Lecture Notes,
Class B Amplifier With Feedback
EE 361, FALL, 2003
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Crossover distortion is, well, distortion. As we'll see in a later chapter, one way of reducing distortion is to apply negative feedback. Fig. 1 shows such a circuit.

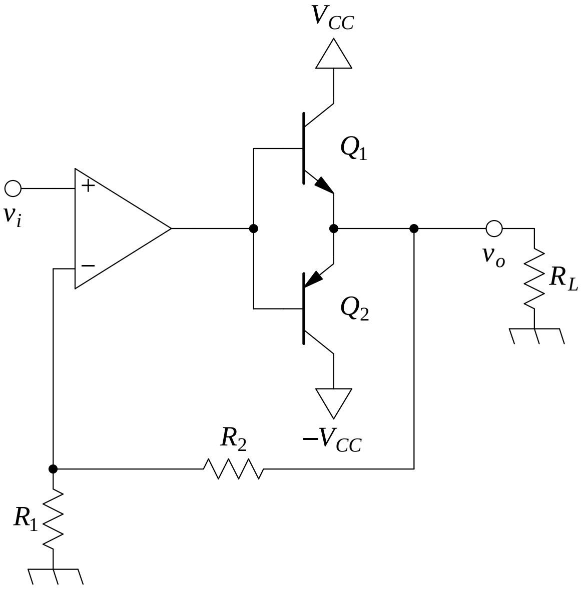

Figure 1: Schematic diagram of a Class-B amplifier with negative feedback.

Here's the idea. The opamp adjusts its output so that $v_+ = v_-$. But $v_+ = v_i$, and $v_- = \frac{R_1}{R_1+R_2} v_o$. Thus, the opamp adjusts its output so that

$$v_- = v_+ = v_i = \frac{R_1}{R_1+R_2} v_o$$

or, solving for v_o,

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

The output is a constant times the input–there's no distortion.

Perhaps this seems like magic. How does the opamp do it? The answer is that it maintains the voltage at its output at about 0.6 V above v_i when the input is positive, and 0.6 V below v_i when the input is negative.

I simulated the circuit with SPICE. I specified a 741 opamp, and set $R_1 = R_2 = 1$ K, and an 8 Ω load resistor. I chose a 1 V, zero-to-peak sine wave for the input, and set the β for the two BJT's equal to 500 so that I don't have to worry about the BJT's loading down the opamp. Fig 2a shows the result for the output voltage (solid line), and the voltage at the bases of the two BJT's (dashed line). Looking at the results in Fig. 2a, the output voltage looks pretty good. It's also pretty clear how the opamp works this magic. The base voltage makes a rapid transition between -0.6 and 0.6 V as the output voltage goes through zero.

There is a skeleton hiding in the closet here, though. Fig. 2b shows similar results for a 10 kHz sine wave input. The crossover distortion has partly returned. Further, if you look closely at the output even for the 1 kHz input, there is a slight glitch in the output voltage at the zero-crossing. Fig. 3 shows a zoomed-in plot of the region around a zero crossing for the 1 kHz input. The glitch in the output is more evident, and the reason for it is as well. The base voltage does not rise vertically from about -0.6 to $+0.6$ V, but has a finite slope of roughly 10^5 V/sec. This is a characteristic of opamps. The output voltage cannot change faster than a specified rate called the *slew rate*. While the opamp output is traversing this dead-band region, the output of the power amp is about 0. For low frequencies, this peccadillo doesn't lead to a significant glitch, but as the frequency increases, the length of the glitch becomes significant in comparison with the signal period.

