6.301 Solid-State Circuits

Recitation 17: Lab 2 Wrap-up, Op-Amps continued
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First of all, congratulations! Consider how far you've come at this point in the term. When we began, designing a simple two-transistor amplifier was a real chore, and analysis was a pain. Now, you have shown that you can handle all the details of a six-transistor design: biasing, bandwidth optimization, and large signal considerations. That is quite an accomplishment.

Let's take a few minutes to discuss your questions on Lab 2…

Now we continue our exploration of op-amp design tricks. Look at the input stage of the LM101. If we draw it out in its simplest form, we see the following:

It has this funny input stage, similar to the 741. Why do we use this? Let's examine in detail…

There are a couple of problems that this input stage very cleverly addresses. The first is the "level-shifting problem." To see how this shows up, consider that in many I_C processes, we'd prefer to use only NPNs in the signal path:

The voltage at (A) is going to be not much more than a V_{BE} above the negative supply rail. This is because Q_6 is the driving force behind much of the gain of this circuit, and so we're not going to permit a lot of emitter degeneration with a large R_2. This means that the voltage at (B) is only a little more than $2V_{BE}$ above the negative supply rail, and suddenly we're restricted to very low common-mode input levels!

This, in a nutshell, is the level-shifting problem. In an ideal world we could fix things by using PNP input devices:

Now, of course, we have plenty of common-mode input range.

This is fine if we have 2N3906s lying around that we can use for the input differential pair (nice, high β_F s). But in the I_C world, where PNPs may have a β of 5 and be slow to boot, what we've constructed here is a pretty poor input stage.

Looking now at the LM101, we can see that by using the emitter follower + common base input stage, they've solved the level-shifting problem. But can we satisfy ourselves that we haven't given up any other important characteristics?

For instance, a differential pair gives us good differential g_m but zero common-mode g_m:

Flipping things over for a common-base stage: