Hands-on Lab 5: Sensing Part 2

EECS 16B Fall 2022

Slides: links.eecs16b.org/lab5-slides-sp23

Administrivia

- **Continue working on the Midterm Lab report! It is due 3/10**
- The following week is a buffer week (lab makeups + lab report help) + study for midterm
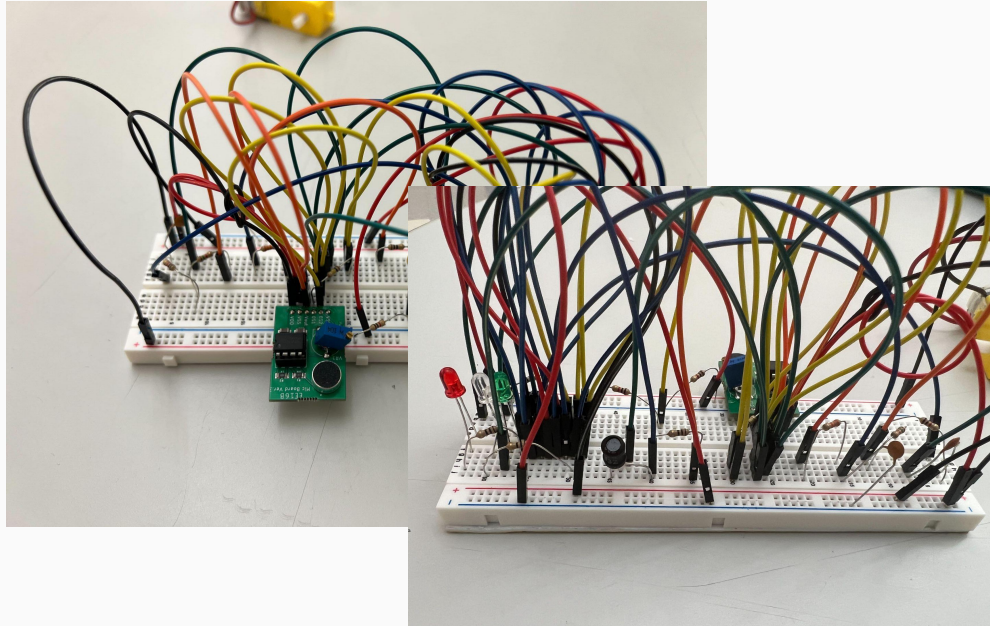
Lab 5 Overview

- Re-tune your mic board

- Implement the following:

  - High Pass Filter (HPF)

  - Notch Filter

  - Together we make a color organ!