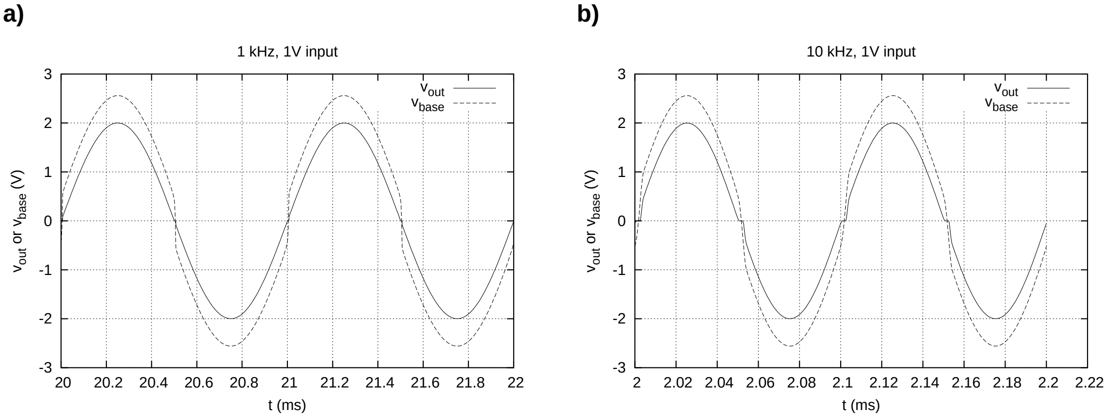

Figure 2: SPICE results showing the output voltage, and the voltage of the bases of the BJT's for (a) 1 kHz, and (b) 10 kHz input.

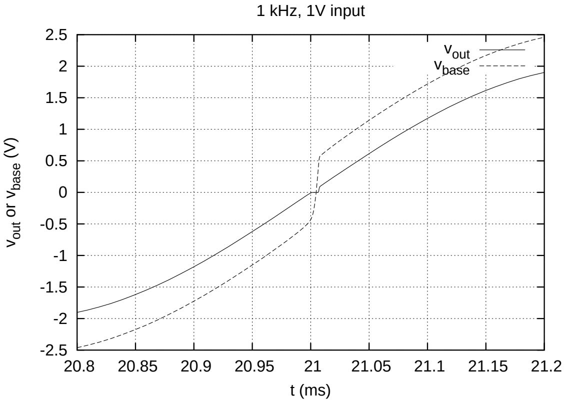

Figure 3: Zoomed-in plot of output and base voltages for 1 kHz input showing.

Because of the finite slew rate of opamps, the best configuration is one using both class-AB biasing to eliminate most of the crossover distortion, and negative feedback to clean up whatever distortion remains from this and other sources.

Finally, I wish to emphasize that it is critical for the feedback scheme to work that the feedback be taken from the output of the full amplifier, not from the output of the opamp. Taking the feedback from the opamp output only ensures that this signal is a faithful copy of the input. Anything outside the loop is free to distort the signal any way it likes. Fig. 4 illustrates this point. It shows the results of a SPICE simulation of the same circuit as in Fig. 1, except the the right side of R_2 is tied to the output of the opamp (the bases of the BJT's), rather than the overall output (the emitters of the BJT's). The crossover distortion in the output as well as the ≈ 0.55V base-emitter drop are evident. The signal applied to the bases of the BJT's, on the other hand seems a perfect sinewave.

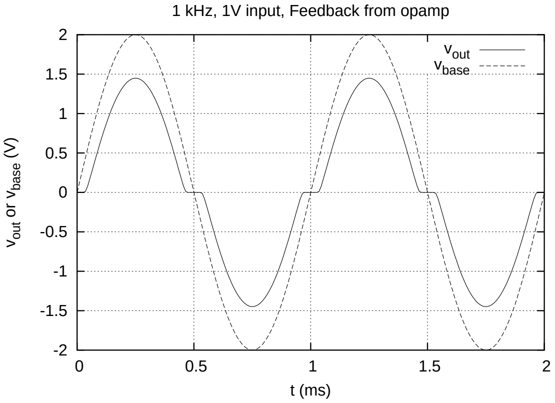

Figure 4: SPICE output for an amplifier similar to that in Fig. 1, except that the feedback to the opamp comes from the opamp output, rather than the emitters of Q_1 and Q_2.