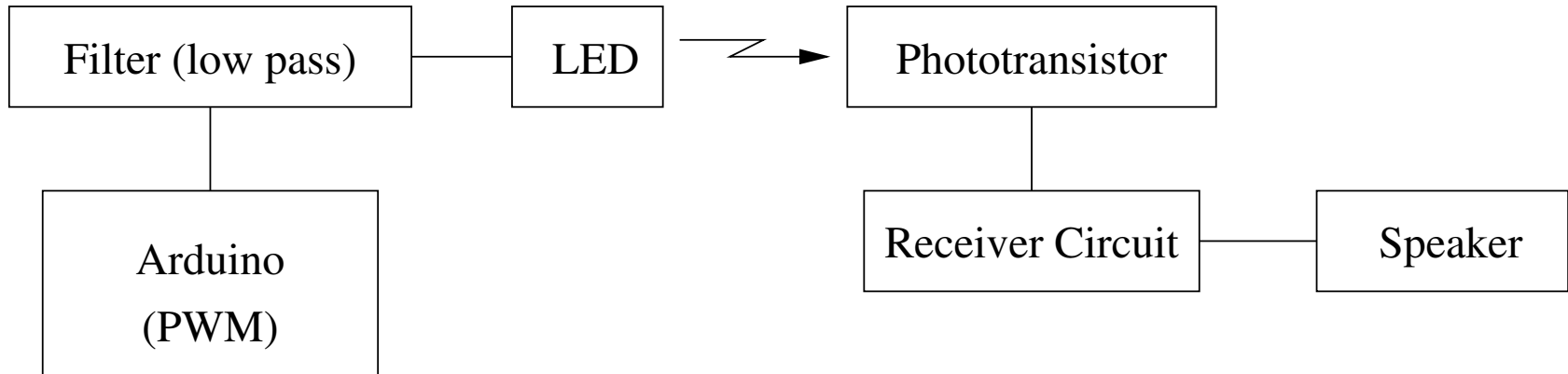


# Today's outline

- Project timeline
  - Laser show Thursday of next week: email a PPT slide to [kankel@solar.physics.montana.edu](mailto:kankel@solar.physics.montana.edu) by Wed.
  - Write-up due Friday of next week.
- Final exam details
  - Cumulative: All HW, lectures & labs are fair game
  - Review = next week's lecture
- Prep for **optional** lab: optical music link
  - Optoelectronics (LEDs, photodiodes, phototransistors)
  - Transmit and receive circuits
- No homework this week: project + practice final

