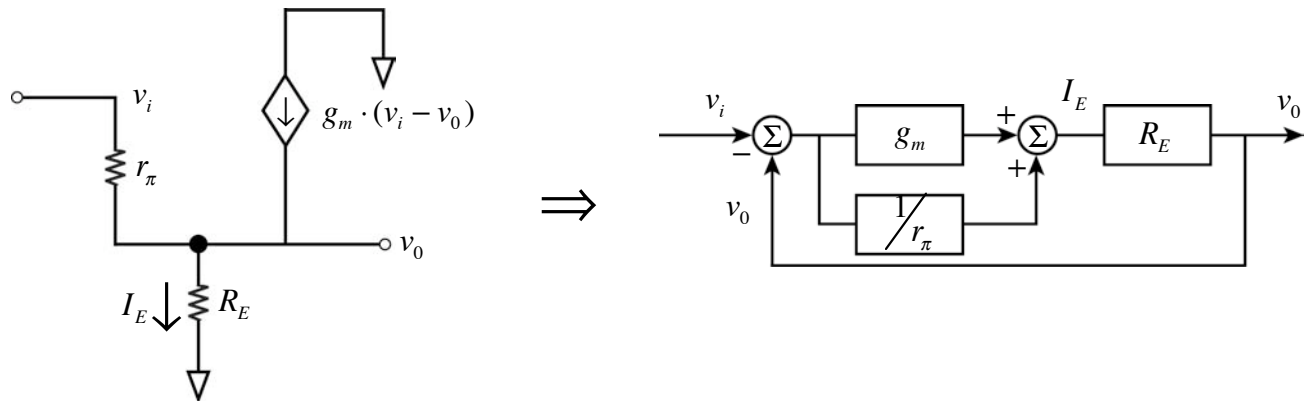


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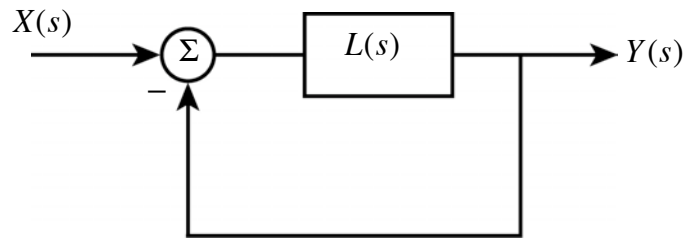
Recitation 9: Feedback Biasing in Circuits

Prof. Joel L. Dawson

Feedback is used all the time in circuit design. What can make the use of feedback difficult to analyze is that “feedback” and “circuits” are often presented as separate subjects, and it is not always obvious how to tie the two together. As an example, you will sometimes hear people refer to an emitter follower as a feedback circuit. What?



Now, remember from 6.003 that for a feedback system



The transfer function is $\frac{Y(s)}{X(s)} = \frac{L(s)}{1 + L(s)}$. Applying that to our emitter follower, we have

$$\frac{v_o}{v_i} = \frac{\left(g_m + \frac{1}{r_\pi}\right)R_E}{1 + \left(g_m + \frac{1}{r_\pi}\right)R_E} = \frac{(g_m r_\pi + 1)R_E}{r_\pi + (g_m r_\pi + 1)R_E} = \frac{(\beta + 1)R_E}{r_\pi + (\beta + 1)R_E}$$

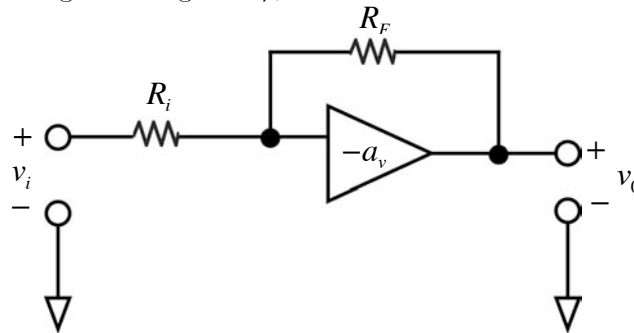
Interesting.

