Audio Filters

What you will do

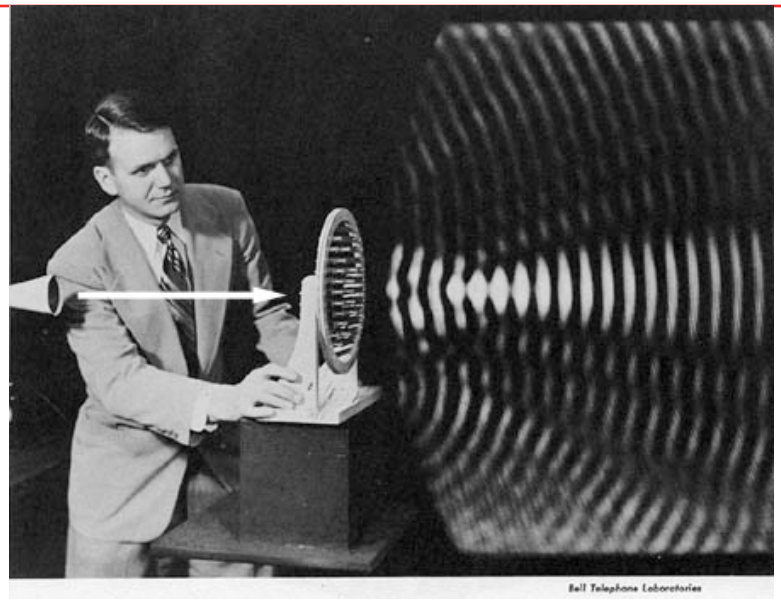
- Build a 3-band equalizer
  - Low pass filter
  - High pass filter
  - Band pass filter
- Connect to a music source (mp3 player)
  - Adjust the strength of low, high, and middle frequencies
  - Play result through a speaker

Gameplane

- Review sound waves and frequency
- Learn to read an electrical schematic
- Build the circuit

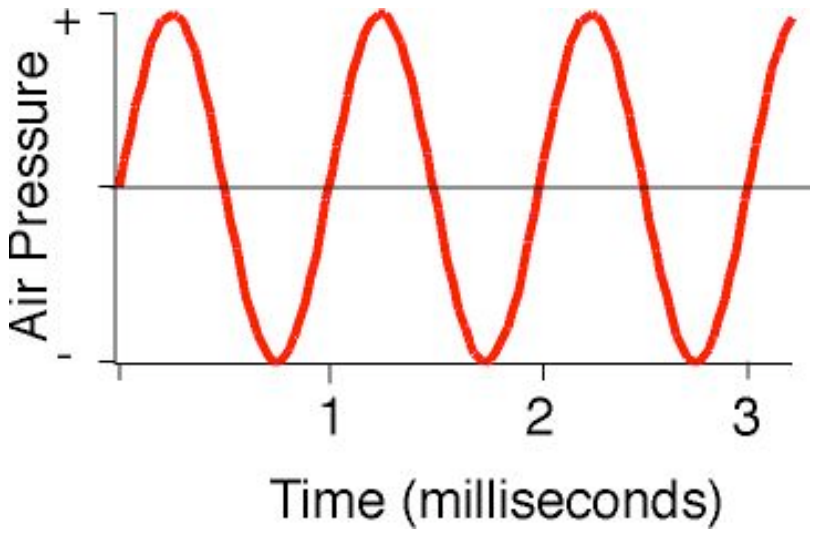
Sound waves

- Compressional waves
- Air density increases and decreases periodically
  - These waves hit tiny hairs in your ear
  - When they wiggle your nerves feel it
  - Brain understands it's sound



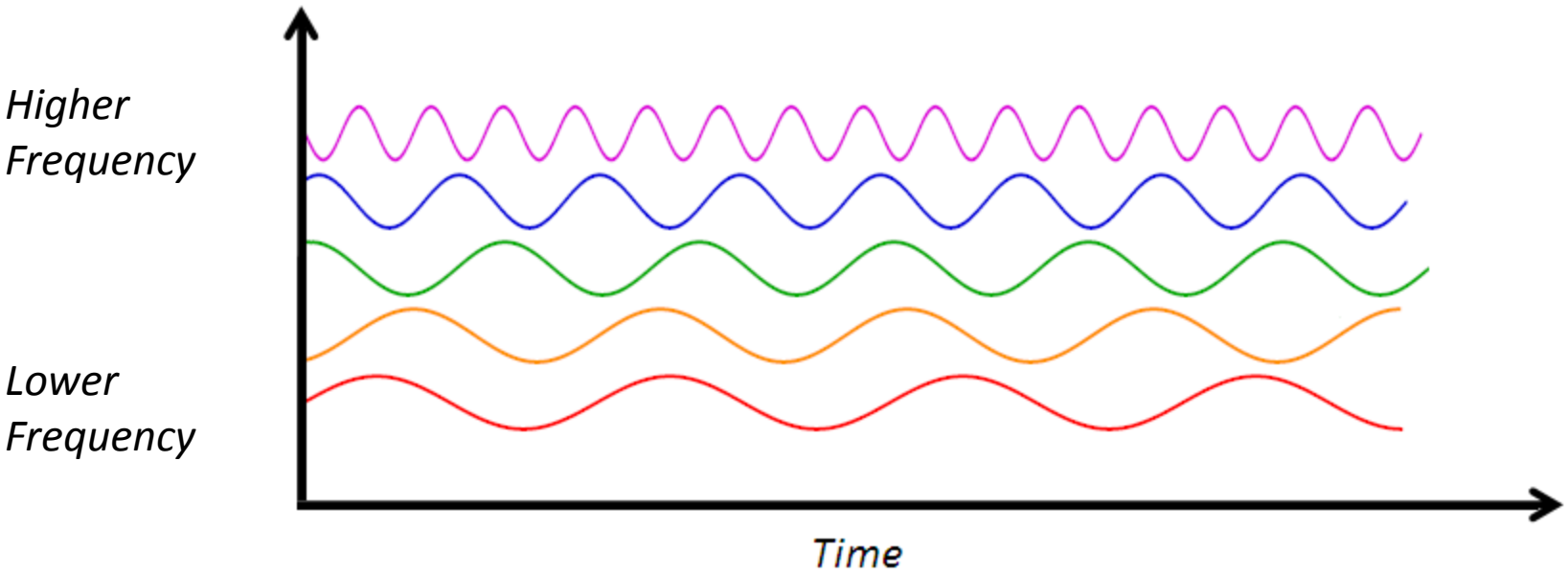
http://www.privateline.com/TelephoneHistory/speech.jpg

Waves: periodic



- Frequency is 1 cycle per millisecond
  - 1000 cycles/sec (1 kHz)
- This one is a sine wave
- Sine wave=Pure tone

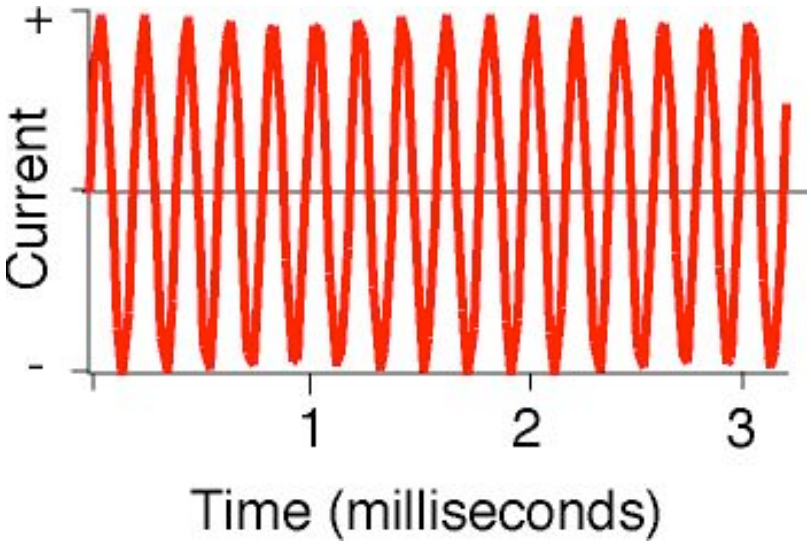
Frequency relates to pitch



P. Lundstrom, ECE 682 student presentation, Autumn 2008.

Electronic version

- Current is proportional to sound pressure
- What is the frequency of this wave?
- Will it sound higher pitched or lower pitched (when played through a speaker)?

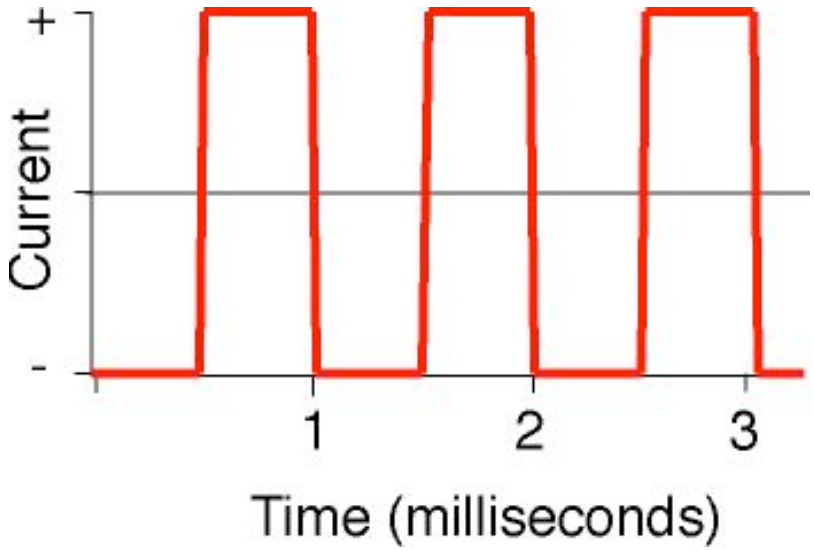


The audible range

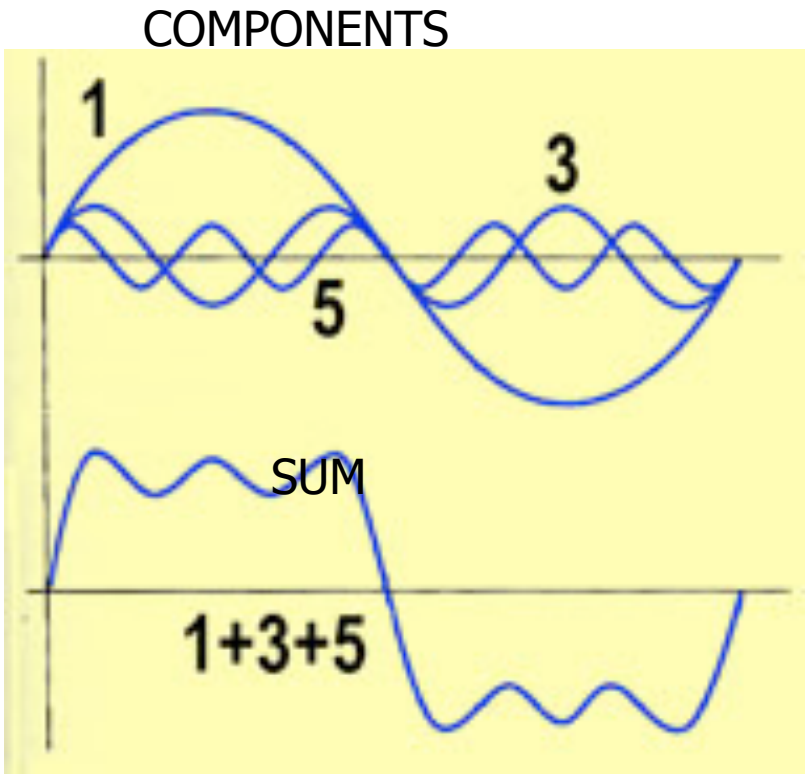
- The audible range for humans is approximately 20 Hz to 20 kHz (20,000 Hz).
- The lowest note on a piano, A0, has a frequency of 27.5 Hz.
- The highest note on a piano, C8, has a frequency of 4.186 kHz (4186 Hz).

Square wave

- What is the frequency?
- Will it sound higher or lower than 1 kHz sine wave?



Square wave contains many frequencies

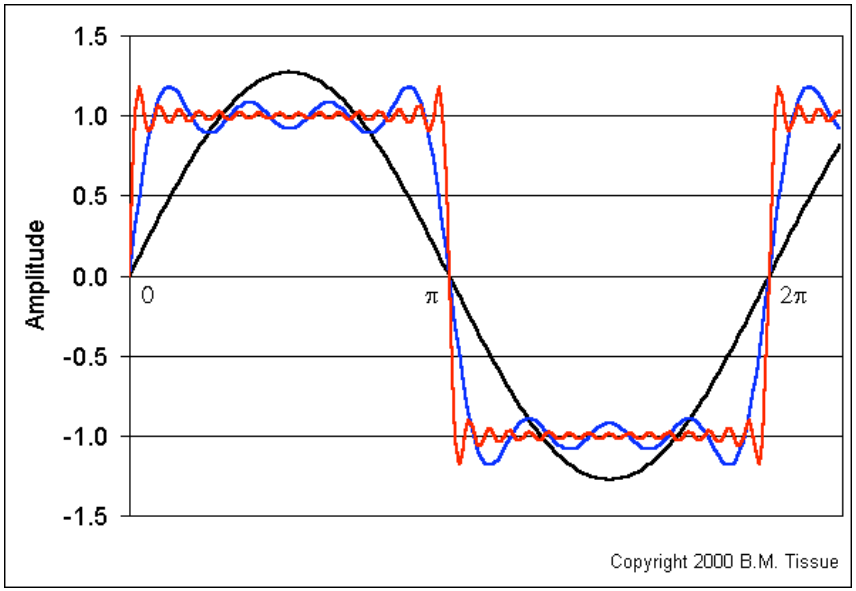


http://sirius.ucsc.edu/demoweb/images/waves/sound/fourier%20analysis_schem.jpg

- Here are three frequencies
- As you add more, looks more like a square wave

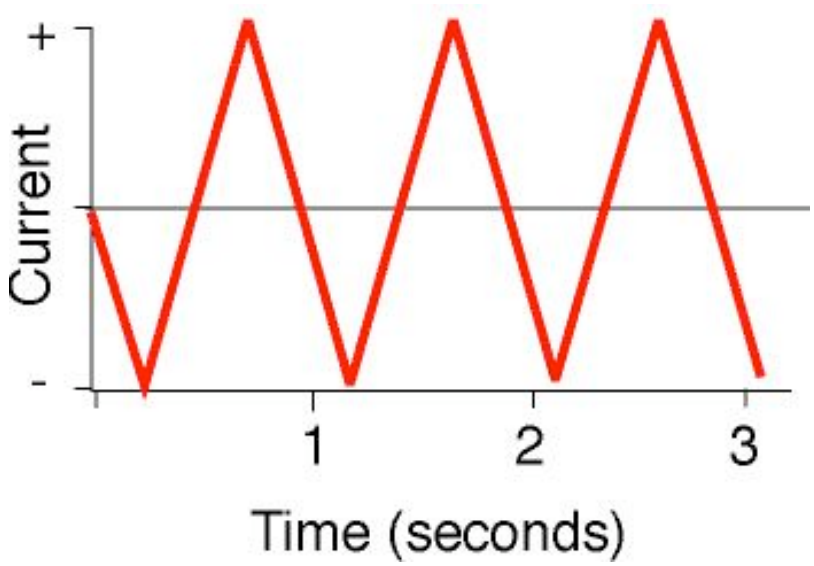
Sounds like?