# Thursday's Lab: Optical Music Link



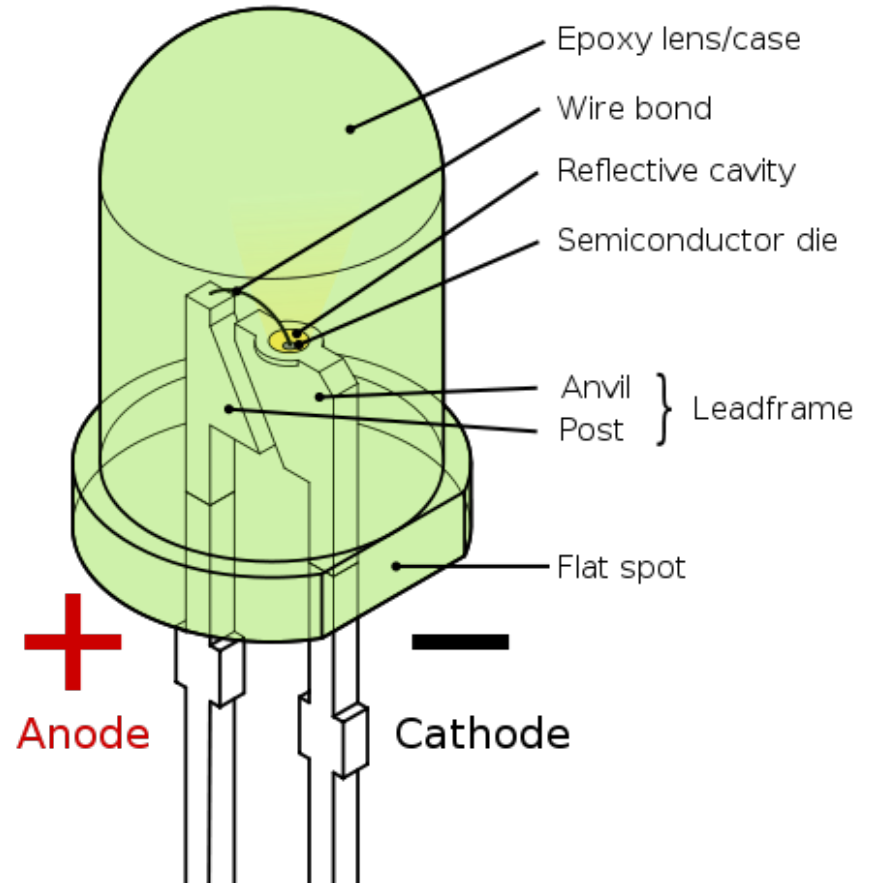
Your mission: Use the Laser Light Show circuit and Arduino to transmit an analog optical signal, receive with a phototransistor and drive a speaker.

- Use an Arduino music program for testing: simpleSine or pinkPanther.
- Figure out how to drive the LED from your laser show circuit.
- Design a receiver/amplifier to pick up the signal from the phototransistor and drive an 8-ohm speaker.

*This lab is optional. Alternatively, you may use the lab period to work on the project. If you complete the Optical Music Link lab, the score will be substituted for your lowest lab grade.*

# Optoelectronics: LEDs

- When LED is forward biased, electrons and holes meet and annihilate, producing photons.
- $E=hc/\lambda$ , approximately the bandgap energy.