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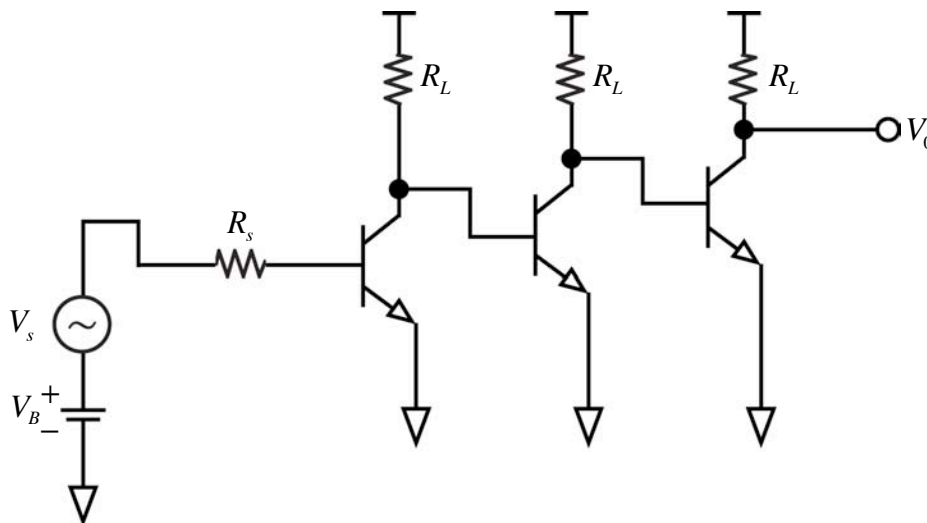
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CLASS EXERCISE: Assuming a finite gain a_v , derive the transfer function for $\frac{v_o}{v_i}$.



(Workspace)

We've seen a few examples of feedback in the circuits we've analyzed ($\mu A733$ video amp, and LM172 AGC AM IF strip). In these chips, feedback has been used sometimes for biasing, and sometimes for signal processing. For an example of using feedback to help with biasing, we turn first to the text and consider the problem of the DC-coupled C_E cascade:

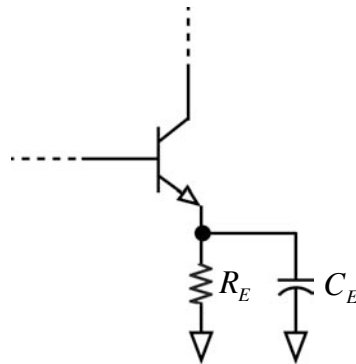


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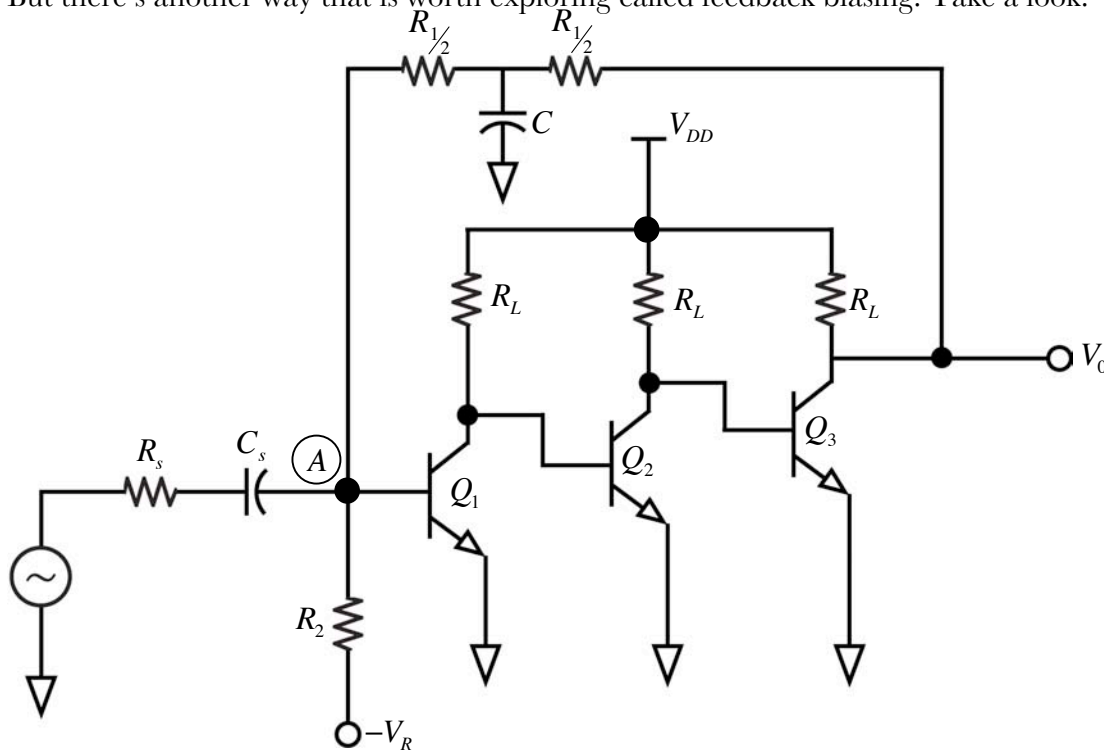
Recitation 9: Feedback Biasing in Circuits