- Pitch is that of fundamental frequency
- Timbre (character) of tone is different than pure tone (sine wave)

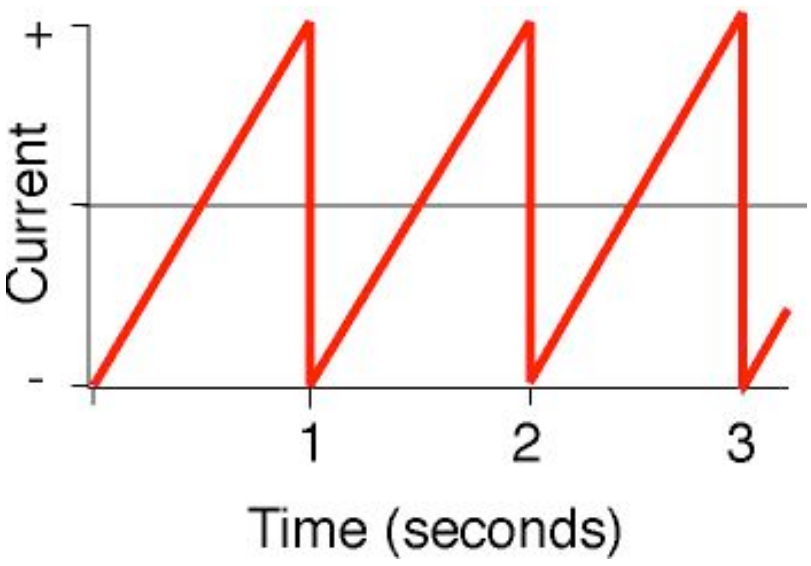


www.chemicool.com/img1/ graphics/fourier-waves.gif

Other waveforms

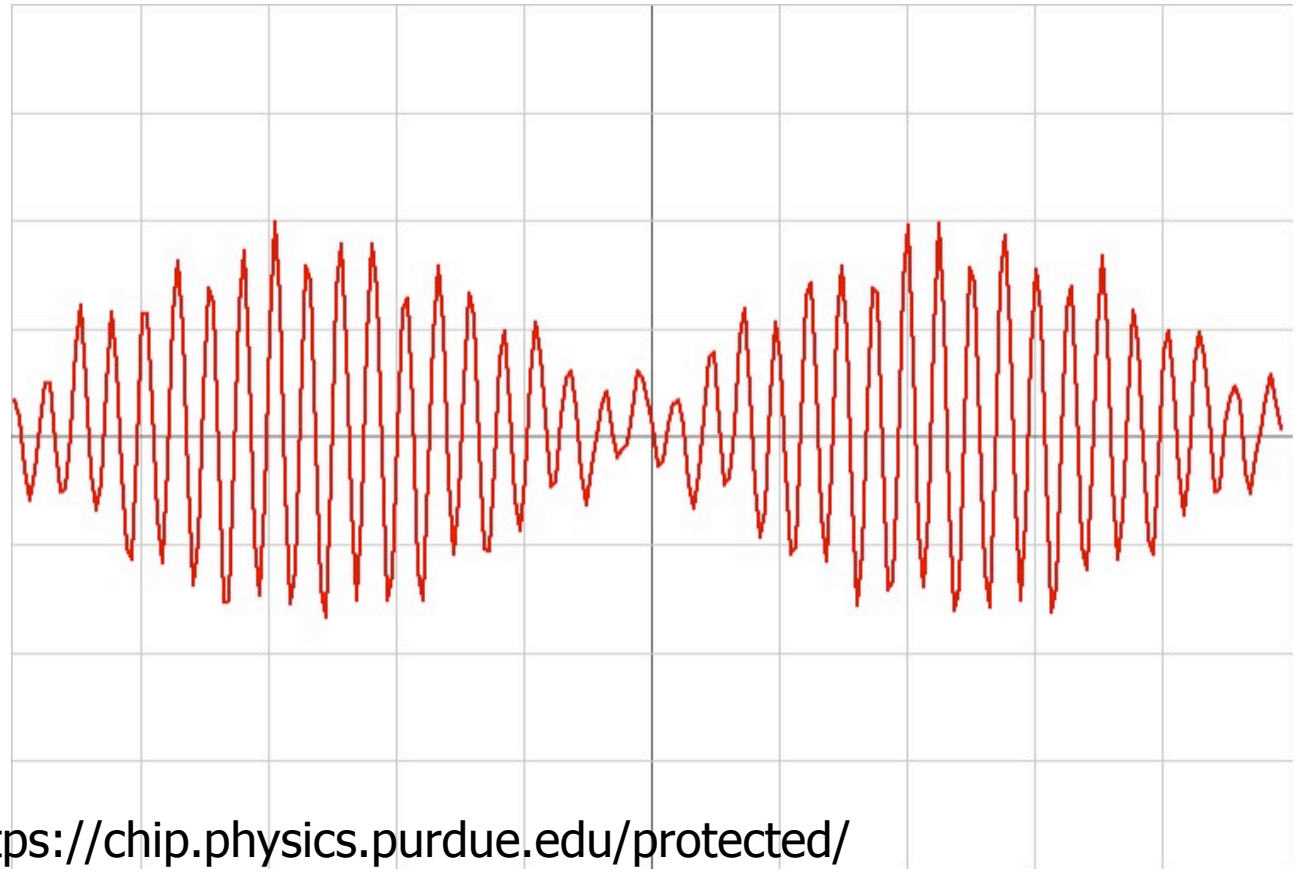


TRIANGLE WAVE



SAWTOOTH WAVE

What would this sound like?

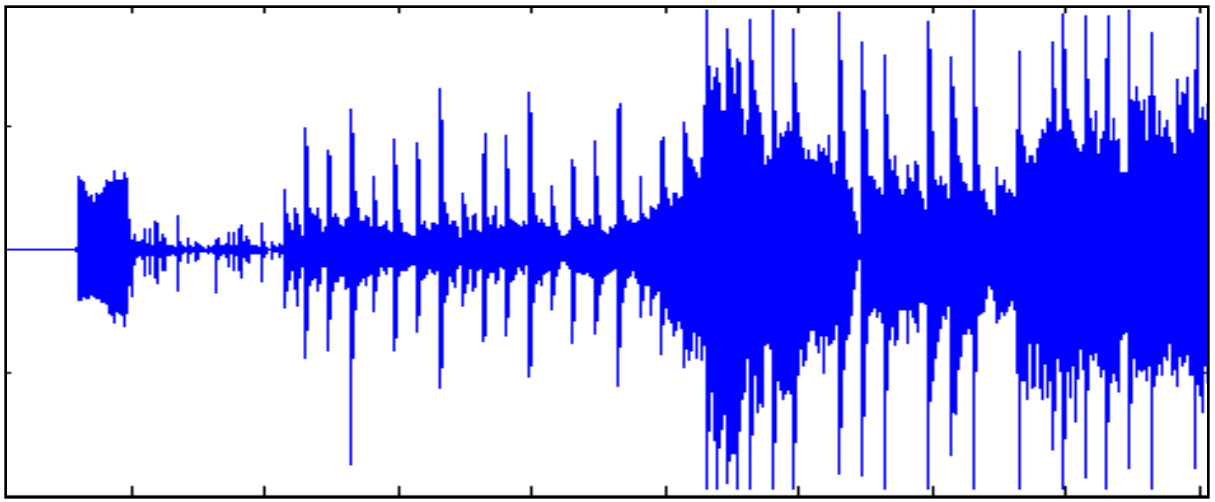


https://chip.physics.purdue.edu/protected/Prelab220newimg/m10q3beats.jpg

Sound consists of:

- Pitch
- Timbre
- Volume
- And all of this varies with time
- Music is a wildly complex combination of frequencies

output of a .wav file



P. Lundstrom, ECE 682 student presentation, Autumn 2008.

Audio equalizer

- Lets you attenuate some frequencies
- Boost others
- This one is a 20-band equalizer
- We'll build a three-band equalizer

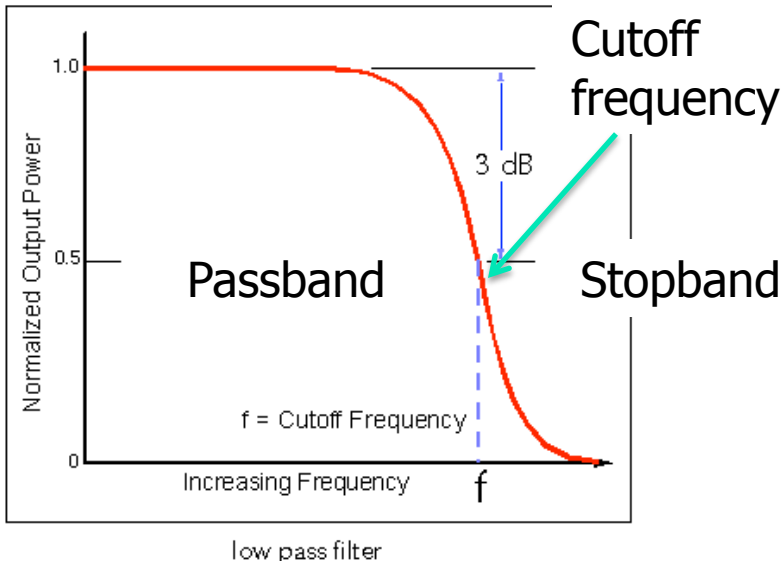
http://www.smeter.net/slc/info/equalization.php

Electronic Filters

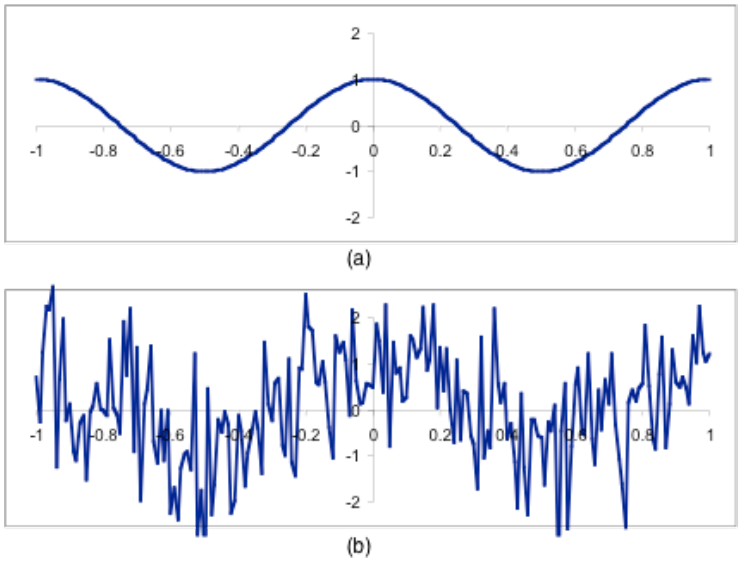
- Filter – A circuit or device that passes certain frequencies and blocks others.
- Pass Band – The range of frequencies that are allowed to pass through the filter.
- Stop Band – The range of frequencies that are stopped by the filter.

Low Band – Low Pass Filter

- A low pass filter passes all frequencies lower than a cutoff frequency and stops all frequencies higher.