- Build the **HPF** and **Notch** on some randomly empty space - will be discarded after lab, we recommend building on a **second breadboard,** there are large ones connected to the lab stations.
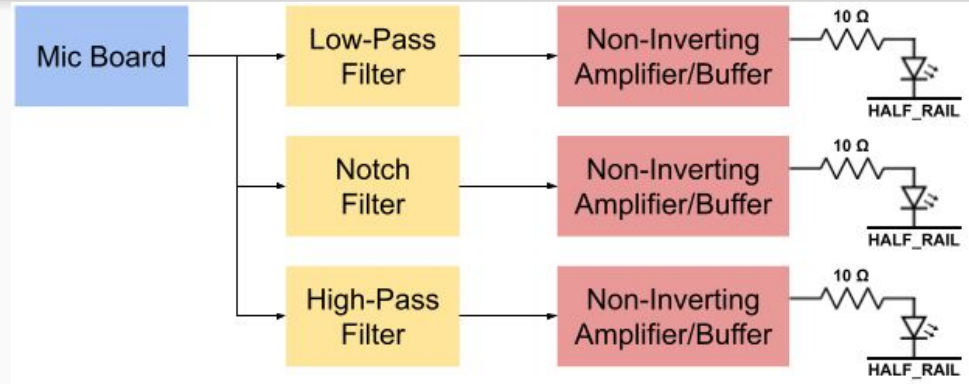
BREADBOARD LAYOUT
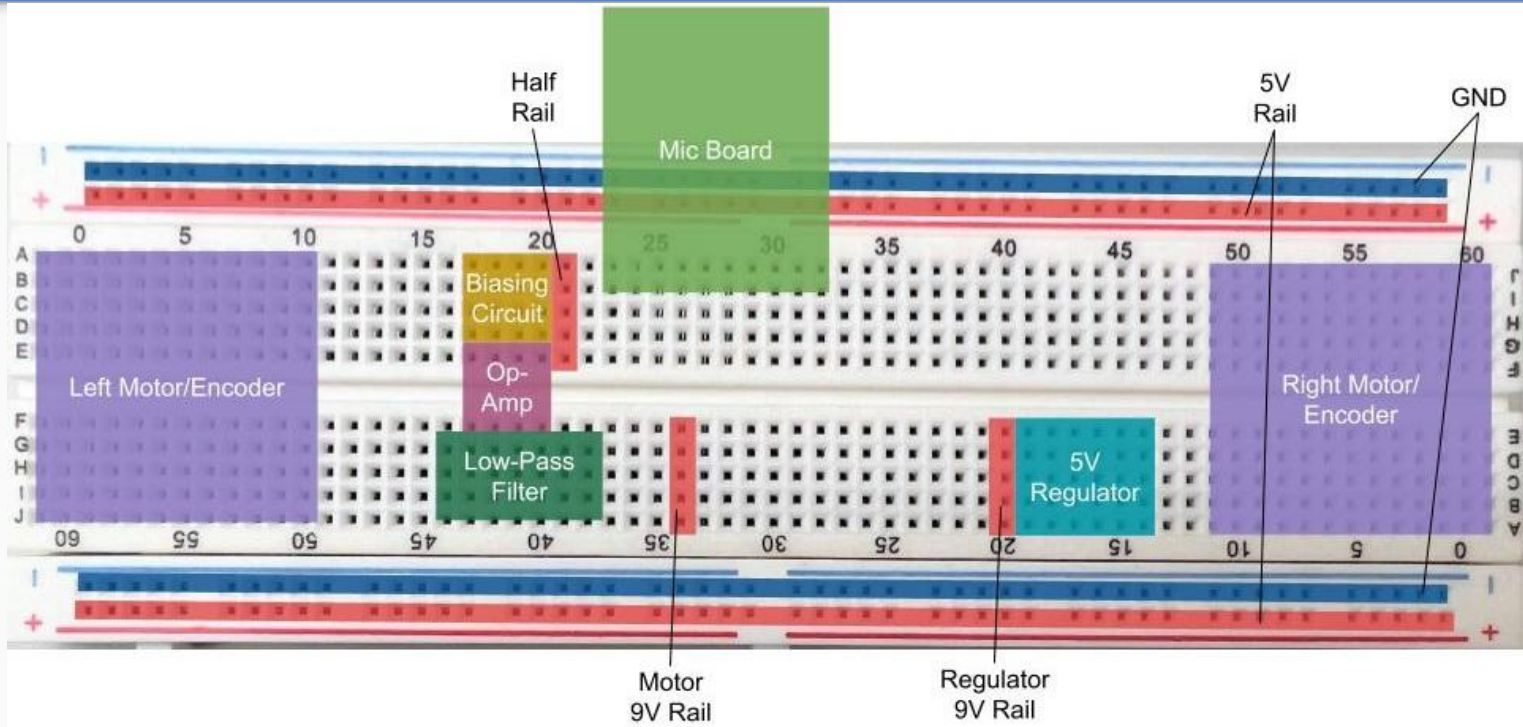
Breadboard No-No's

- **Messy Wiring,** and the use of excessive **Jumper Wires** make circuits exponentially more difficult to debug.
- As our breadboard circuits get more and more complex and large, we HIGHLY recommend students to clean up their breadboards (it makes both our lives easier), as there also may be no space for future circuits.

Filters

First Order Filters

- **Cutoff frequency** (f_c) is where signal has attenuated by 1/2 power (3dB)
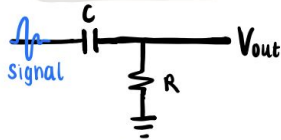- Recall:

$$P = IV = \frac{V^2}{R}$$

$$\frac{P}{2} = \frac{1}{2} \cdot \frac{V^2}{R} = \frac{1}{R}\left(\frac{V}{\sqrt{2}}\right)^2$$

- We can find the cutoff frequency by finding the frequency that causes the voltage to drop to $(1/\sqrt{2})V_0 \approx 0.707V_0$
- For RC circuits, the cutoff frequency is given by: $f_c = \dfrac{1}{2\pi RC}$ [Hz]
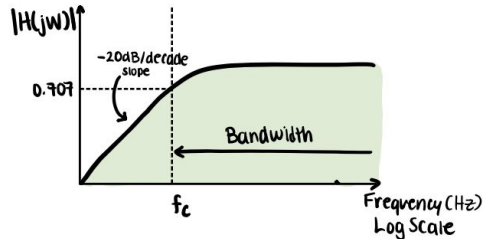
High-pass Filter Cutoff Derivation

High Pass Filter

Circuit Schematic

signal — C — V_{out}, R to ground

Think: the "gate" is <u>higher</u>.

