Bass Boost Amp Workshop Overview

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TECHNICAL ADVANCEMENT GROUP

Circuits

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ECE ILLINOIS

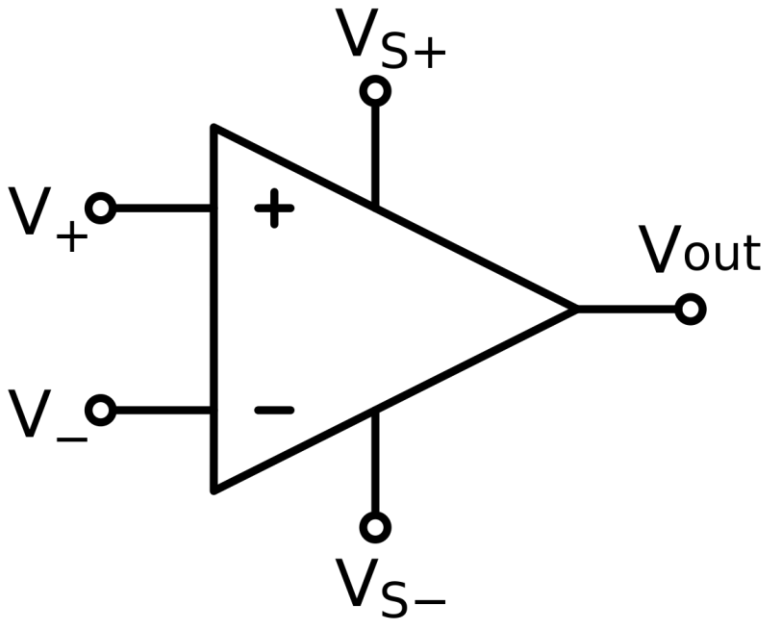
ILLINOIS

HIGH LEVEL

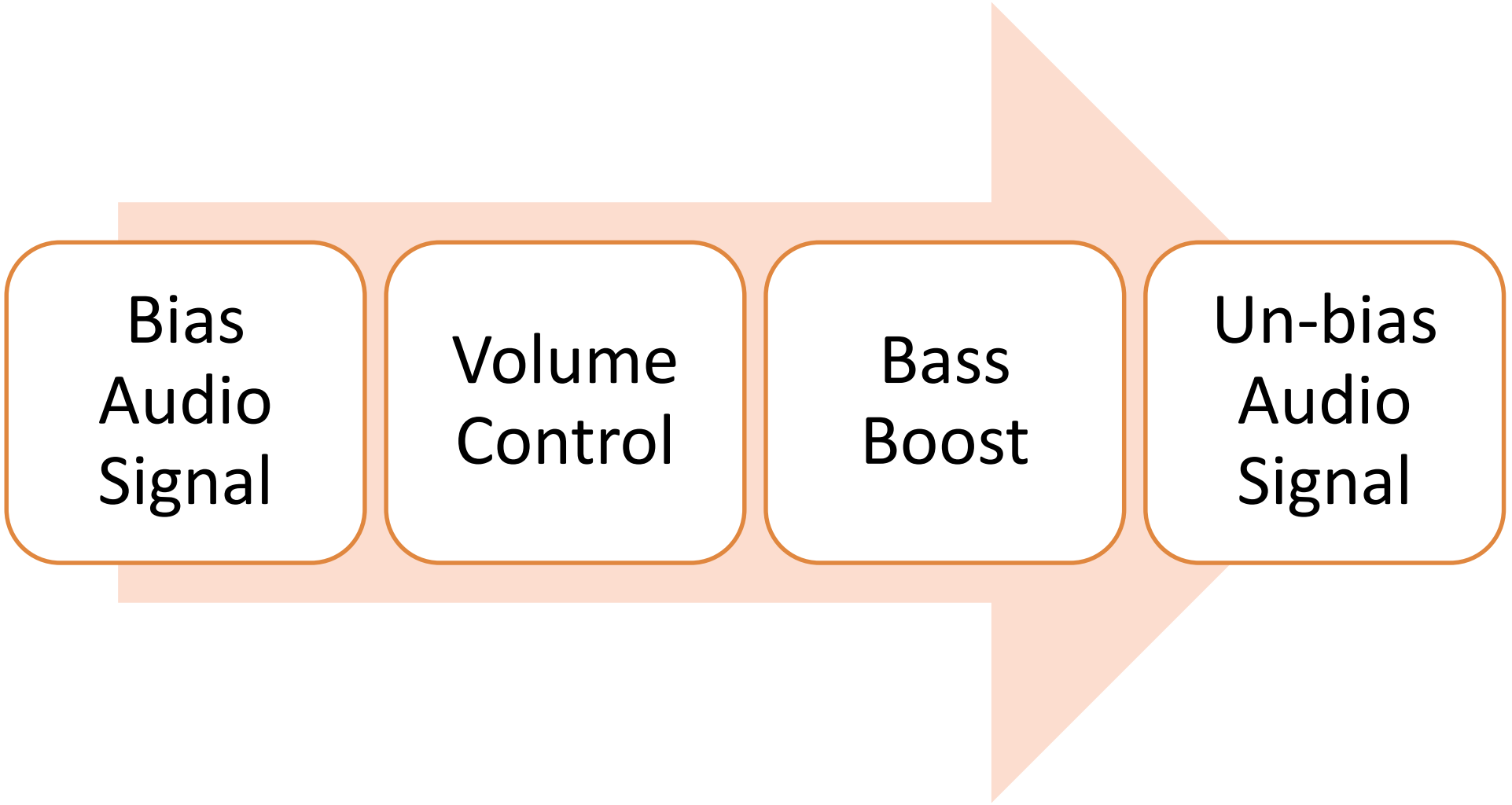
- Component Overview
- Ideal Amp
- Gain<->Bandwidth Tradeoffs
- Implementation
- PCB
- Sources