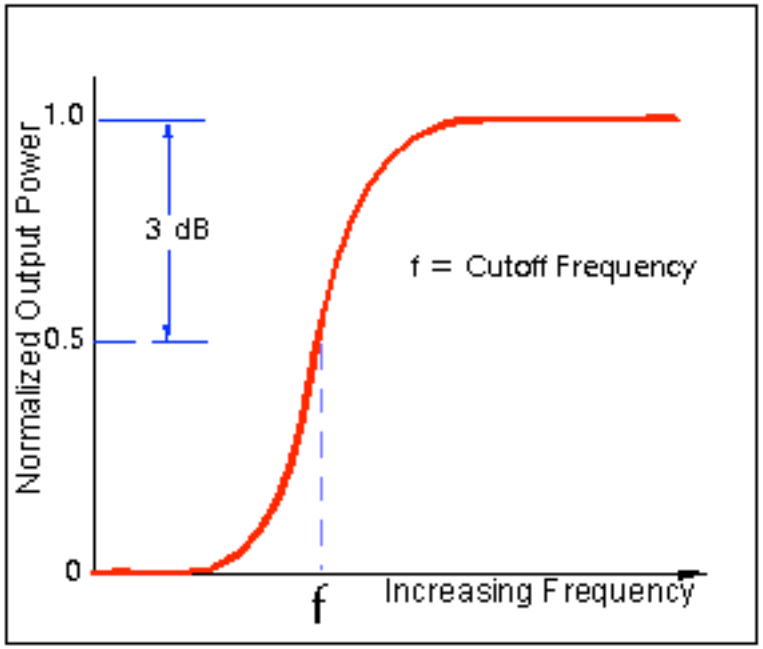


http://www.its.bldrdoc.gov/projects/devglossary/images/lpfiltec.gif

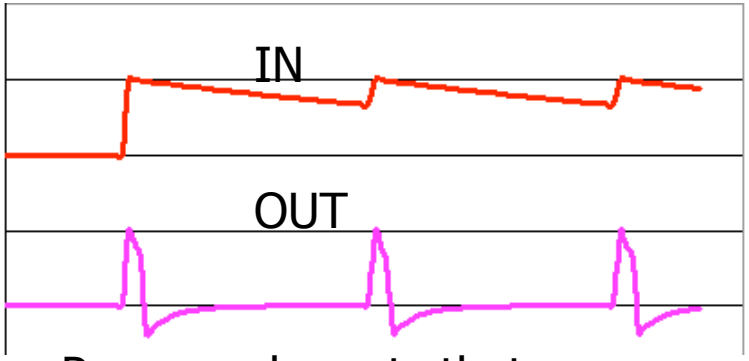


Audio Input
20Hz – 20kHz

High-pass filter



high-pass filter

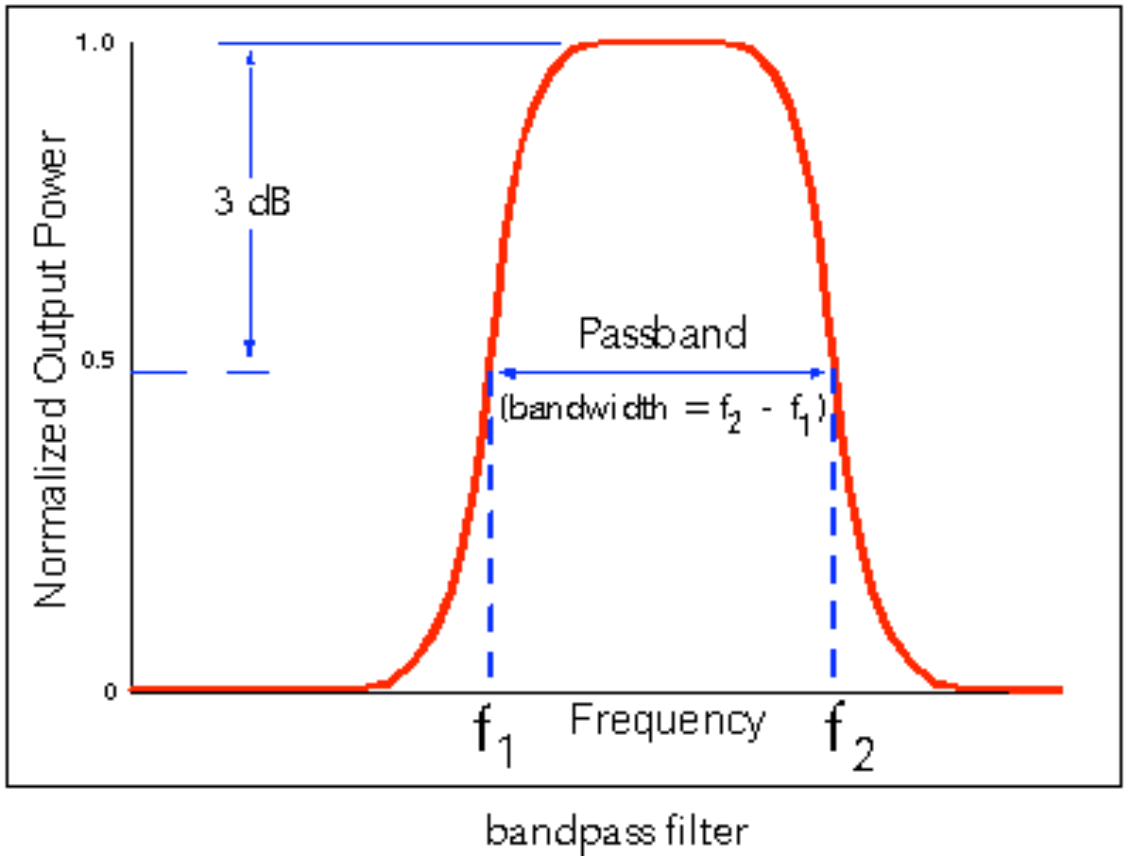


Passes only parts that are changing rapidly

http://www.its.bldrdoc.gov/projects/devglossary/images/hpfiltec.gif

http://homepages.which.net/~paul.hills/Circuits/Failsafe/DetectorTiming.png

Passband



http://www.atis.org/glossary/images/pbfiltec.gif

READING SCHEMATICS

Electrical schematics

- Shows how components are connected
  - Not how they're arranged physically
- Once you can read one, you can wire up any circuit
  - Even if you don't know what it does or how it works

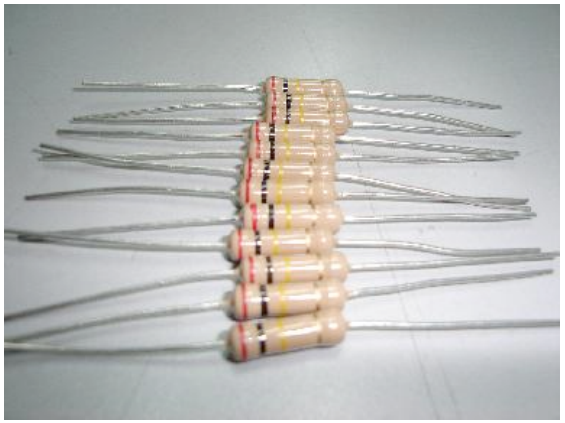
What's this?

AC signal source

How about this?

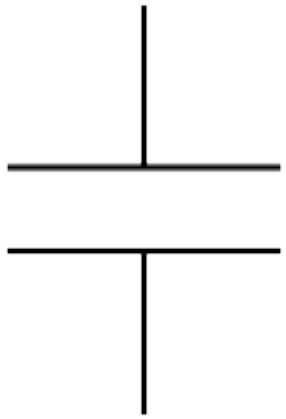
- Resistor
- "Resists" electricity
- Why?

- Lets you control how much current flows
- Protect components



And this?

- Capacitor
- Stops DC, passes AC
- The lower the frequency, the less it passes
- We'll use it in our filters

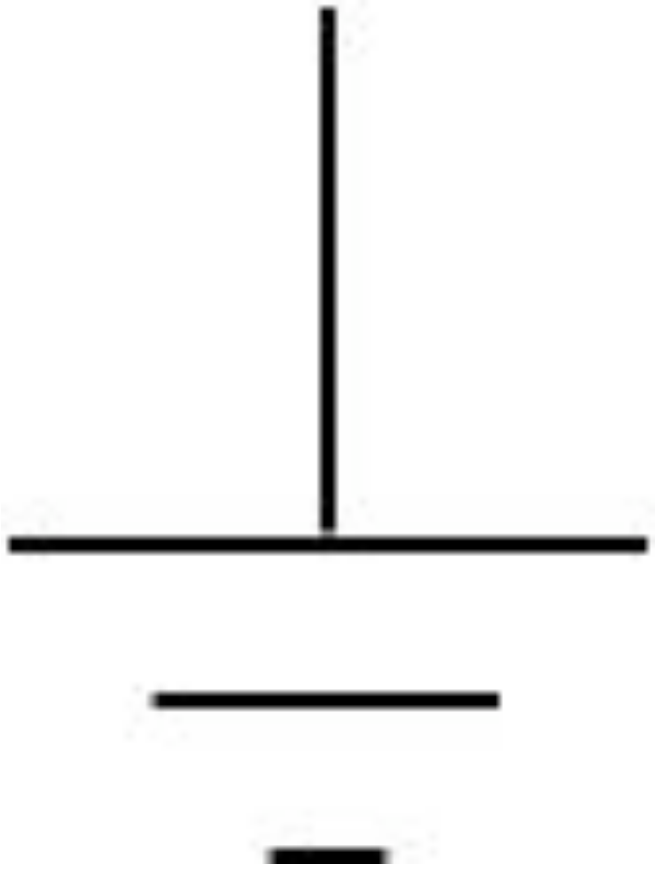


What's this one?

- Inductor
- Passes low frequencies, stop high frequencies
- We could use them…
- But hardly anyone uses inductors anymore

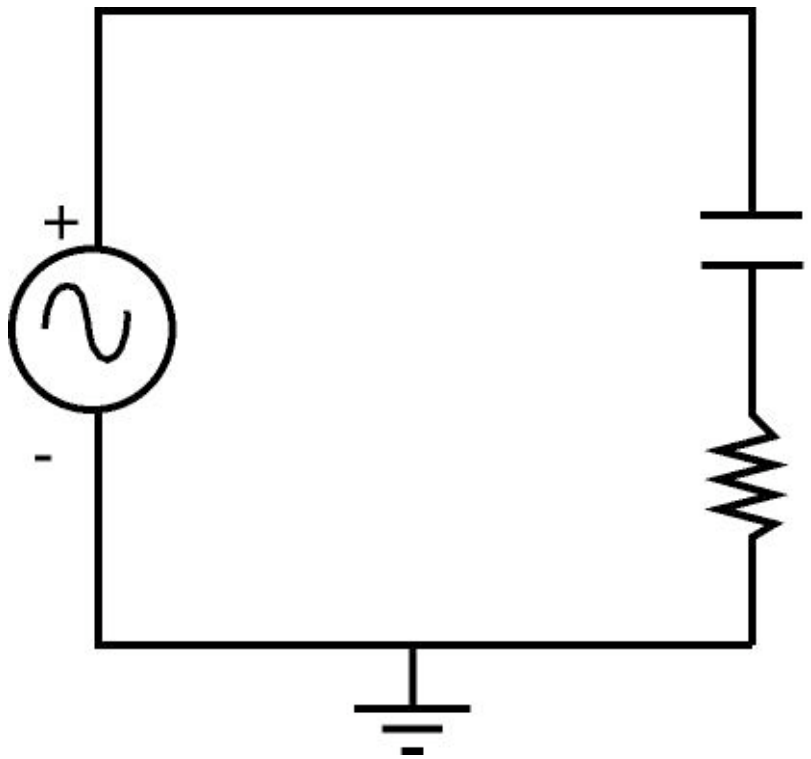
Another useful symbol

- Ground
- In your house, for safety
  - Connected to a cold water pipe
  - Earth is infinite source (and sink) of electrons
- Sometimes we pick a common point and call it ground
- By convention is always at zero volts



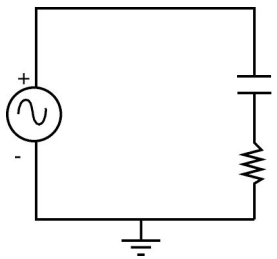
This is a loop

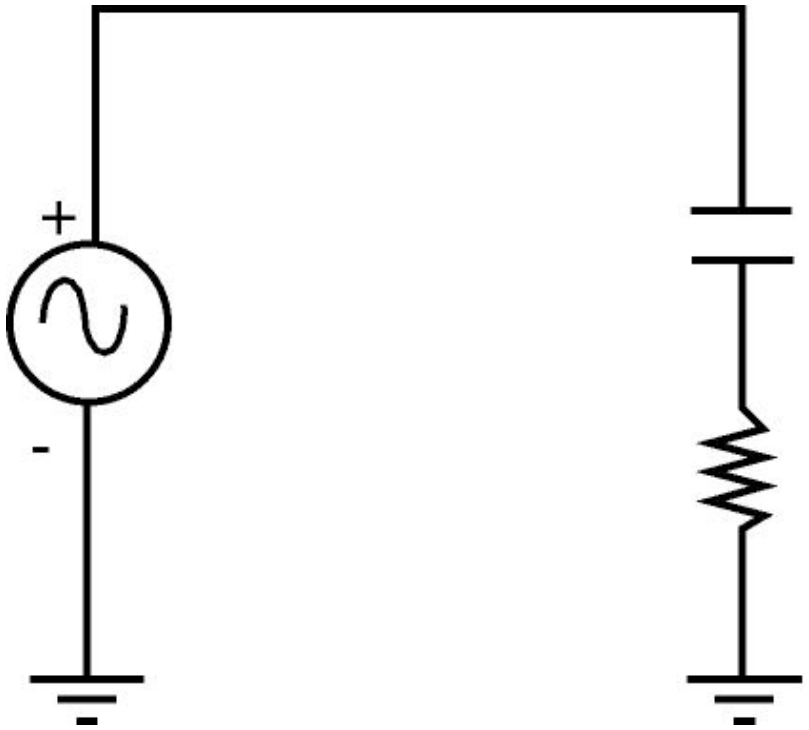
- Every circuit has to have at least one loop
- That's why they call it "circuit"



This is the same circuit

- Still a loop
- We know that all grounds are connected together
  - Don't have to draw them that way

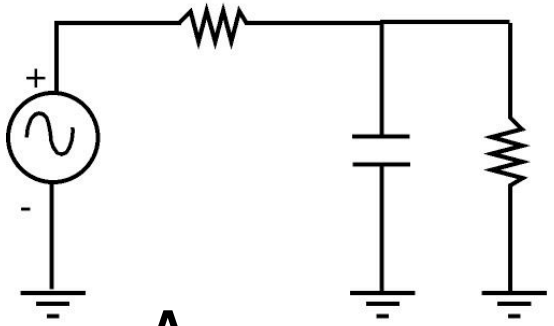




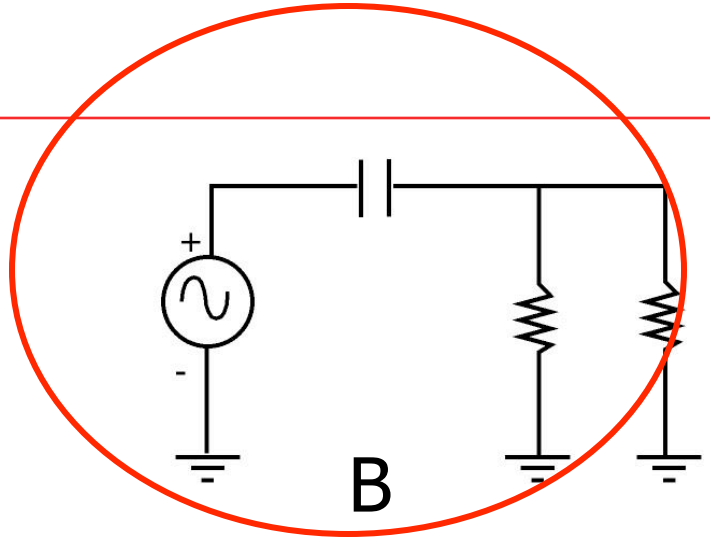
The point:

- We can draw things lots of different ways and still have them be the same electrically

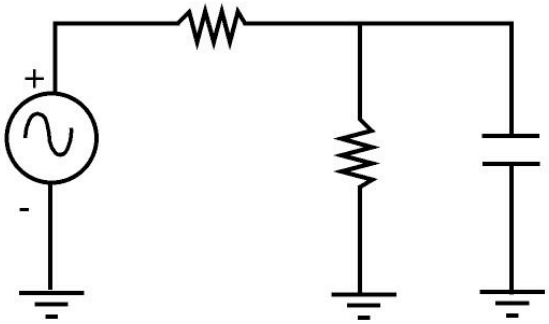
Which of these things is not like the others?



