Lab 10: Op-amp II: Amplifiers Continued

Before You Begin:

(a) Most of the time we will use $\pm 15\,\mathrm{V}$ as the supply voltages (you can and should check whether this is safe by referring to the Absolute Maximum Ratings). Often, the power supply connections will not be explicitly shown on diagrams. Don't forget them — we can't get gain for free!

(b) In addition, you should always place *bypass capacitors* between the supply lines and ground, close to the power supply pins. The datasheet recommends $0.1\,\mu\mathrm{F}$, but the precise value isn't critical. These capacitors help ensure that the voltage supplied to the op-amp remains constant; it also prevents oscillation. If you don't bypass (and sometimes even if you do), you may find that the scope traces appear fuzzy, as in Figure 1-left. What's that fuzzy stuff on the bottom of the otherwise nice sine wave? We expanded the horizontal trace and got the detail seen in Figure 1-right — aha, an oscillation at 120 MHz! Active circuits that have amplification can do this, because if some of the output gets back into the input, it can produce a self-sustaining oscillation. We'll talk about this more in later labs. For now, just remember to bypass, bypass, bypass!

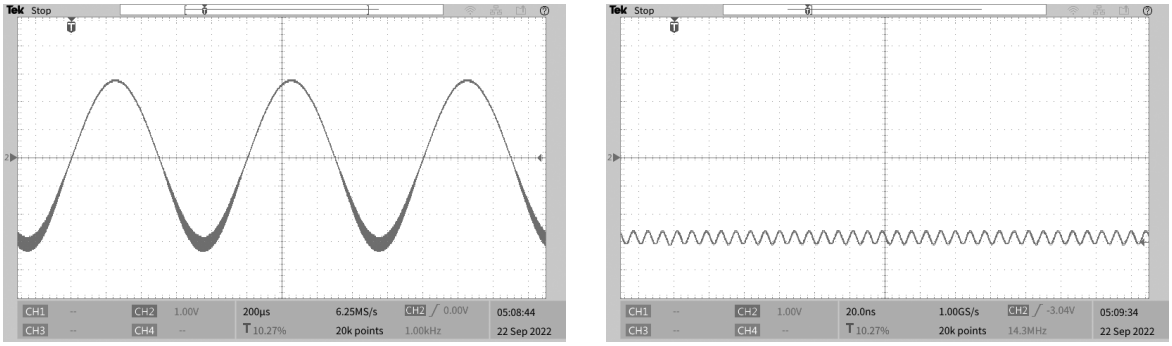


Figure 1: A *parasitic oscillation* often appears as "fuzz" on a scope trace, as here (we encouraged it by removing bypass capacitors). The right figure is an expanded version of the left figure at 20 ns/div, showing the 120 MHz oscillation.

1 Push-pull follower: goodbye to crossover distortion!

In the last lab we saw nasty crossover distortion in the push-pull BJT emitter follower. But here we'll compensate for the crossover, by including the push-pull follower *within* the feedback loop.