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If the overall gain of the cascade is A , we get exactly the kind of bias sensitivity that we feared: A function of a few millivolts at the input turns into a fluctuation of $A \cdot$ (few millivolts) at the output bias point. Before, we handled this with our degeneration trick:



But there's another way that is worth exploring called feedback biasing. Take a look:



Before diving into the math, take a second to convince yourself conceptually that the feedback is doing the right thing. If the voltage at (A) were to go up just a little bit, V_0 would go down by a lot because there is substantial negative gain between (A) and V_0 . The effect of V_0 going down would be to pull down on (A). We see that deviations from a nominal value at (A) are met with a “restoring force.”

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How, then, does this thing wind up biasing up? Well, Q_1 and Q_2 are easy. Assuming negligible base currents:

$$I_{C1} = I_{C2} = \frac{V_{DD} - V_{BE}}{R_L}$$

For Q_3 we need to figure out V_0 . Once again, it helps to assume a negligible base current for Q_1 . The base of Q_1 will nominally rest at V_{BE} ; KCL at that base gives

$$\frac{-V_R - V_{BE}}{R_2} = \frac{V_{BE} - V_0}{R_1}$$

$$\frac{1}{R_1}(V_0) = \frac{1}{R_2}V_R + \frac{1}{R_2}V_{BE} + \frac{1}{R_1}V_{BE}$$

$$V_0 = \frac{R_1}{R_2}V_R + \frac{R_1 + R_2}{R_2}V_{BE}$$

Before, we had $V_0 = A \cdot V_{BE}$; now, choosing $R_1 = R_2$ (for example) means

$$V_0 = V_R + 2V_{BE}$$

Quite an improvement!

Now for a couple of questions about the topology.

1) Why do we need V_R ?

Because we don't want to restrict ourselves to $V_0 = V_{BE}$. Notice that if we remove V_R by making $R_2 = \infty$:

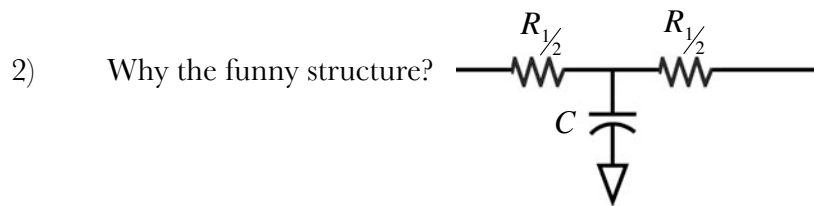
$$\lim_{R_2 \rightarrow \infty} V_0 = 0 \cdot V_R + V_{BE}$$

V_R gives us a degree of freedom that we use to our advantage. Note that there are other ways to decouple V_0 and V_{BE} .

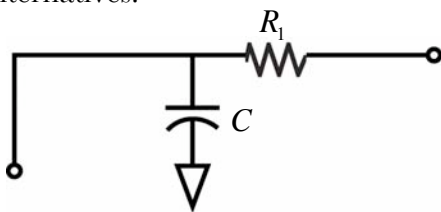
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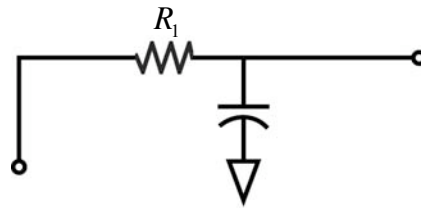
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Couple of reasons. First, we want to preserve the cascade gain at midband, while only using the feedback to stabilize the low-frequency bias point. As to the structure, consider the alternatives:

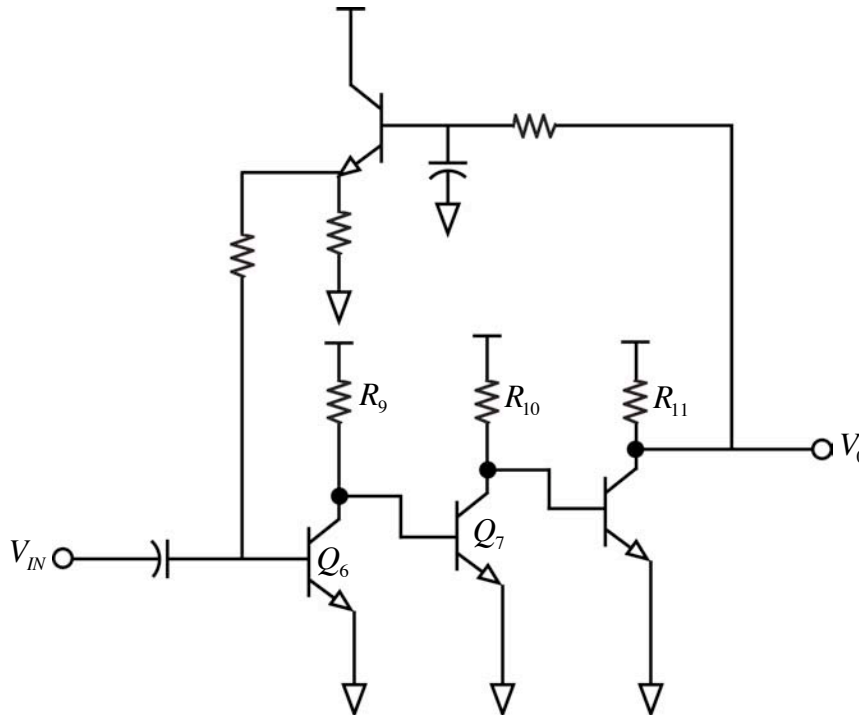


Capacitively loads input!



Capacitively loads output.

Finally, look back at how the LM172 realizes this concept:



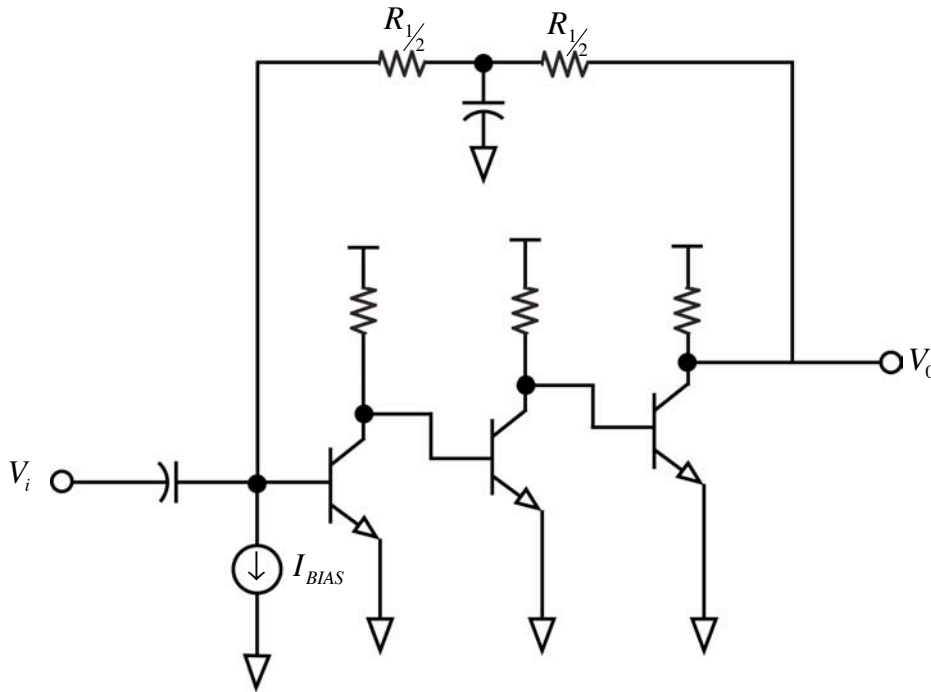
The emitter follower provides a diode drop, and allows them to place V_O at $2V_{BE}$.

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Here's one more way to decouple the output bias level from V_{BE} .



$$\frac{V_o - V_{BE}}{R_1} = I_{BIAS}$$

$$V_o - V_{BE} = I_{BIAS} R_1$$

$$V_o = I_{BIAS} R_1 + V_{BE}$$

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