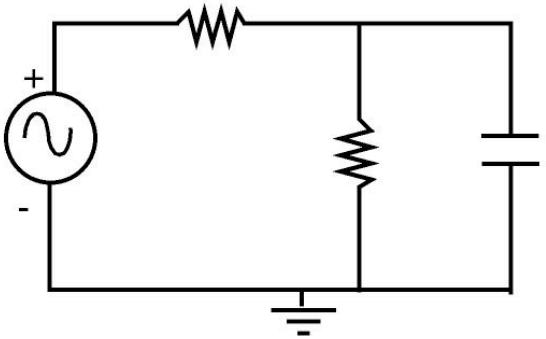
A



B

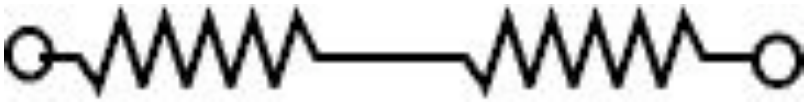


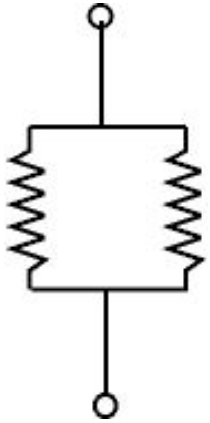
C



D

Series vs. parallel

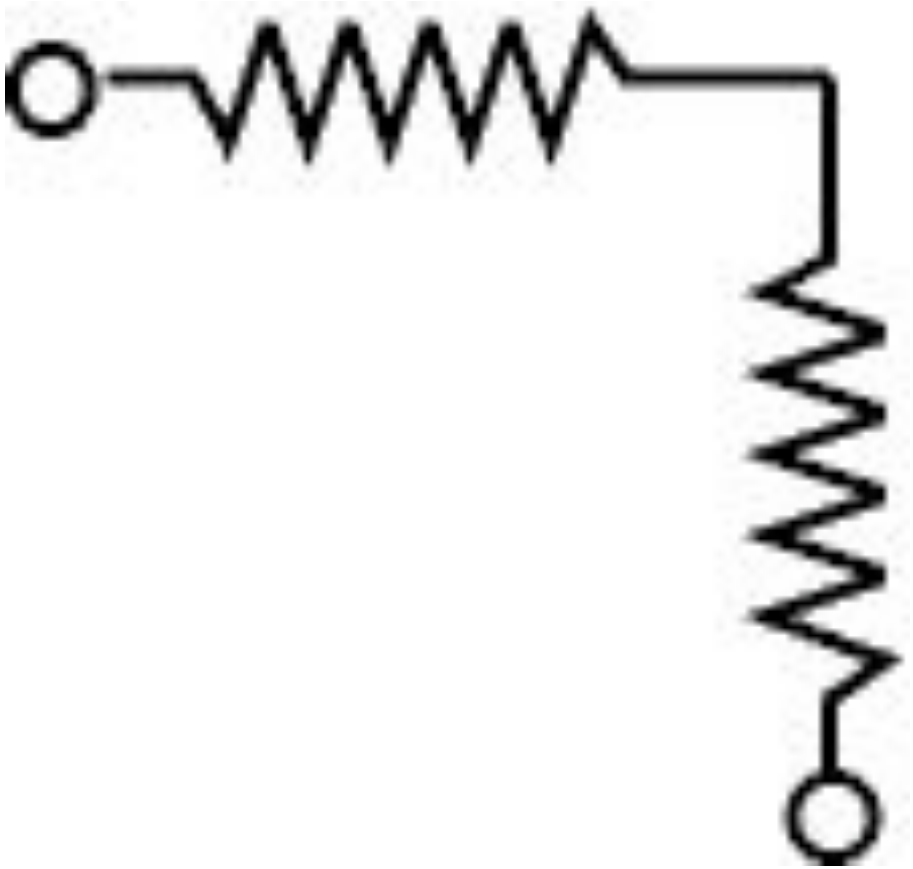




Series

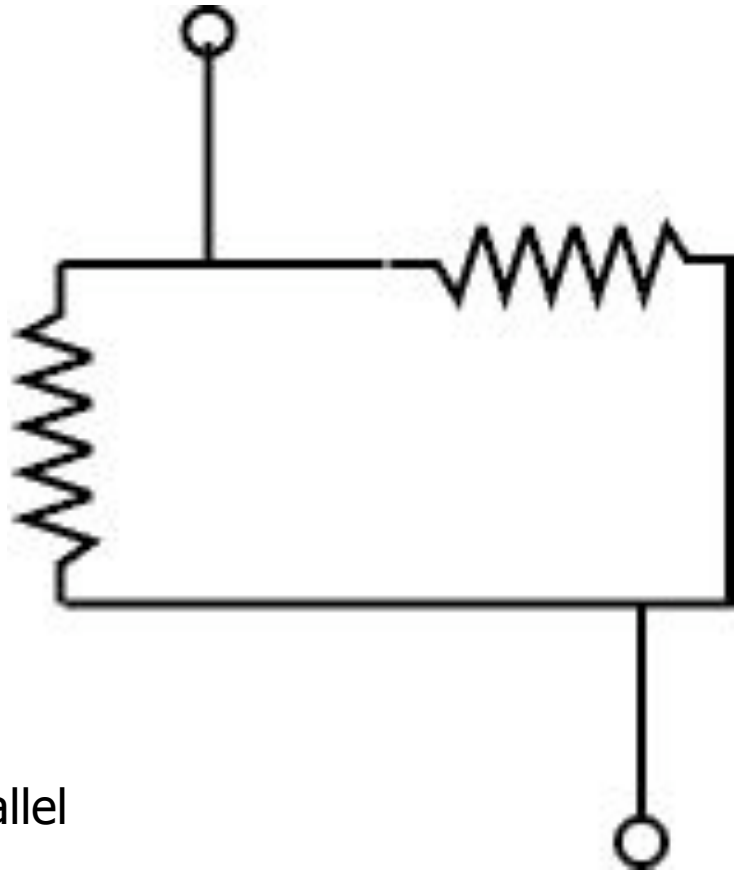
Parallel

Series or parallel?



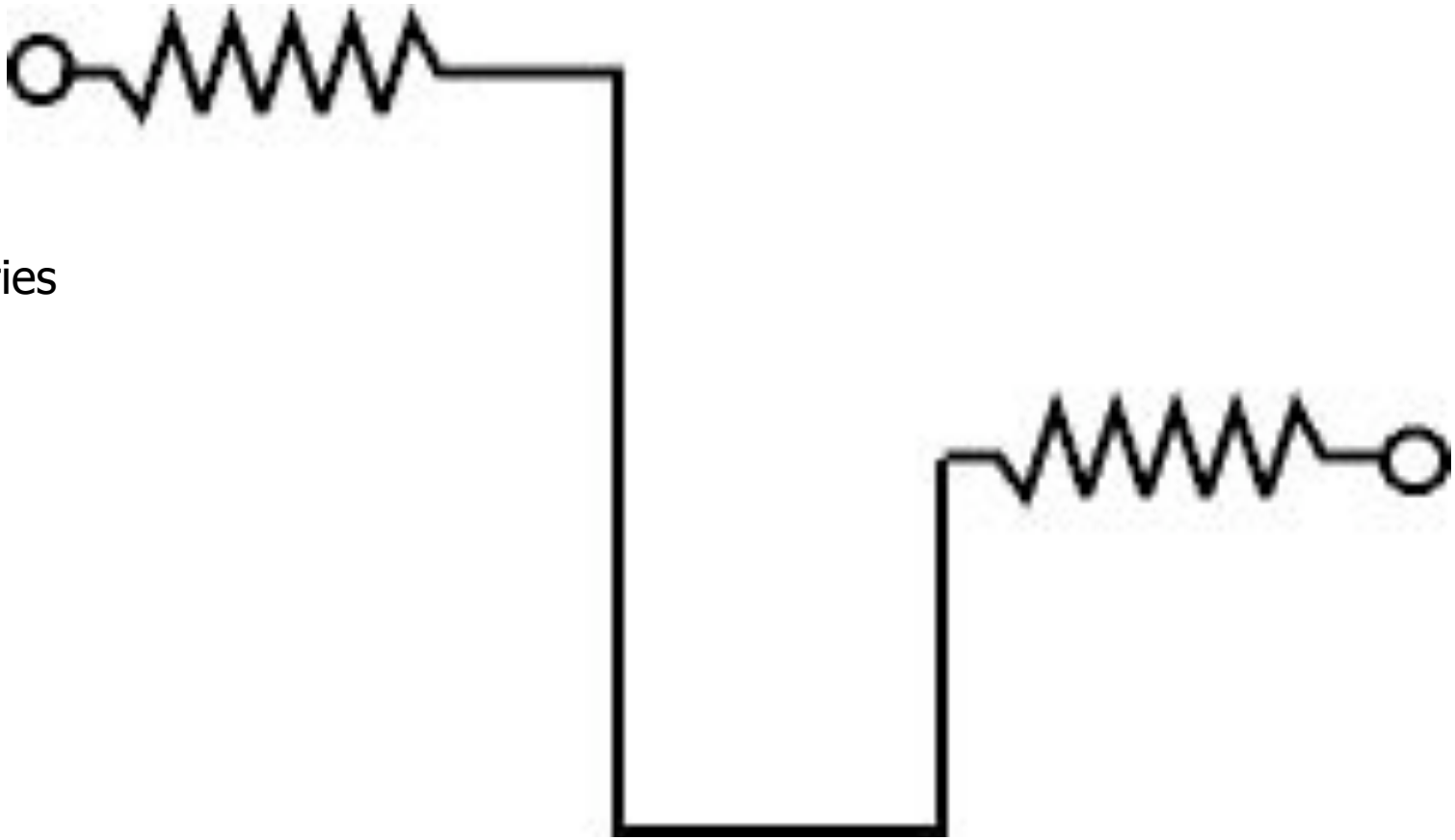
Series

Series or parallel?



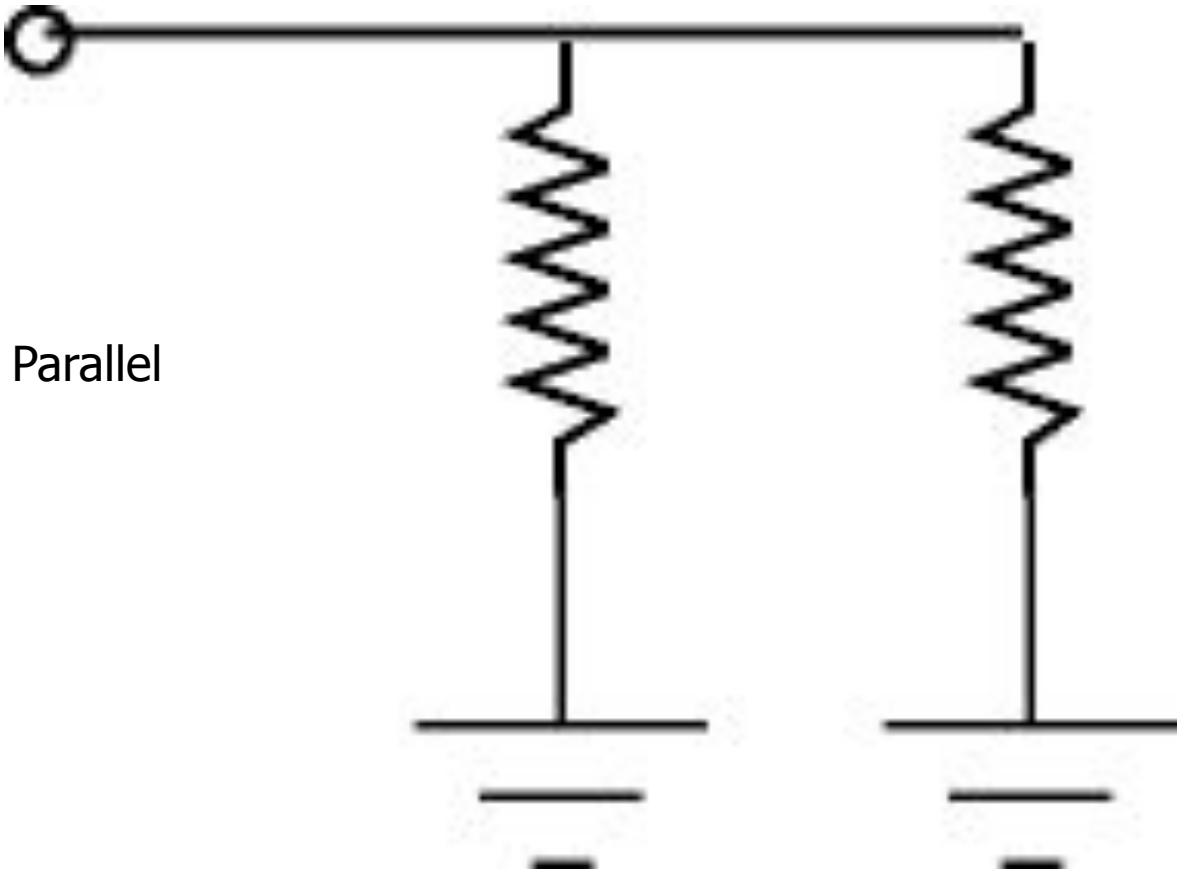
Parallel

Series or parallel?