# Optoelectronics: LEDs

Our LED for lab: **307P**  
*Spec sheet on course website.*

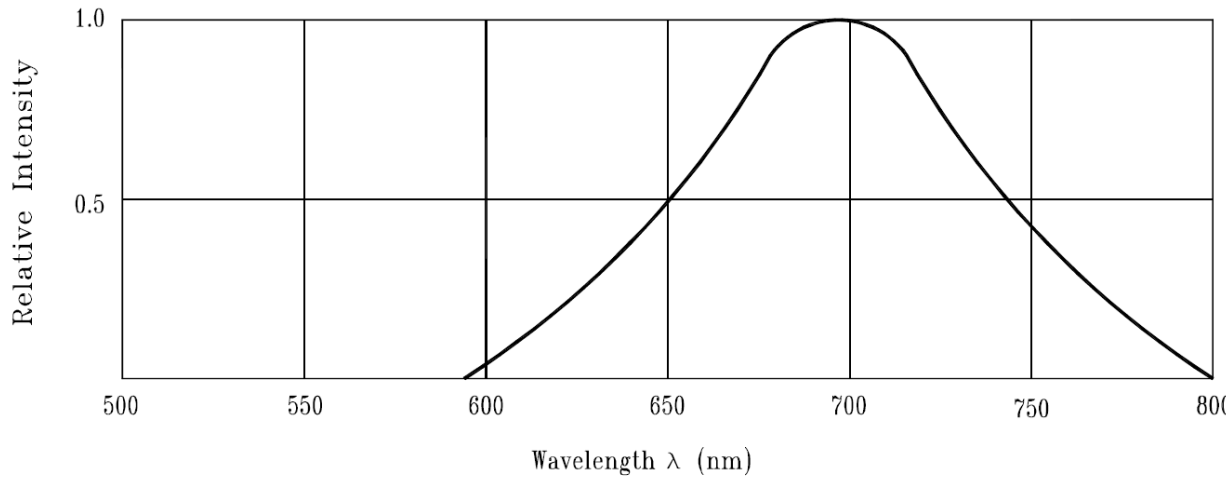
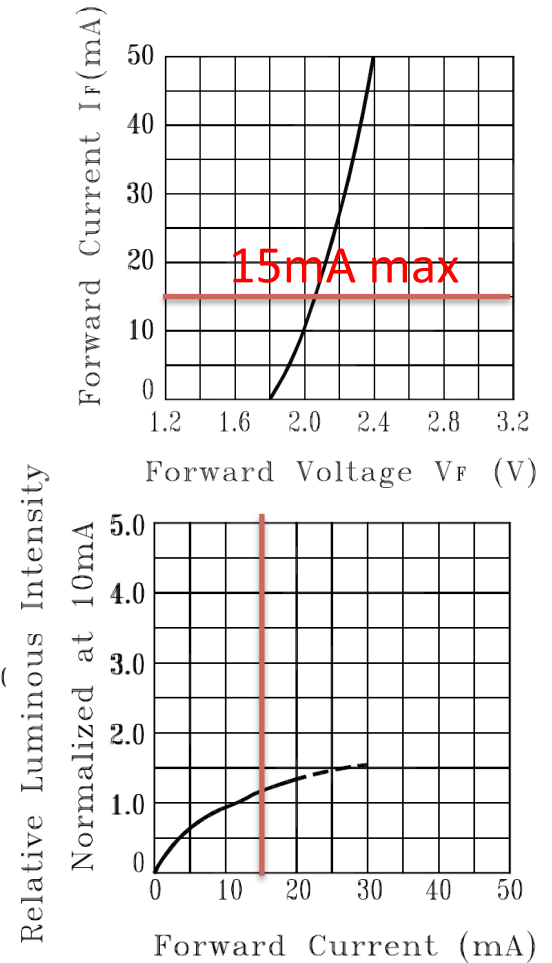
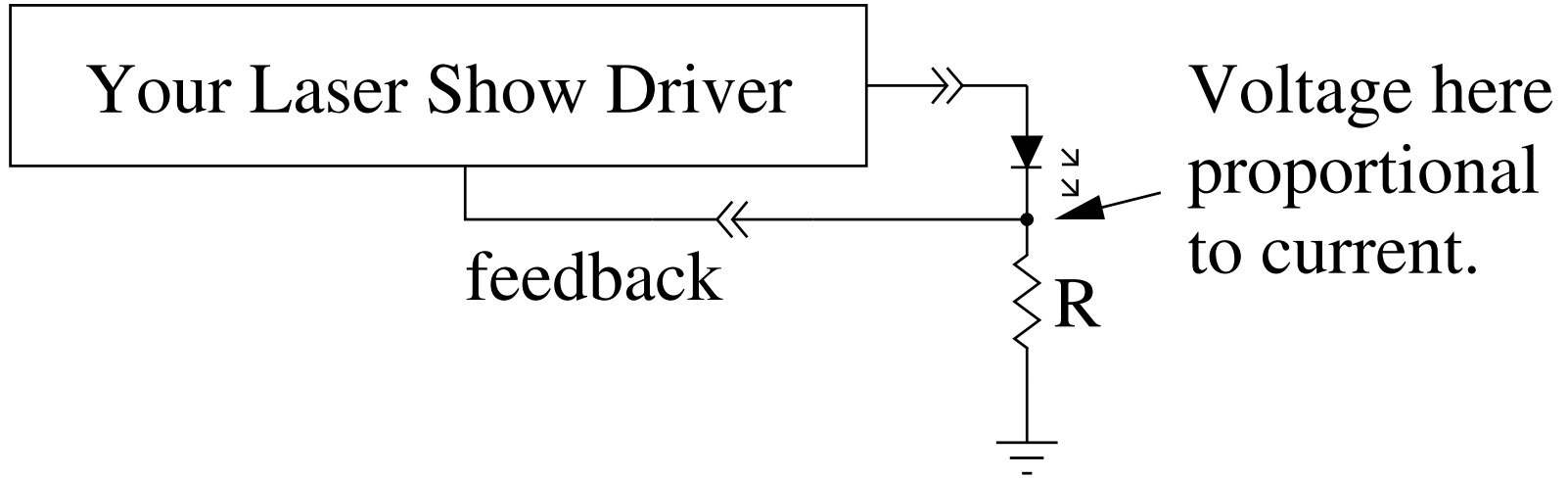