High Pass Frequency Response

$|H(jw)|$ axis, $-20dB/decade$ slope, 0.707, Bandwidth, f_c, Frequency (Hz) Log Scale

$$\tilde{V}_{out} = \tilde{V}_{in} \cdot \frac{Z_R}{Z_R + Z_C} = \tilde{V}_{in} \frac{R}{\frac{1}{jwC} + R}$$

$$|H(jw)| = \frac{|\tilde{V}_{out}|}{|\tilde{V}_{in}|} = \frac{1}{\sqrt{2}} = \frac{\sqrt{R^2}}{\sqrt{\left(\frac{1}{wc}\right)^2 + R^2}}$$

$$\frac{1}{2} = \frac{R^2}{\left(\frac{1}{wc}\right)^2 + R^2}$$
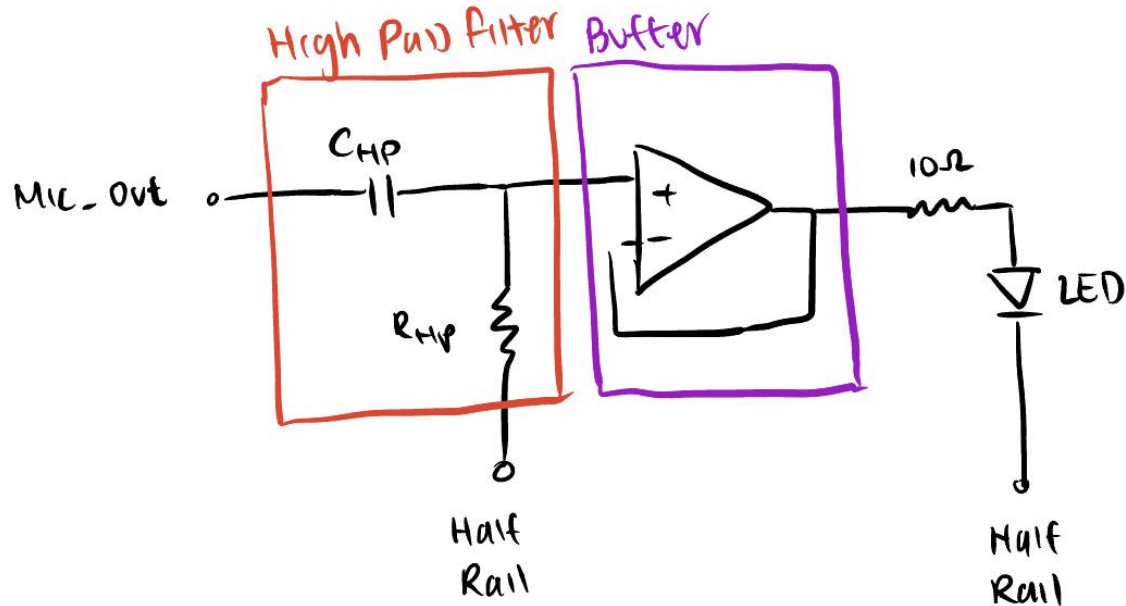
$$\left(\frac{1}{wc}\right)^2 + R^2 = 2R^2$$

$$\left(\frac{1}{wc}\right)^2 = R^2$$

Conceptually: as $w \to \infty$, $|H(jw)| \to 1$
as $w \to 0$, $|H(jw)| \to 0$

$$w = \frac{1}{RC} \quad \text{angular cutoff frequency}$$

$$f_c = \frac{1}{2\pi RC} \quad \text{cutoff frequency}$$

Color Organ High Pass Filter

Notch Filters (make sure to return inductor)

- **Notch Frequency**: The only frequency where the signal gets attenuated **OR** the only frequency where the signal passes through (depends on your filter implementation!)
- **Q factor**: The quality of the filter (is there a steep attenuation slope?), a higher Q factor -> higher quality filter

Notch Frequency: $w = \sqrt{1/(LC)}$, $f = w/(2*pi)$, we will be using f, rather than w !!