Series

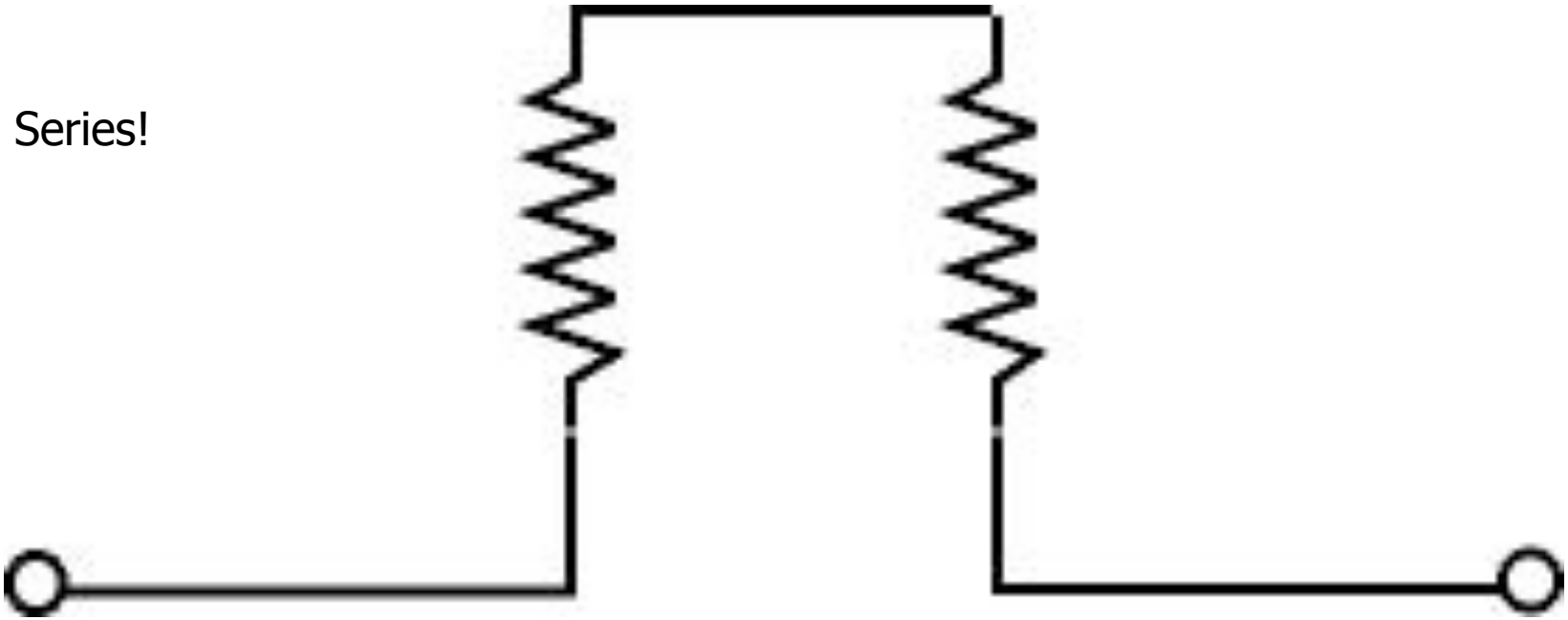
Series or parallel?



Parallel

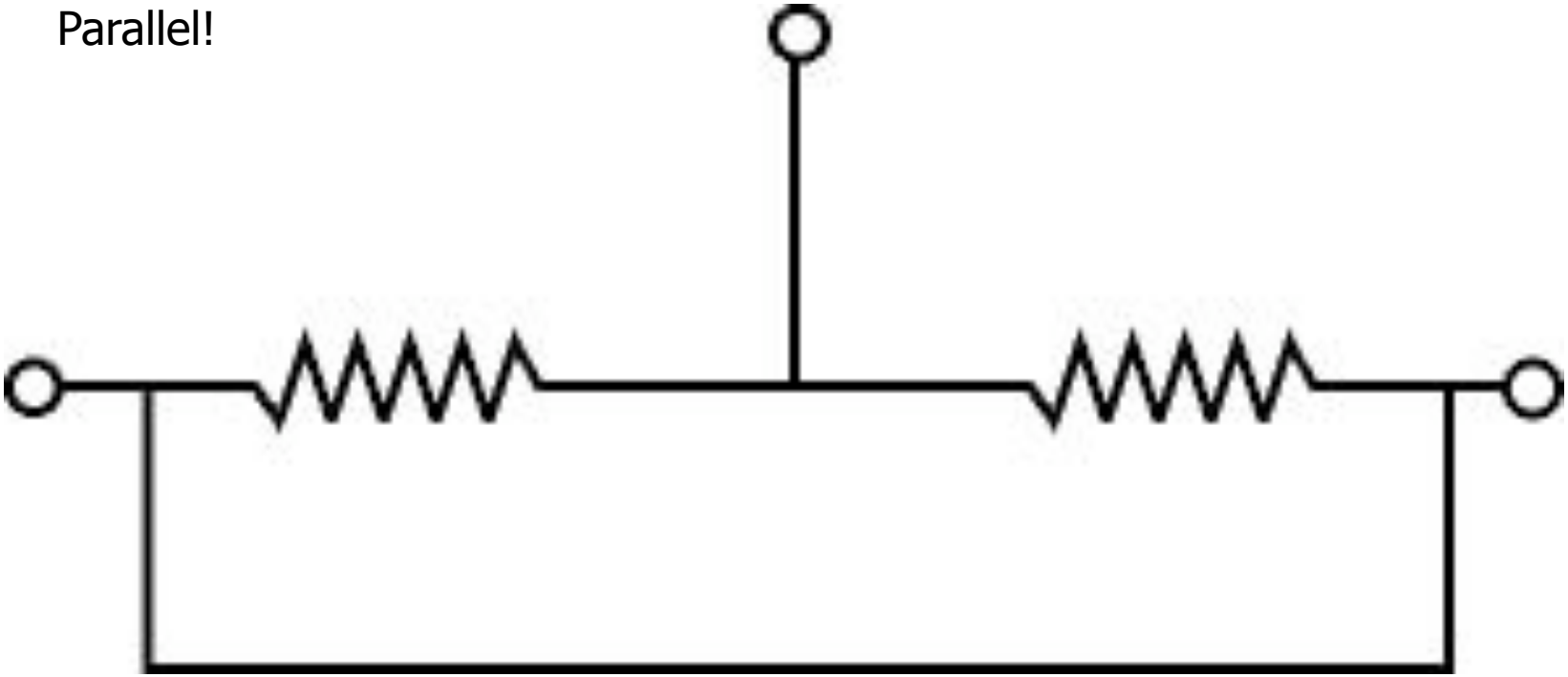
Series or parallel?

Series!

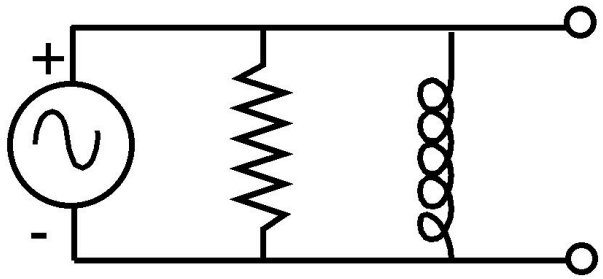


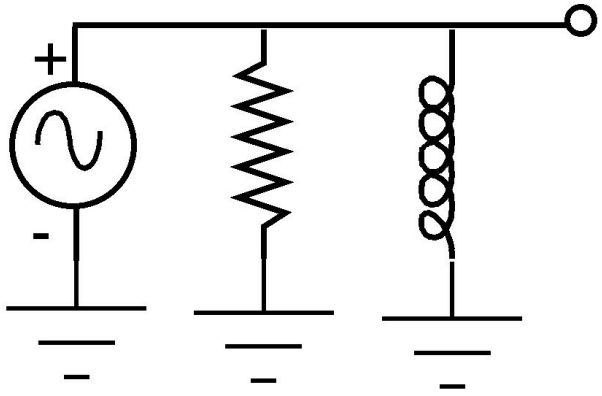
Series or parallel?

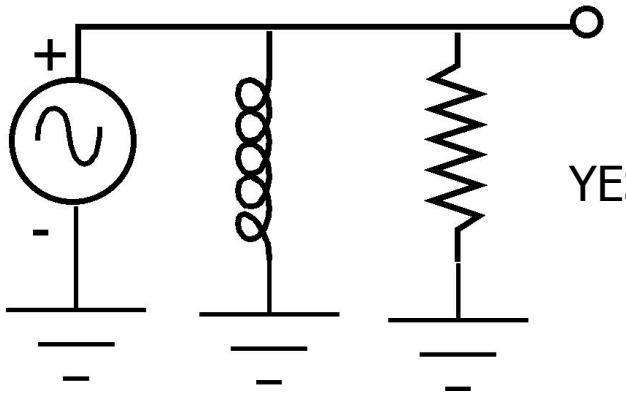
Parallel!



Are these the same?

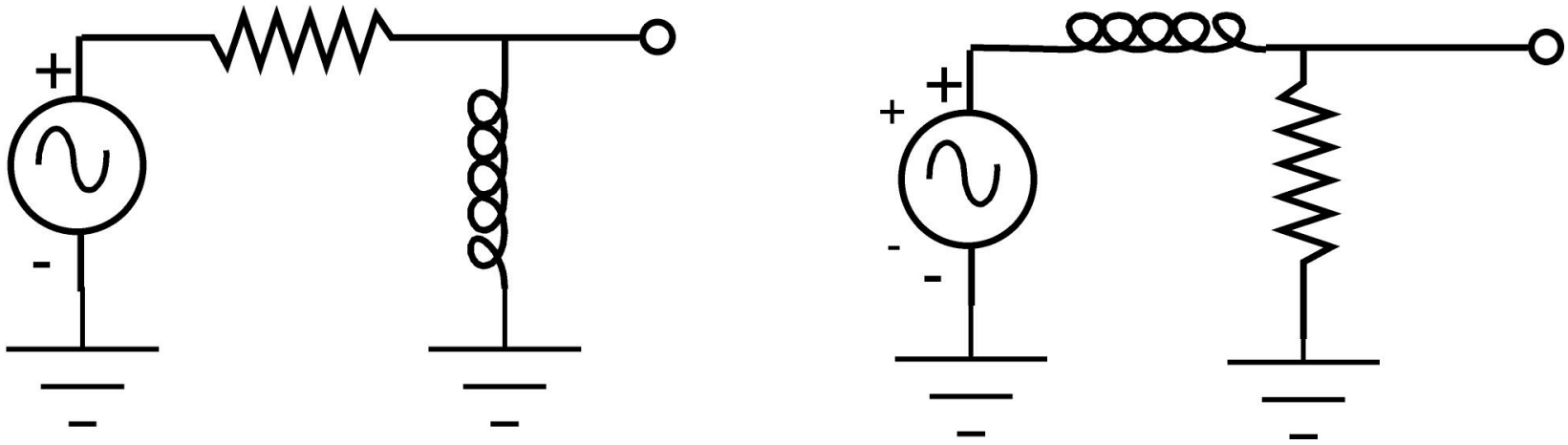






YES

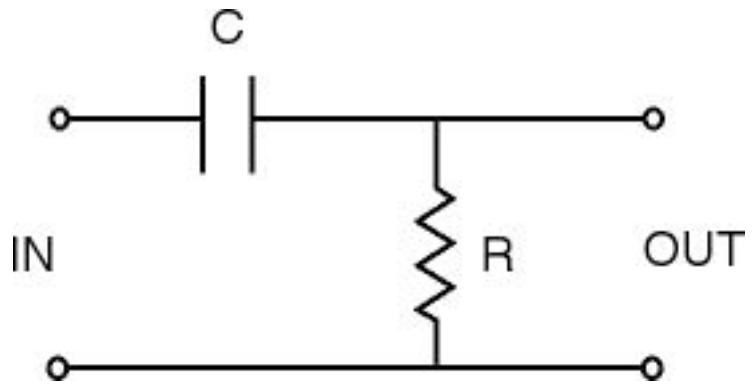
Are these the same?