Fig.1 Relative Intensity vs. Wavelength



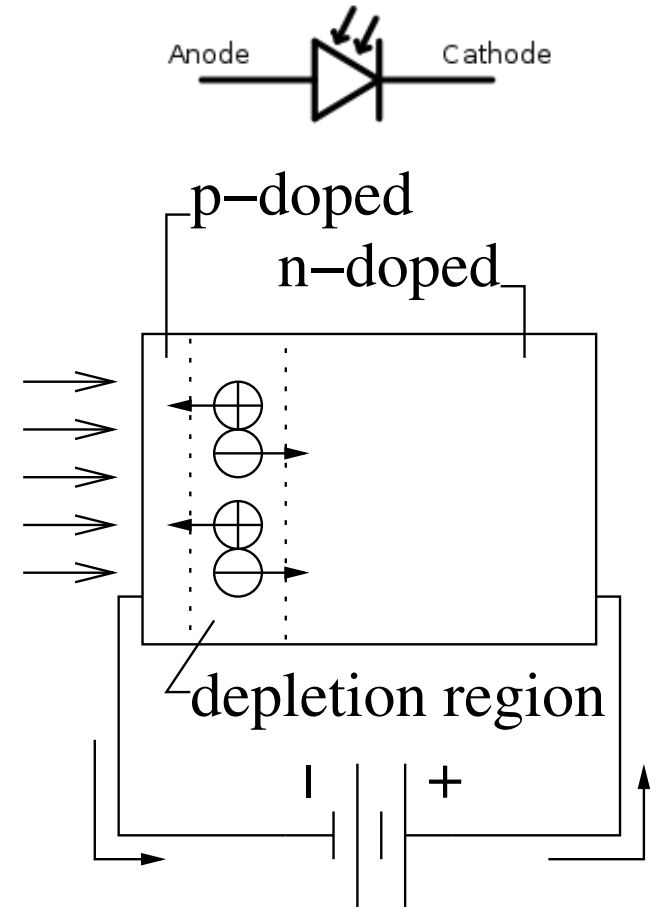
# Driving the LED



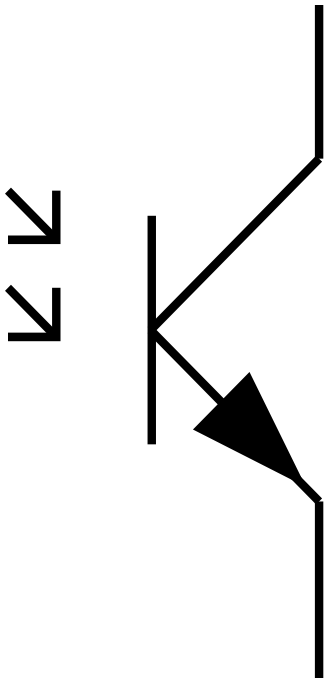
- Your circuits output  $-1V < V < +1V$ . *Where can you tap your circuit to get a positive output?*
- LED needs bias  $> 1.8V$  to conduct current.
- Want current  $< 15mA$ , and proportional to signal.
- *How will you select R?*

# Optoelectronics: Photodiodes

- LED can be used as a poor man's photodiode.
- Photoelectric effect: a photon in or near the junction is converted to electron-hole pair.
- Used with reverse bias ("photoconductive mode"), the electron-hole pair are swept apart by E-field in the depletion region.
- Photocurrent (electrons per second) equals number of photons converted per second.
- Can also be used unbiased ("photovoltaic mode").