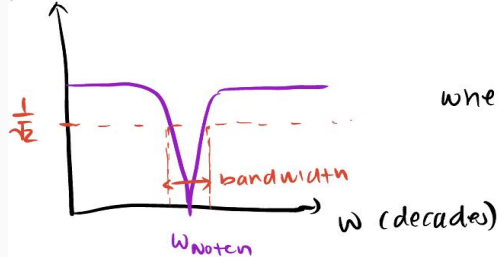Q Factor (only for RLC in series) = wL/R (w = Notch frequency)

Notch Frequency Derivation
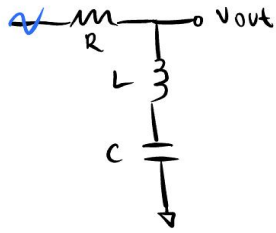
Color Organ Notch Filter
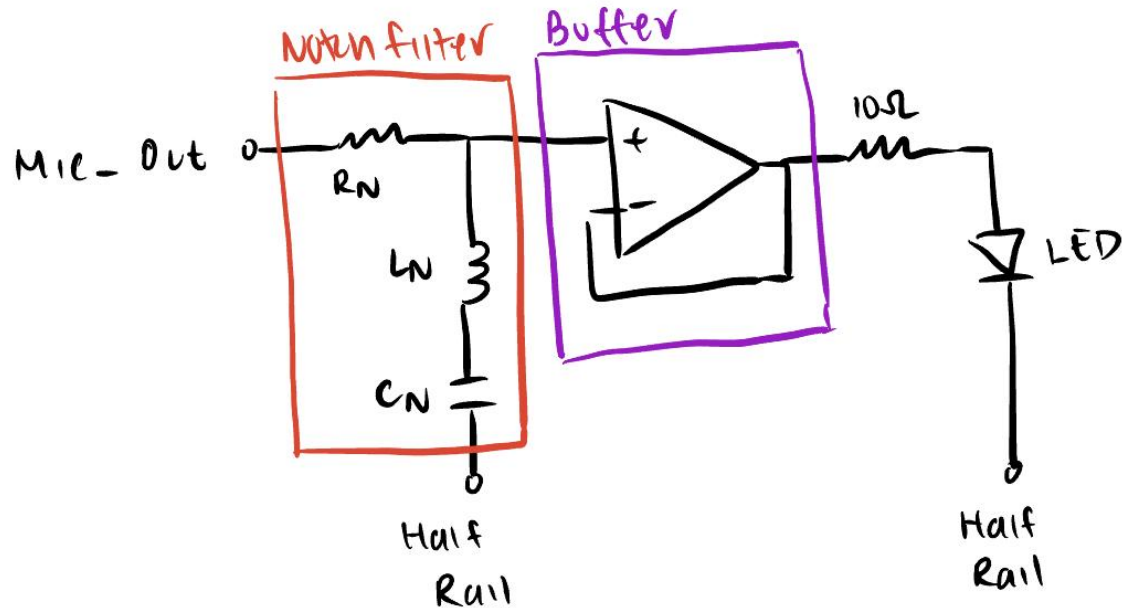
Debugging: Why aren't my LEDs lighting up?

- Make sure your filter(s) indeed does work using the function generator (sweep a range of frequencies, ones that should be attenuated, and ones that should pass through).
- Increase the gain of your system!
- You can start by increasing the gain of your micboard by tuning the potentiometer (CCW for increasing gain).
- If your LED lights up after adjustment, tune your micboard back to normal, and use this gain to build a non-inverting amplifier at the output of your filter!

*Buffer can be swapped for non-inverting amplifier!

filter_out

R_1

R_2

Half
Rail
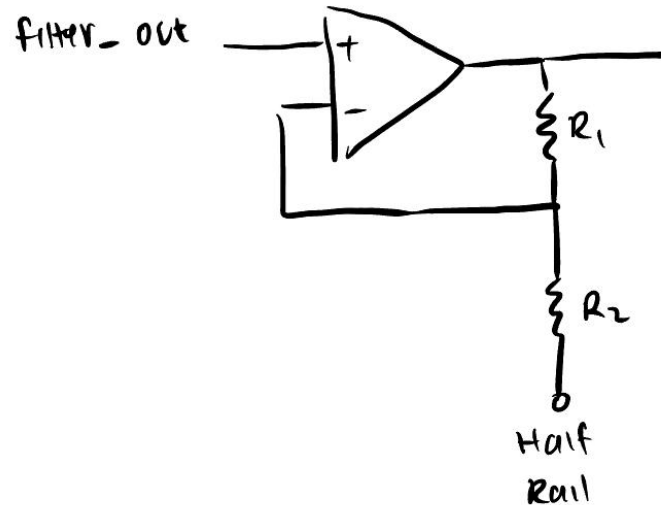
$$Gain = 1 + \frac{R_1}{R_2}$$

*Choose reasonable ($1k\Omega$ >)
values for R_1, R_2.

Review: Mic Board Schematic
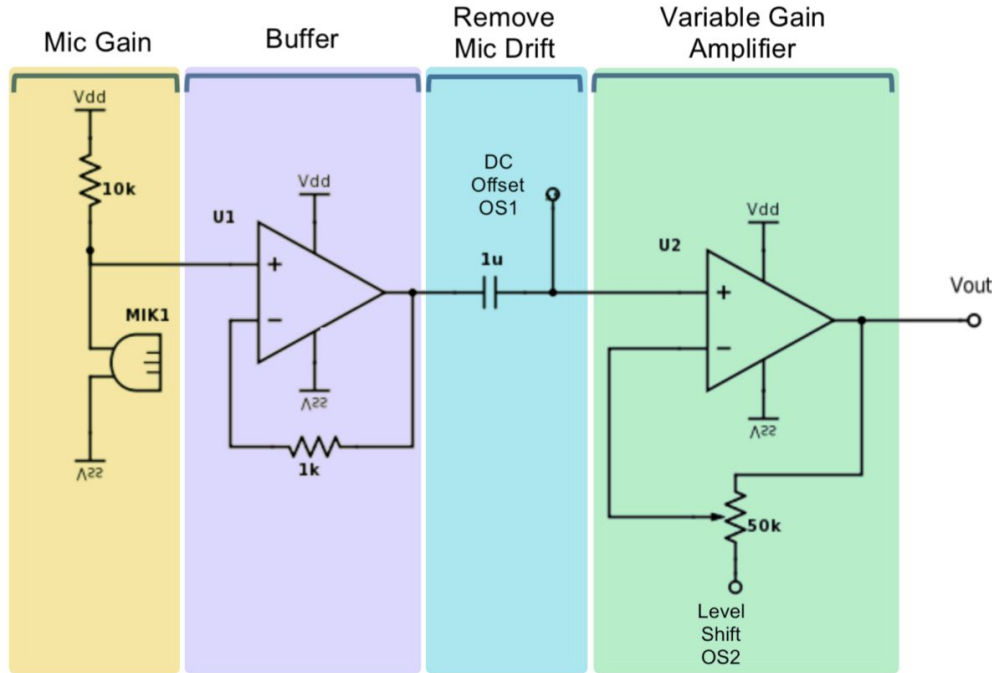
1. **Mic Gain**
   - Mic is a variable current source,
   - Convert it to a voltage signal
2. **Buffer**
   - Prevent Loading
3. **Removing Mic Drift**
   - The 1μF capacitor is a *coupling capacitor*, meaning it serves as a short to AC voltage but blocks DC voltage
   - **OS1** - centers signal at 1.65V. Connected through a 100kΩ resistor, since OS1's voltage isn't equal to our signal.
   - **NEW: This creates a high pass filter, but its cutoff frequency is 1.59Hz, so nearly all the signal passes**
4. **Non-inverting amplifier**
   - Uses a potentiometer for variable gain
   - **OS2** - serves as a virtual ground so we don't amplify the 1.65V offset

Important Forms/Links

- Help request form: https://eecs16b.org/lab-help
- Checkoff request form: https://eecs16b.org/lab-checkoff
- Extension Requests: https://eecs16b.org/extensions
- Makeup Lab: https://makeup.eecs16b.org
- Slides: links.eecs16b.org/lab5-slides-sp23
- Anon Feedback: https://eecs16b.org/lab-anon-feedback
- Lab Grades error: https://links.eecs16b.org/lab-checkoff-error