NO

Now, our filters

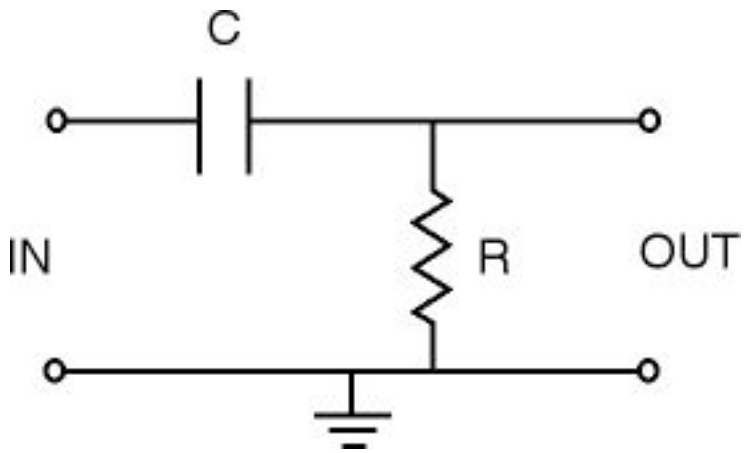
- Recall capacitor blocks low frequencies
- Is this a high-pass or low-pass filter?



•High pass!
•Low frequencies can not pass to output

What is the cutoff frequency?

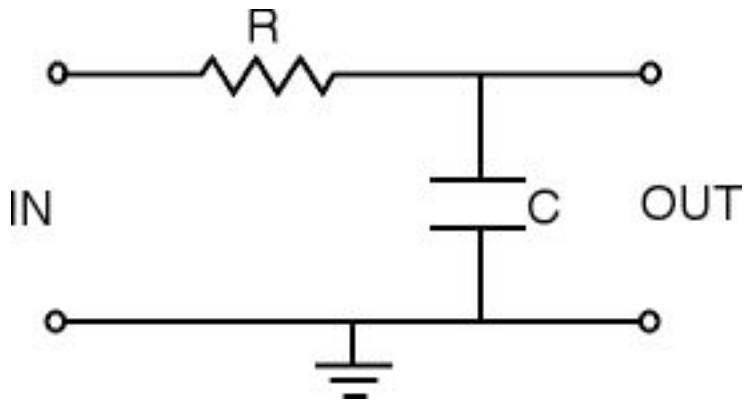
$$f = \frac{1}{2\pi RC}$$



- We adjust the cutoff frequency by our choice of R, C
- We'll use:
  - R=680 Ω
  - C=0.1 μF
  - f≈ 2,500 Hz
- Will pass frequencies above 2.5 kHz

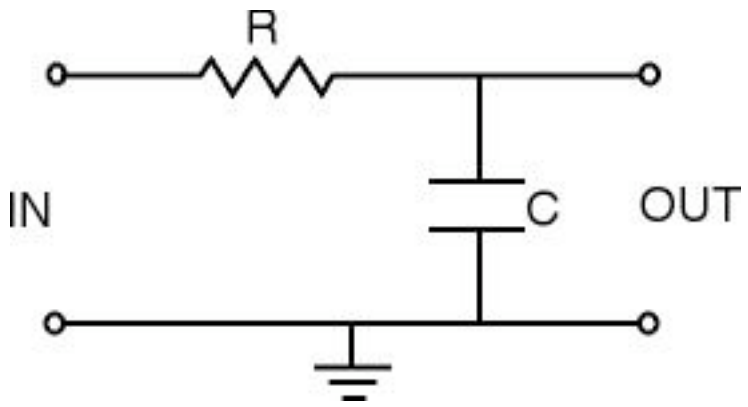
Low-pass filter

- All frequencies pass through R
- High frequencies pass through C
  - They go to ground!
- Only low frequencies go the output



What is the cutoff frequency?

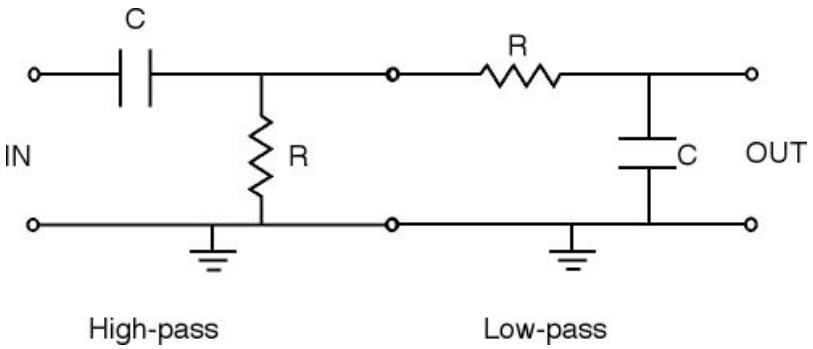
$$f = \frac{1}{2\pi RC}$$



- Same equation
- Here we'll use:
  - R=1.6 kΩ
  - C=0.1 μF
  - f≈1000 Hz
- Will pass frequencies below 1 kHz

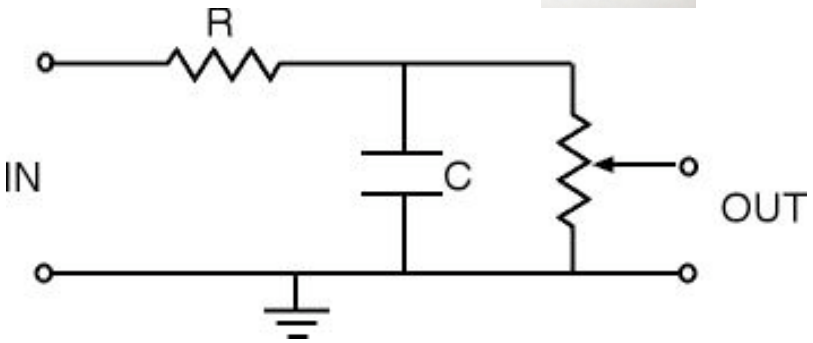
Bandpass

- First filter out high frequencies (high-pass filter)
- Pass remaining signal on to the next stage
- Low-pass-filter what's left



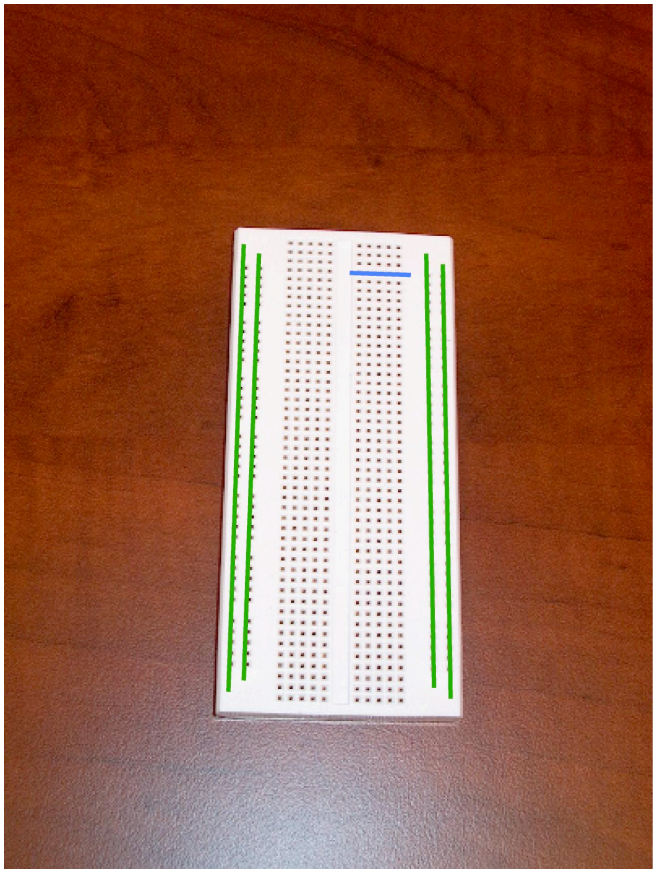
Potentiometer

- Add variable resistor to output
- As you turn the wheel, the amount of signal passed to output changes
- This is a volume control
- You'll have one for each filter

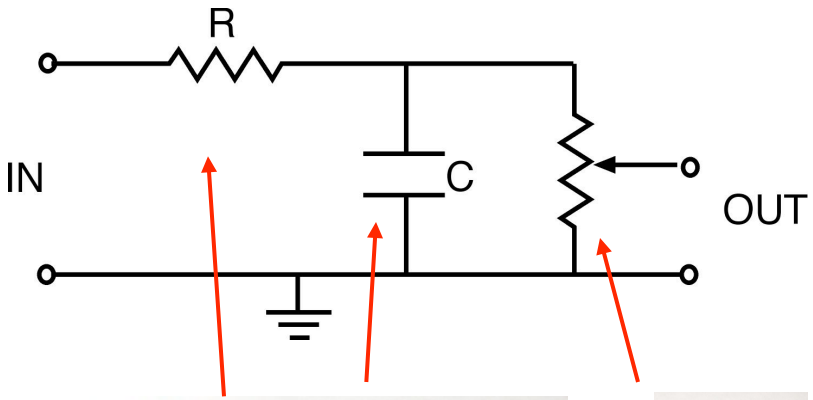


Now we're ready to build

- We'll use a breadboard
- All holes in long columns connected together
  - These are called "buses"
  - Handy for when you have to connect many things to the same point
- Holes in short rows connected



