1. Photodiode Amplifier

Construct the circuit shown in Fig. 1, a simple way to get the signal from a photodiode. Use a 10k resistor for \( R \). Determine which lead of the photodiode has to be connected to the positive voltage supply (if you connect it the wrong way no current will flow). Measure the voltage across the resistor with your X10 probe to verify the photodiode works. What makes the signal large, what makes it small? Roughly, what is the max output voltage?

![Fig. 1 – The basic photodetector circuit.](image1)

Now connect the photodiode to an op amp to amplify the signal, as shown in Fig. 2. Wire up a low pass filter to the output of the op amp. Pick the R and C of the filter to effectively attenuate 100 kHz signals. (There will be some high frequency noise on the signal that we’d like to eliminate).

Measure the DC value of \( V_{out} \)? How does it compare to the first circuit?

Let’s make the photodiode mobile. Use alligator leads to attach the photodiode to the circuit. Point the photodiode at the lights. What’s \( V_{out} \)? Is it a steady DC value or is there some ripple? To focus on the ripple, switch the input coupling on the probe channel to AC – this filters out the DC part. Now you can turn down the Volt/Div to magnify the signal. Also have your Time/Div knob set to 2 ms/Div. What is the amplitude of the AC signal? Roughly what frequency is it? What’s generating this signal?

Return the input coupling to DC and set the volts/Div to 0.5 and the time/Div to 0.5 ms. Zero the trace near the top of the screen. Test how the photodiode responds to different colors of light (use LEDs from around the room). Which generates a larger response?

Now hold the photodiode close to the screen of the oscilloscope and observe what happens. What’s going on? Describe it and sketch a few traces in your lab book. The oscilloscope is now part of the feedback of the op amp circuit.

![Fig. 2 – The op amp photodetector circuit.](image2)
2. Driving a speaker.

When building these circuits with a speaker, be sure to turn off the power on your protoboard while you build the circuits. Only after you have the circuit completely wired and checked should you turn on the power. This will protect the speaker (and also the op amp) from nasty signals.

Build a unity gain inverting op amp circuit with 1k input impedance. Attach a speaker to the output. Find the resistance and power rating of the speaker and record them in your lab book. (You could verify the resistance with the help of a DMM). Use the Function Generator to input a 0.5 V amplitude, 1 kHz signal. Monitor the input and the output voltage on the oscilloscope. Does the speaker work? Can you hear it? Play around with the frequency and the amplitude of the signal. Be careful not to increase the amplitude too much – you might destroy the speaker! At what input voltage does the output voltage begin to clip? How does this make the speaker sound? Are you surprised that the op amp is clipping at this voltage? Disconnect the speaker from the output and monitor the output voltage; does it still clip at the same input voltage level? What voltage can the output go to without the speaker connected? What do you think is going on here?

Now connect the output of the op amp to a transistor, as shown in Fig. 3. What kind of filter does the capacitor and resistor form, and what is $f_{3dB}$? At what voltage is the base of the transistor biased? Monitor the signal at the base and at the emitter. Again drive the circuit with an input signal with 0.5 V amplitude at 1 kHz. How does the loudness of the speaker now compare to the circuit with just the op amp? Play around with the amplitude (again being careful not to drive it too loudly) and see what it sounds like. Compare the waveforms to what you hear. What appears to be the advantage of adding the transistor?

Find a photoresistor from the rack of electronic components. Use a DMM to measure the resistance of the device as you cover and uncover it. What does a photoresistor do?
Replace the 1k resistor at the input to the op amp with the photoresistor. Now you can control the loudness with your hand!

3. Constant Current Source

Time to revisit the constant current source and see how an op-amp and negative feedback do a better job than the circuit with only a transistor that we built before. The circuit below is a typical design for a constant current source (note the PNP transistor). Build the following circuit and test how constant the current is as you vary $R_{\text{Load}}$ between 0k and 10k. To understand why the current source fails to provide a constant current, it may help to use an additional meter to test the voltage across the transistor: $V_{CE}$.

References

Significant parts of this lab, including diagrams, are taken from a lab written by John Essick of Reed College.

A diagram for this lab is taken from Hayes and Horowitz, Student Manual for the Art of Electronics, Cambridge University Press (1989).