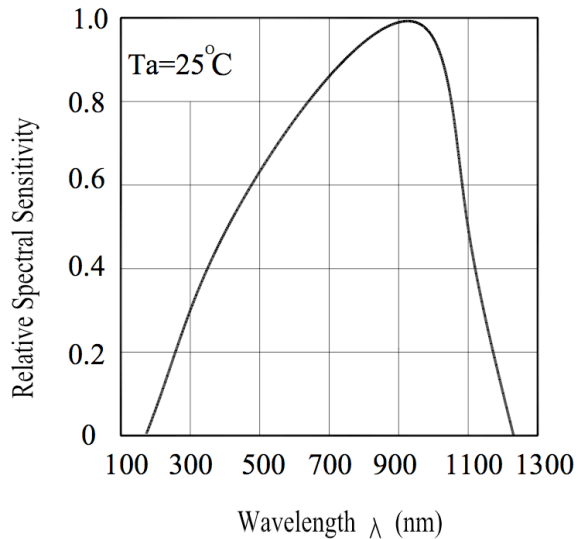


# Optoelectronics: Phototransistors

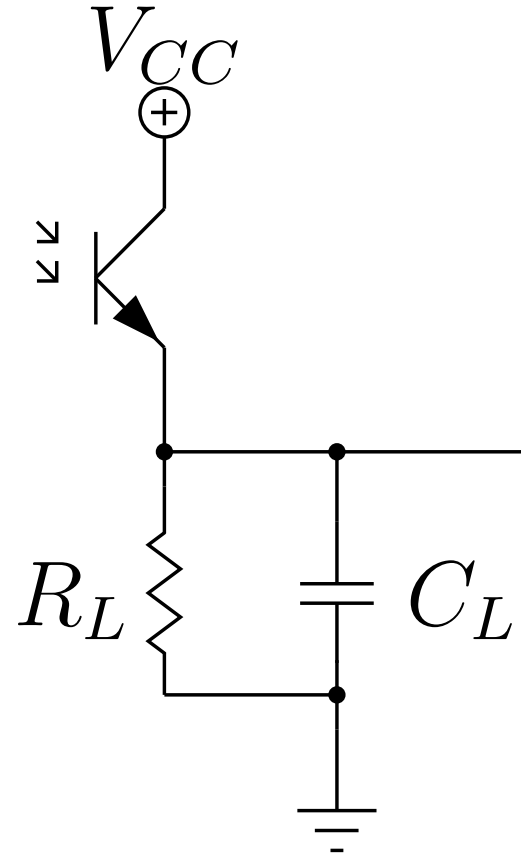


- A phototransistor is a BJT in which the base-collector junction is a PN photodiode.
- Photocurrent is  $I_B$ ;  $I_C = \beta I_B$ . In essence, then, there is some built-in amplification.