Example of the Circuit

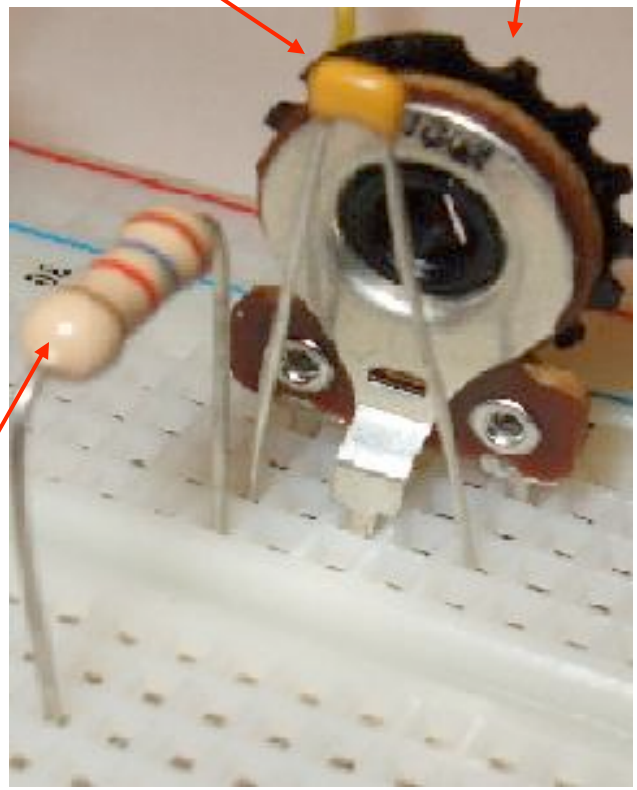


Low Pass Filter Schematic

Capacitor

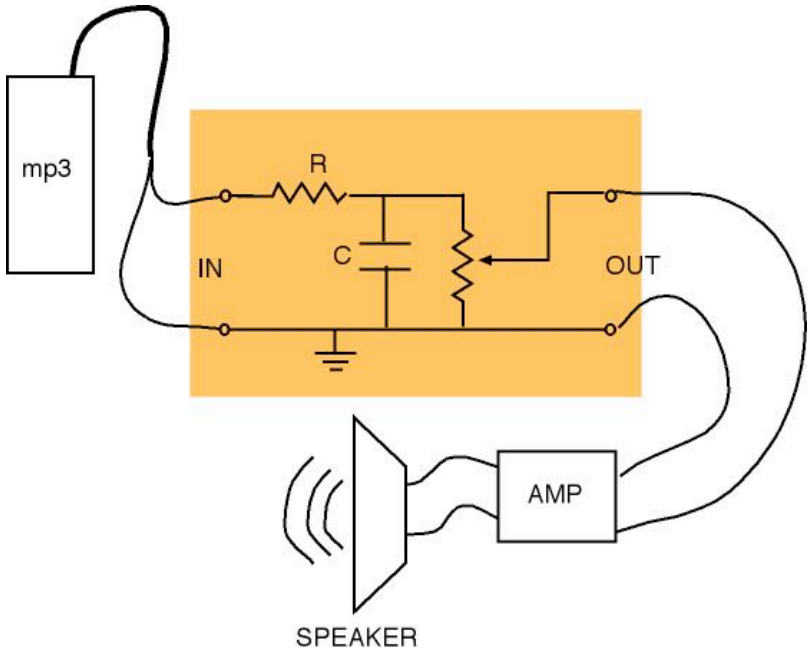
Potentiometer

Resistor

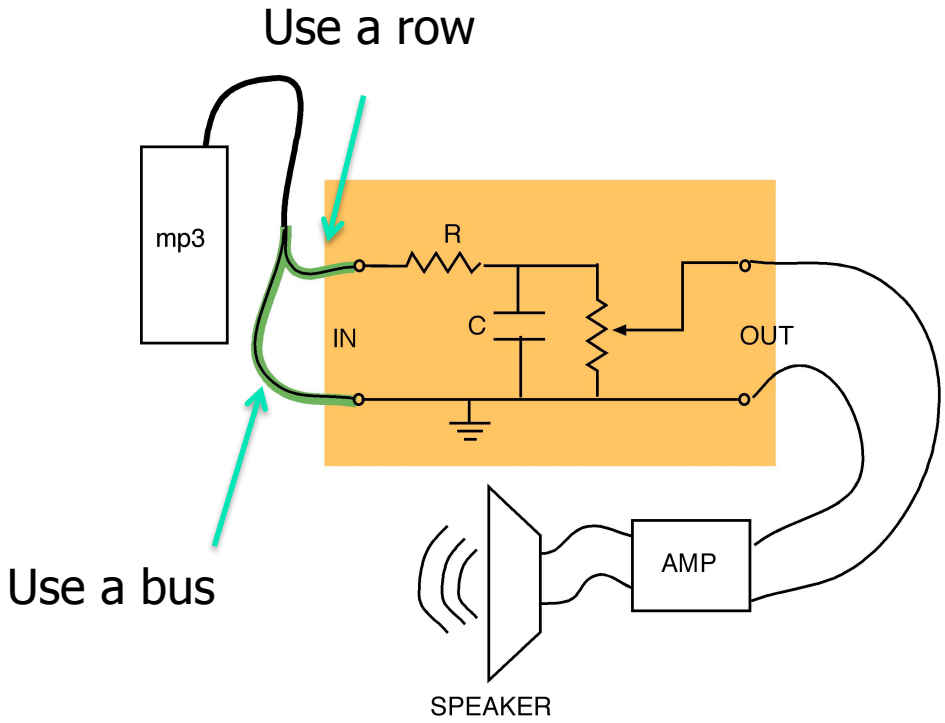


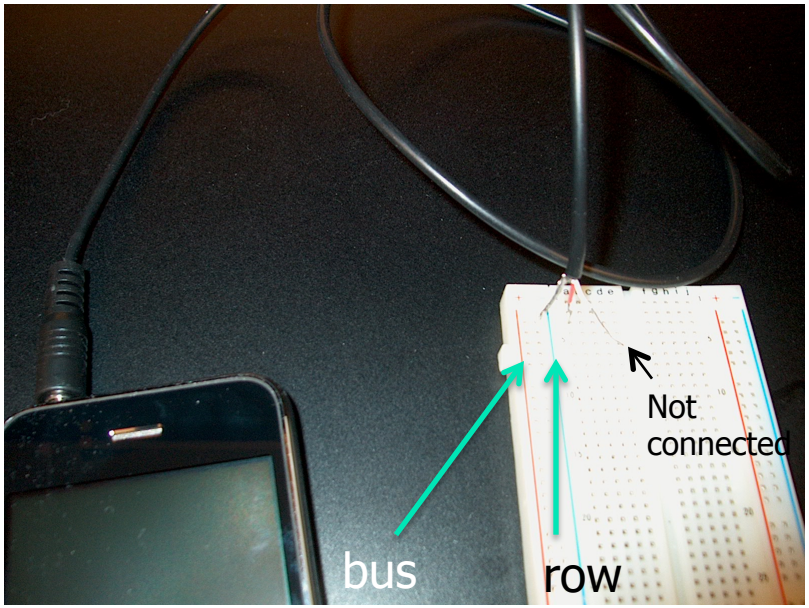
Start with low pass

- Here's the entire circuit
- We'll provide amplifier, speaker
- You provide music source

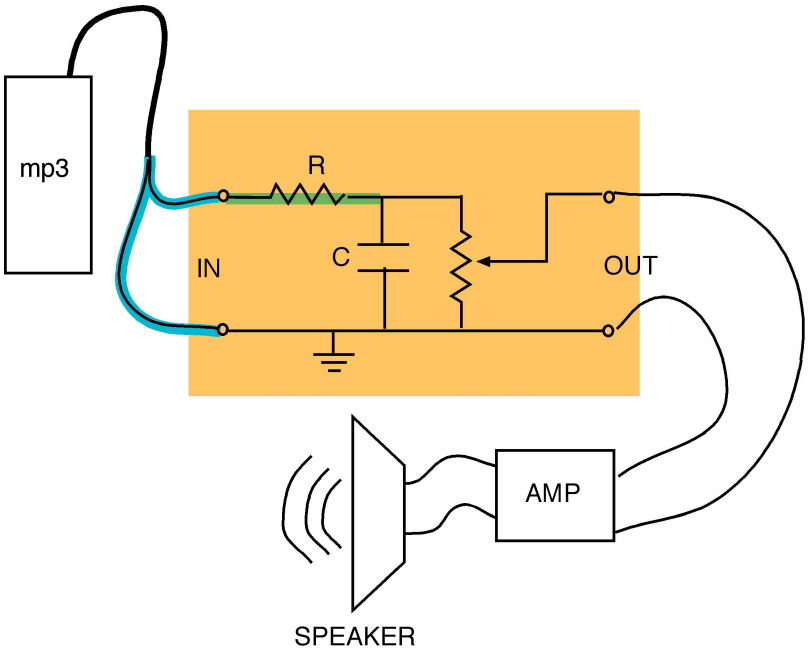


Connect player to breadboard

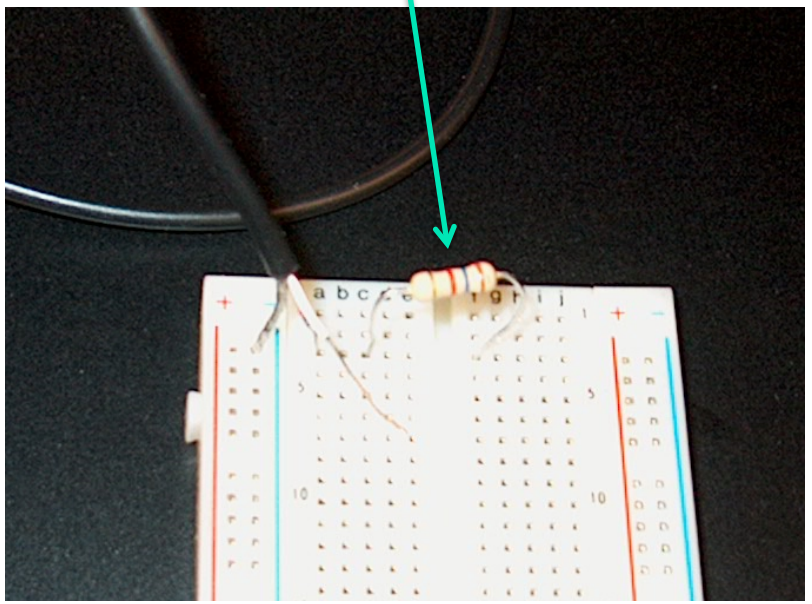




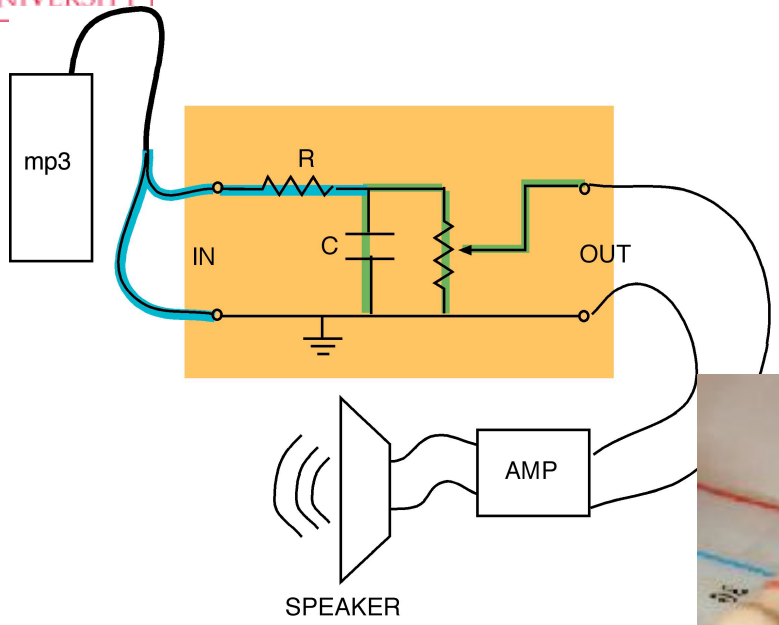
Input connects to 1.6kΩ R

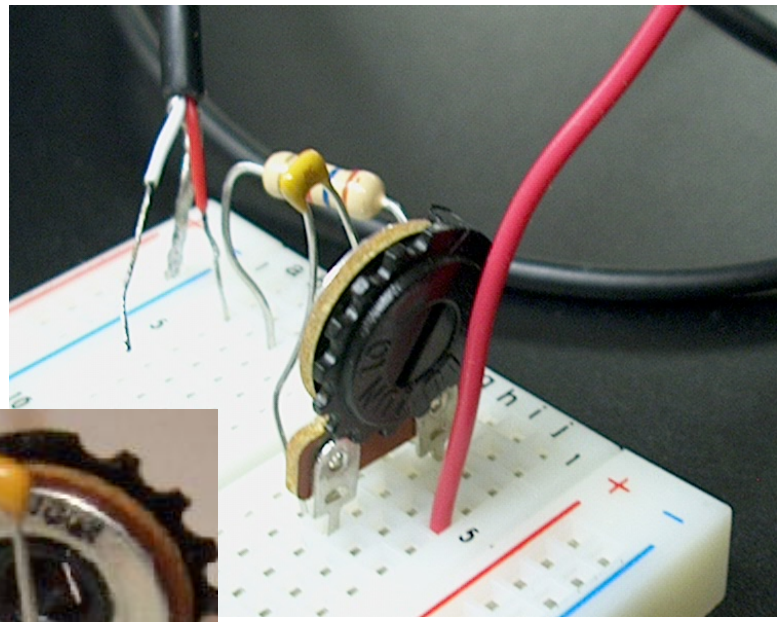


Stripes: brown, blue, red



Install pot and cap





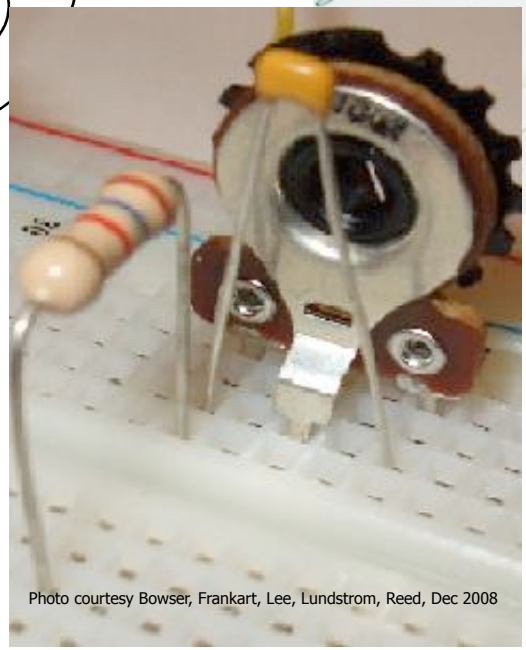
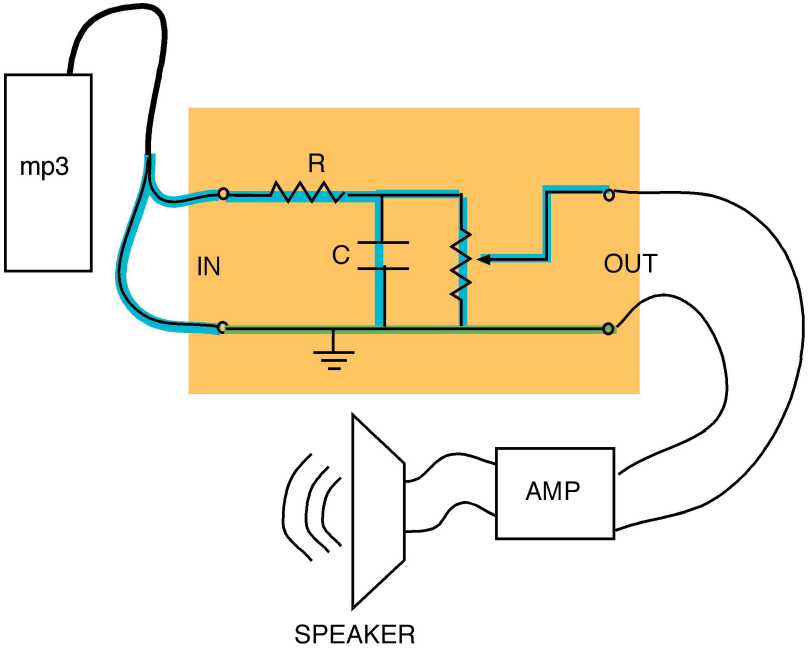
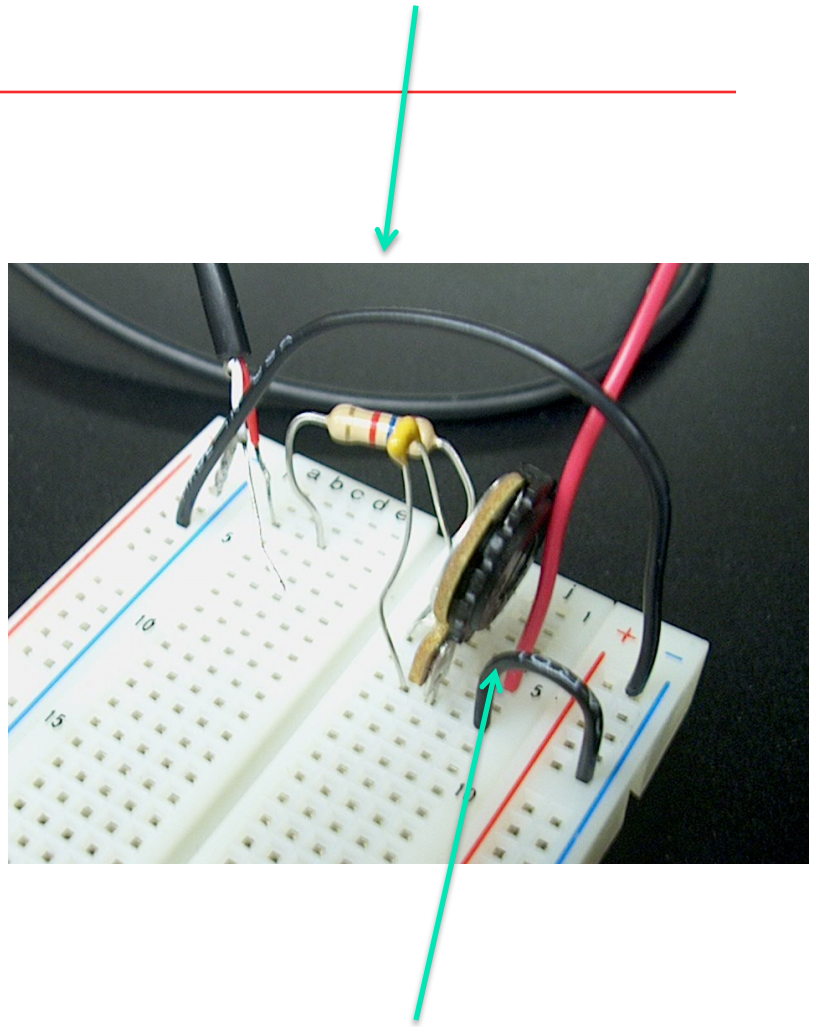


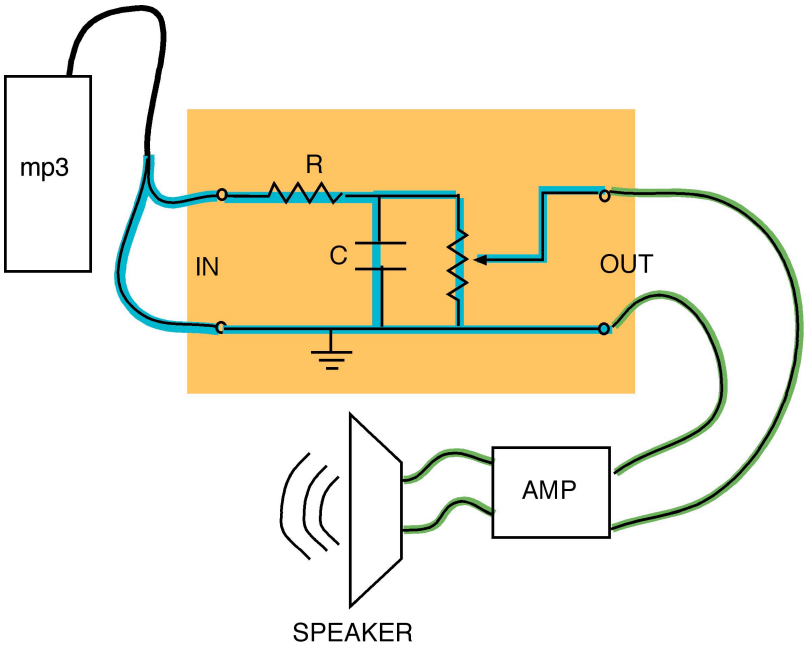
Photo courtesy Bowser, Frankart, Lee, Lundstrom, Reed, Dec 2008

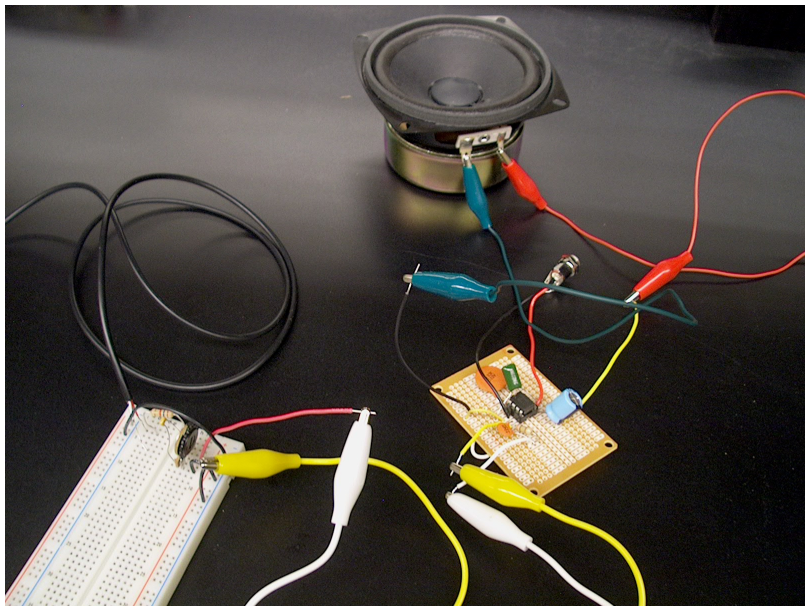
And grounds



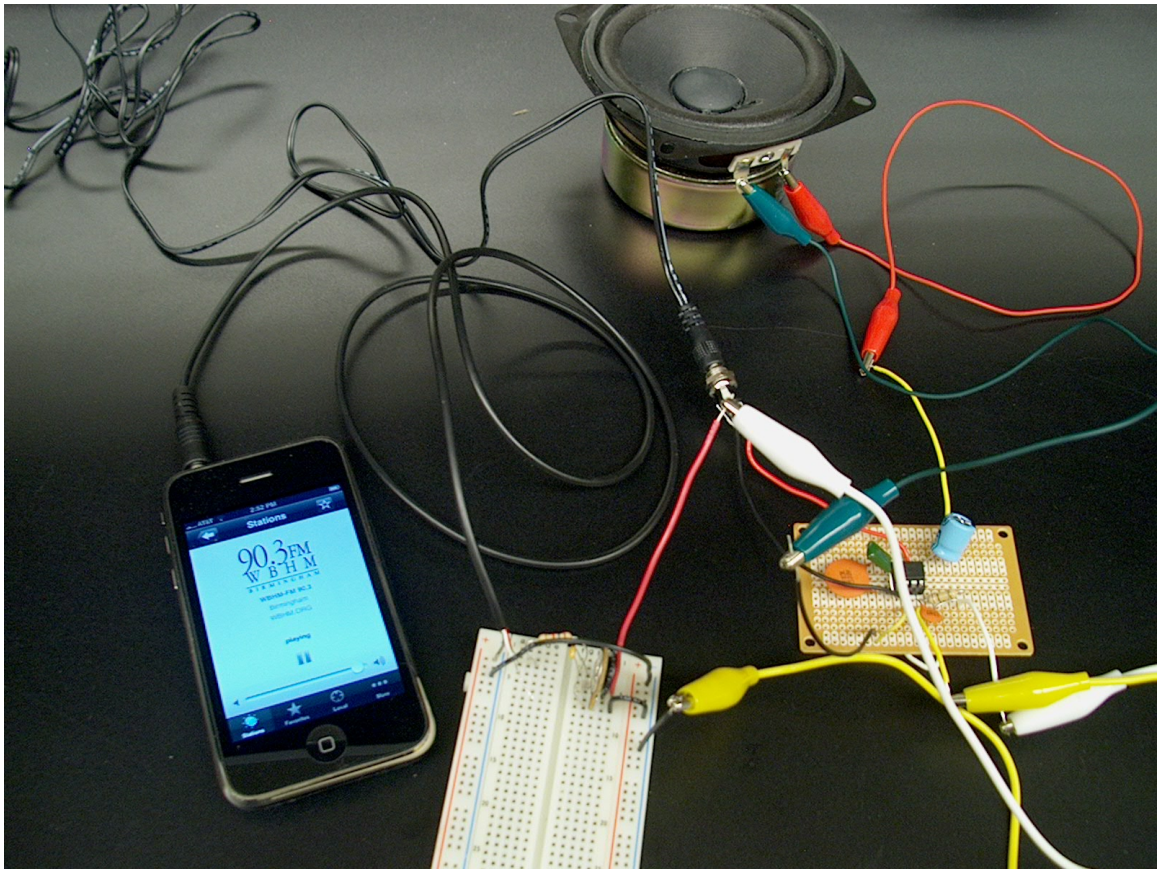


Finally, amp and speaker

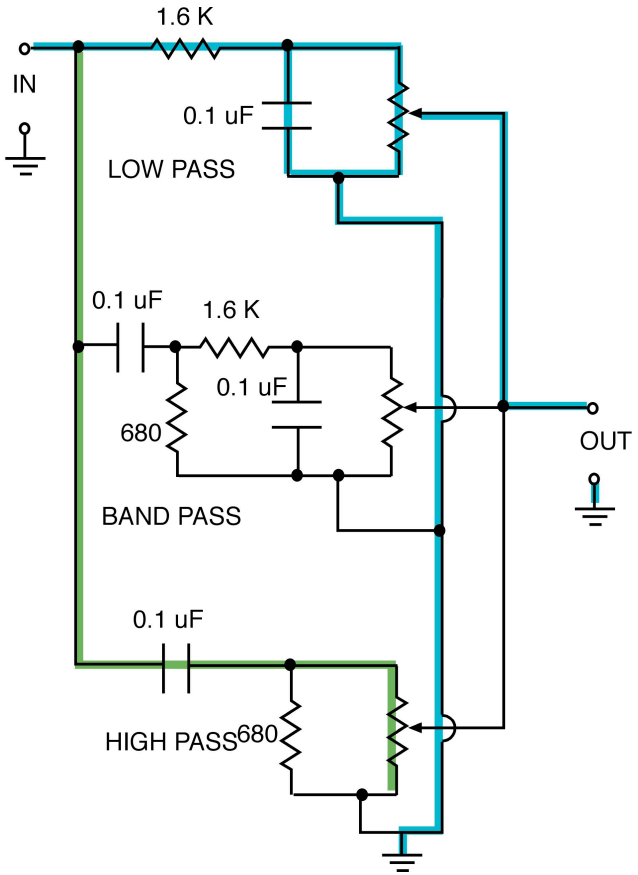


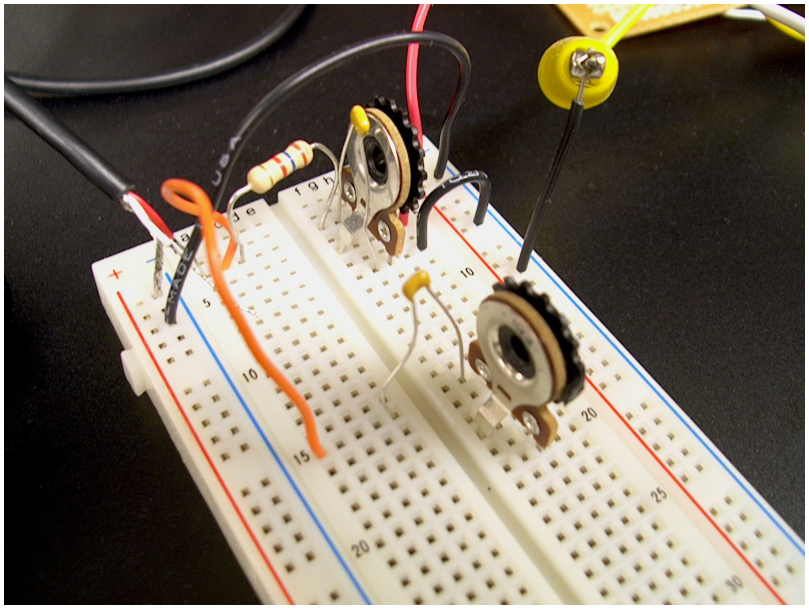


Plug it in and try it

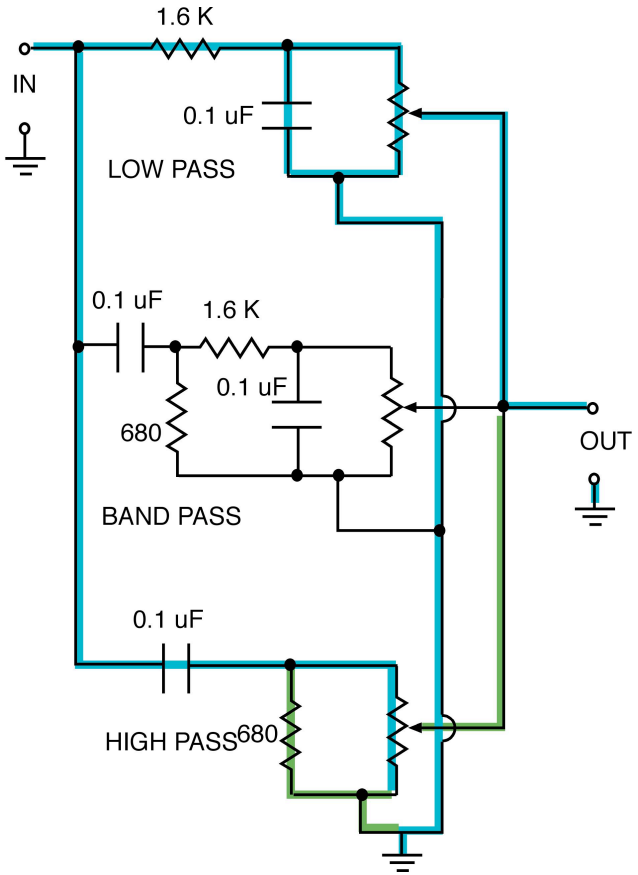


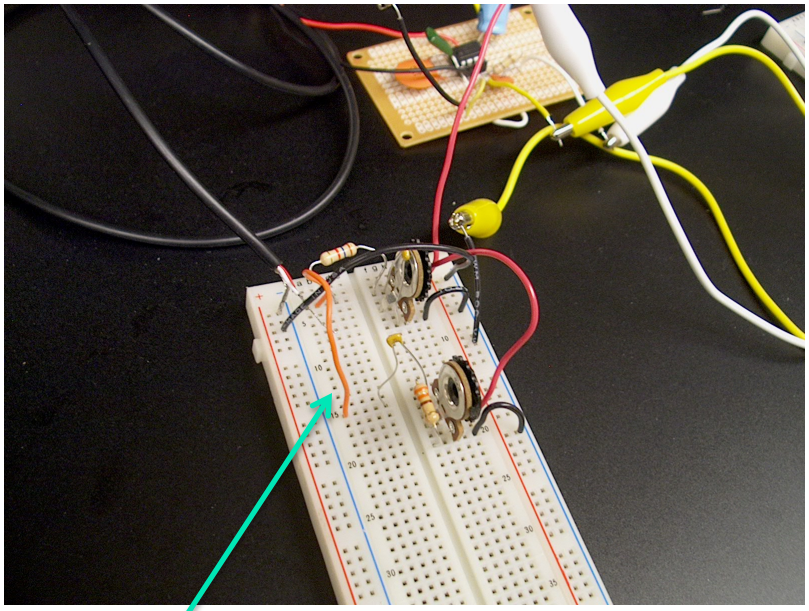
Now start the high-pass filter





And finish it





Stripes: blue, gray, brown

If you have time, add the bandpass