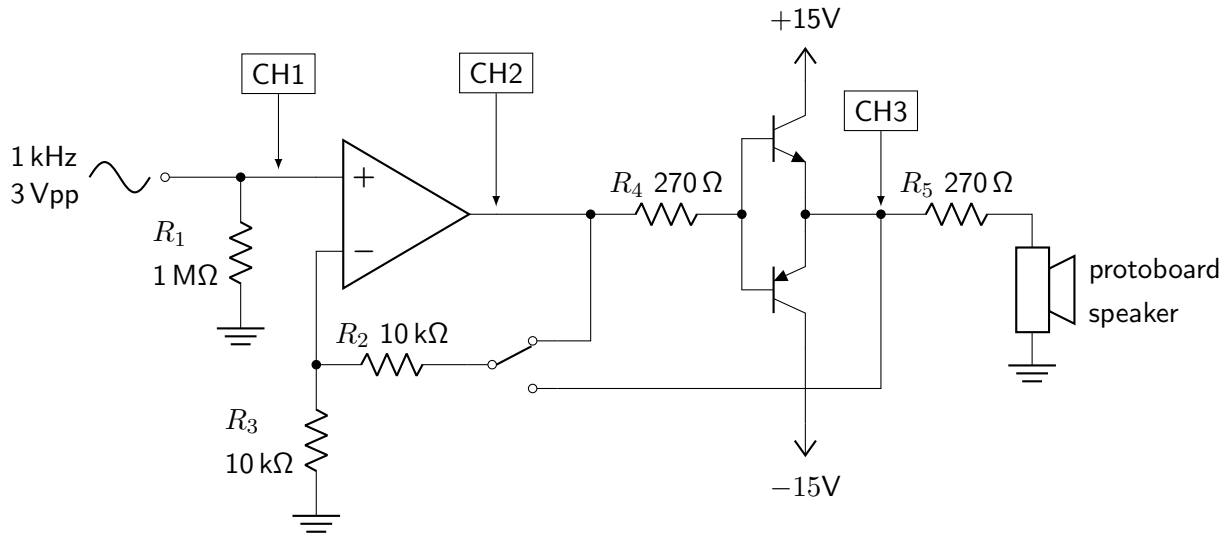


Figure 2: Putting the push-pull follower inside an op-amp's feedback loop.

The circuit in Figure 2 includes a SPDT switch[1] that decides where the feedback is taken from. When the SPDT switch is up, the push-pull follower is *outside* the feedback loop. When the SPDT switch is down, the push-pull follower is *inside* the feedback loop.

(a) When the push-pull is *outside* the feedback loop, predict what the voltage on the output pin of the op-amp will do when the input voltage passes through 0 V.

When the push-pull is outside the feedback loop, the op amp just outputs a sine wave (the input sine, multiplied by two). Then the push-pull affects that sine wave, and the speaker sees a wave that has been affected by crossover distortion.

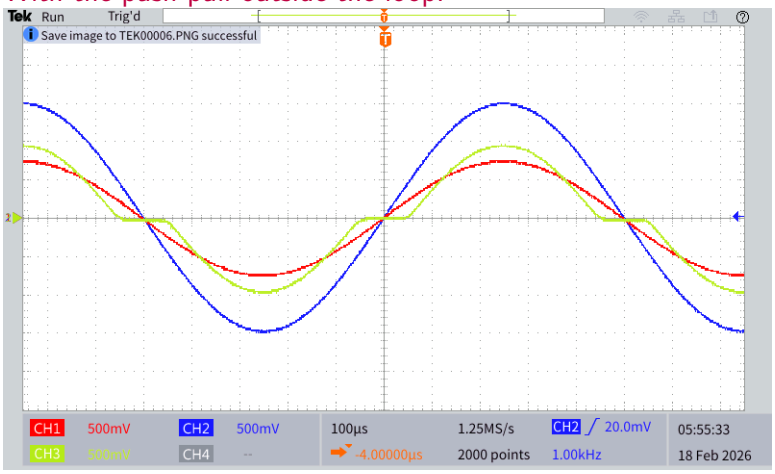
(b) What about when the push-pull is *inside* the loop?

When the push-pull is inside the feedback loop, the op amp outputs whatever it needs to in order to keep its two inputs at the same voltage. In this case, that means producing a sine wave at the point labeled CH3 (and then that sine wave is divided down by the 10k/10k divider, and appears at the inverting input). In order to get an undistorted sine wave *out* of the push-pull, the op amp output has to overshoot by 0.6 V in both directions. So the waveform at the op amp output is a sine wave plus 0.6 V (when positive) and -0.6 V (when negative). Essentially, this is the inverse of the function that the push-pull applied to the waveform! The push-pull subtracts voltage, so the op amp had to add voltage to compensate.