# Optoelectronics: Phototransistors



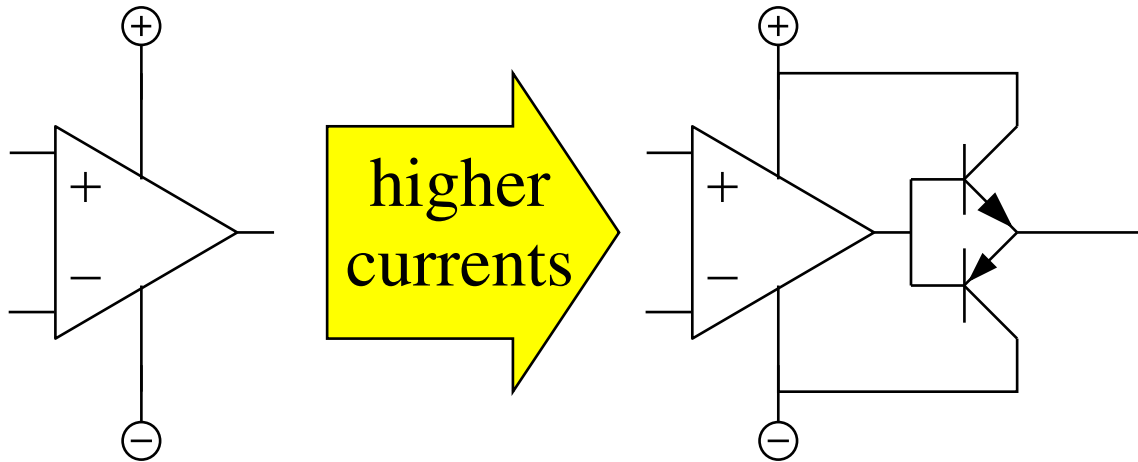
- Our phototransistor for lab: **PT204-6C**
- Converting photocurrent to voltage: How do we choose  $R_L$  and  $C_L$ ?
  - $I_C < 20\text{mA}$
  - $V_{out} < ??$
  - $RC = ??$





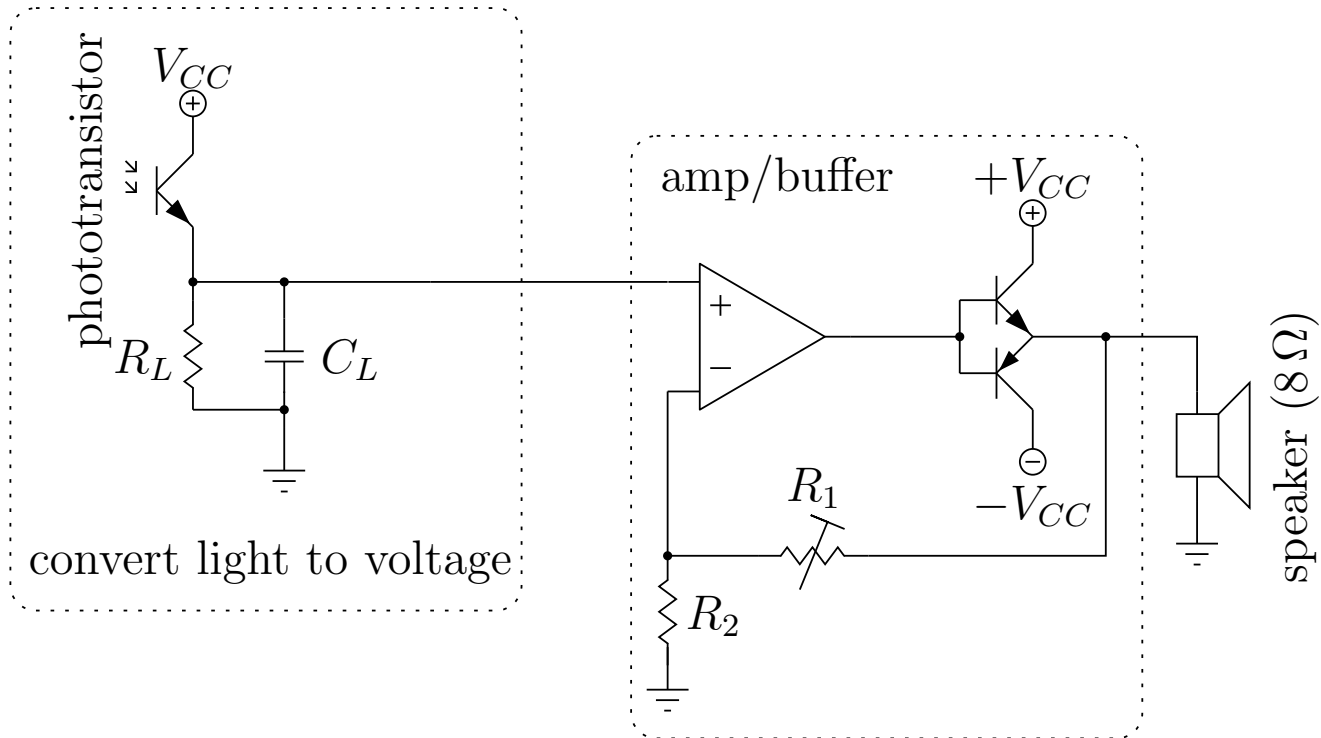
# How to drive speaker?

