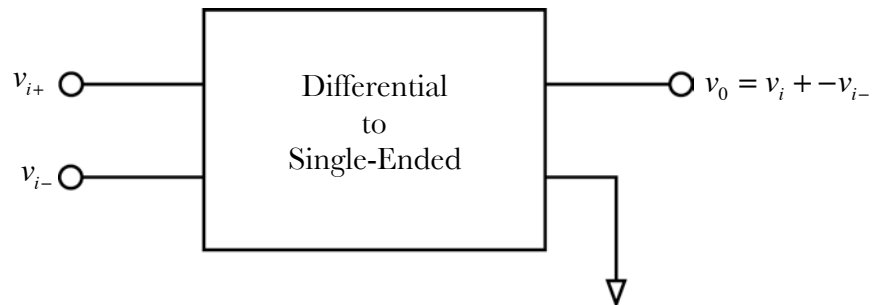
$$v_o = -R_f \sum_{i=1}^N \frac{v_i}{R_i}$$

(3) Differential Amplifier

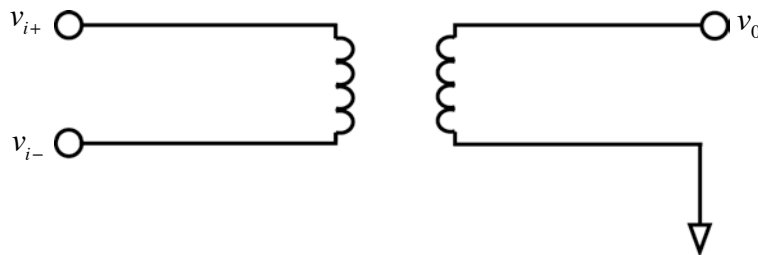
Those of you who continue on to do advanced circuit design, particularly for ICs, will probably work with differential signal paths. An example is a fully differential amplifier:



Sometimes it becomes necessary to convert to a single-ended signal, that is



If we're concerned only with AC signals, we can use a transformer (sometimes called a balun):

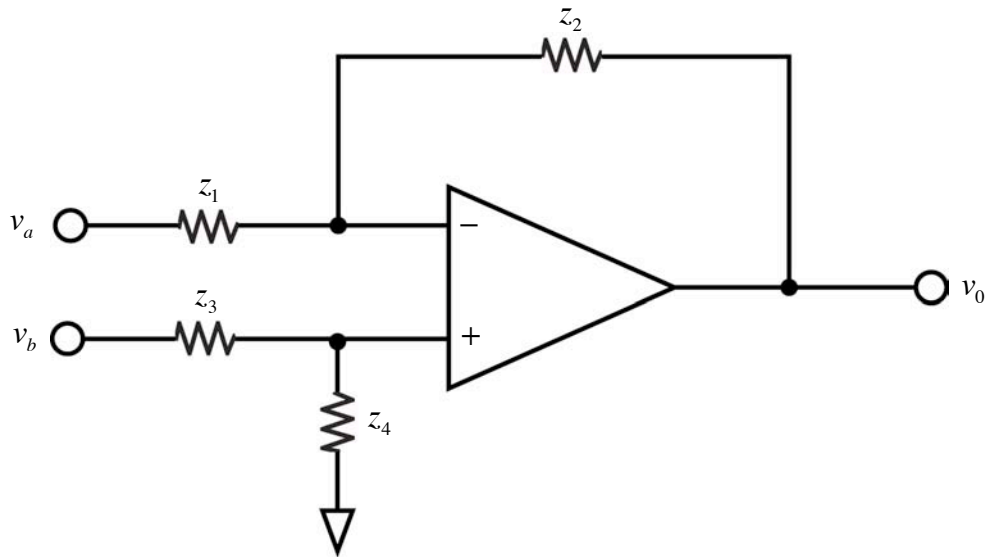


But if we care about the DC component, we must find another solution. Once again, the op-amp rides to the rescue:

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We can lower our heads and grind on this one, or take advantage of superposition and our previous results:

$$V_o = \left(\frac{z_4}{z_3 + z_4} \right) \left(\frac{z_1 + z_2}{z_1} \right) V_b - \frac{z_2}{z_1} V_a$$

Now suppose we choose $\frac{z_4}{z_3} = \frac{z_2}{z_1}$

$$V_o = \left(\frac{\cancel{z_4}/z_3}{1 + \cancel{z_4}/z_3} \right) \left(\cancel{1 + \frac{z_2}{z_1}} \right) V_b - \frac{z_2}{z_1} V_a$$

$$V_o = \frac{z_4}{z_3} V_b - \frac{z_2}{z_1} V_a = \frac{z_2}{z_1} (V_b - V_a)$$

The op-amp has many, many useful applications. Soon, we will learn how they work on the inside.

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