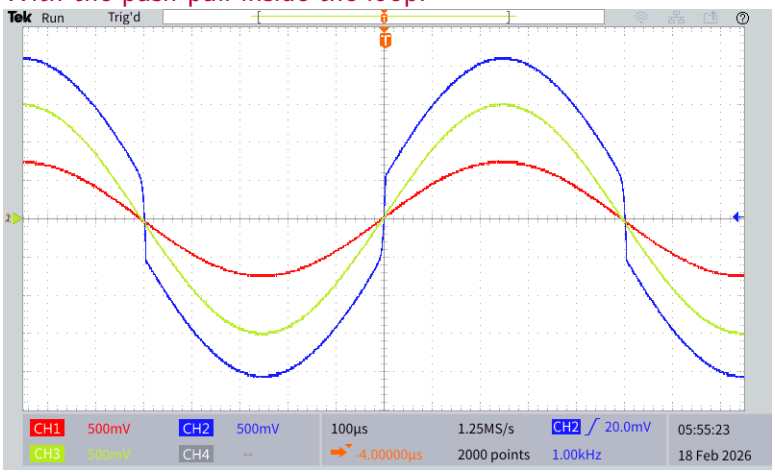
[1] There is an SPDT switch on your protoboard, or you can use a separate one that you plug into the breadboard.

(c) Wire up the circuit of Figure 2. Then drive it with a 3 Vpp sinewave from the Siglent func gen, choosing the frequency to be 1 kHz, or your favorite musical note (261.6 Hz for middle C, perhaps, or 440 Hz for A_4). Use the SPDT slide switch to select which signal is used as feedback. Probe the three nodes as shown. Be amazed! Sketch the waveforms you see when the push-pull is inside the feedback loop, and explain how the op amp eliminates the crossover distortion.

With the push-pull outside the loop:



With the push-pull inside the loop:



Time Permitting: Current source

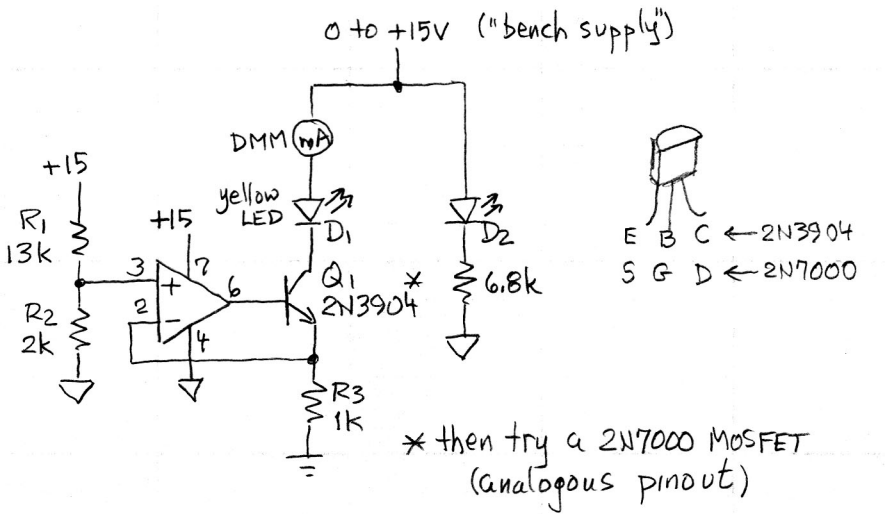


Figure 3: A very cool circuit!

(a) Rig up the circuit of Figure 3. **NOTE: for this circuit the op-amp is powered from +15V and ground (not −15V!)**; see if you can figure out why we did that. To explore its behavior over a range of load voltages, we use a separate "variable bench supply" to power the LED loads. We've included a second LED with a resistor, to let you see the comparison of constant-current versus variable-current (the 6.8k on D_2 sets the current about the same when the variable supply is set to +15V). What current do you expect to see on the DMM? And over what range of voltages?

(b) Vary the voltage on the bench supply and observe the two LEDs.

(c) What should be the voltage at the top of R_3? And at the base of Q_1? How is this circuit using feedback to provide a constant current?