- An op amp would be convenient. If more current is needed to drive the speaker, add a push-pull.



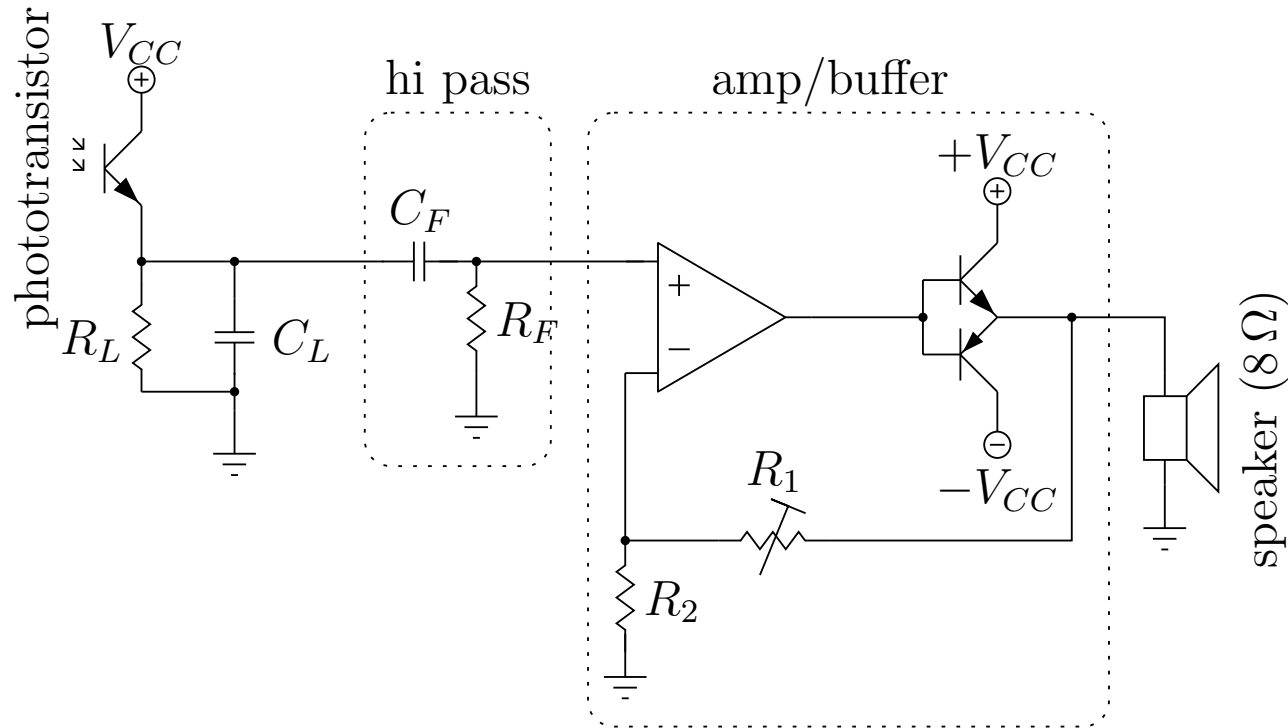
- Exercise: How would a Sallen-Key filter look if we replace the op amp with this?

# Receiver/Speaker Driver



- Why not use the pot for *both*  $R_1$  and  $R_2$ ?
- Want time-averaged voltage on speaker to be zero (why?)
- Suggestion: AC coupling

# Receiver (untested, YMMV)



- How would you size  $R_F$  and  $C_F$ ?