OP AMPS

- 5 Terminal Device!
  - Positive/Negative INPUT
  - Positive/Negative SUPPLY
  - OUTPUT
  - Tend to not draw the supply
- Complex to make
  - 15+ transistors usually
- Op amps have 2 “Golden Rules”
  - No current flows INTO the INPUTS
  - The output does whatever it has to in order to make the positive input equal the negative input

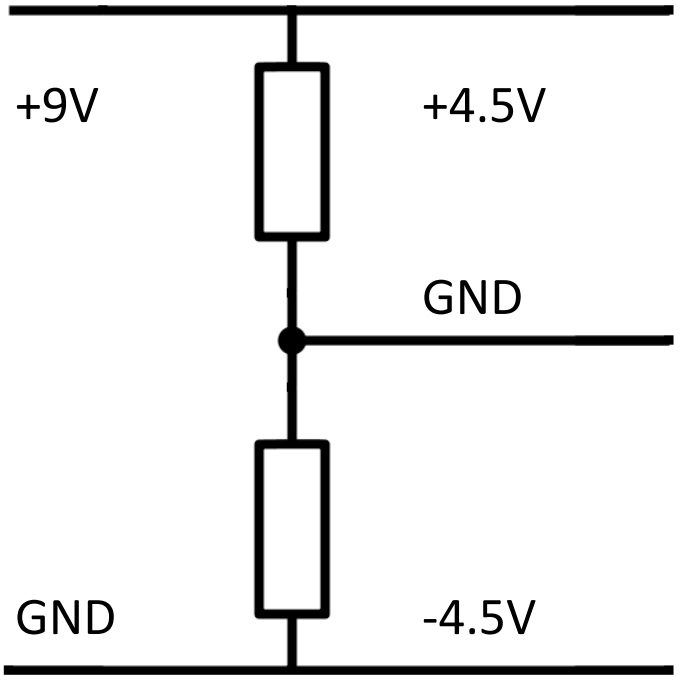


BLOCK DIAGRAM



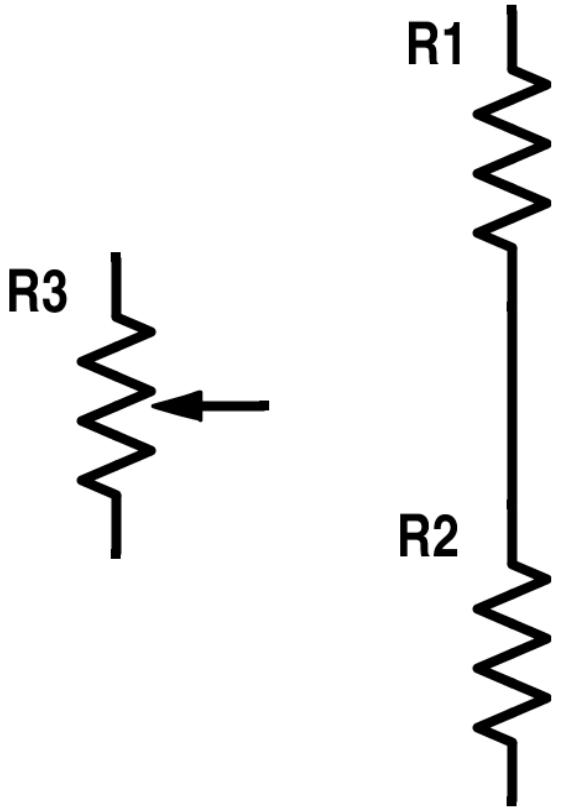
BIASING

- Audio signals are 0V centered (+/- 0.450mV approximately)
  - But we only have one 9V battery to power this!'
- Need a rail splitter!
- Creates a *virtual ground* for us to use
- Not a "real" ground, still moves up and down slightly



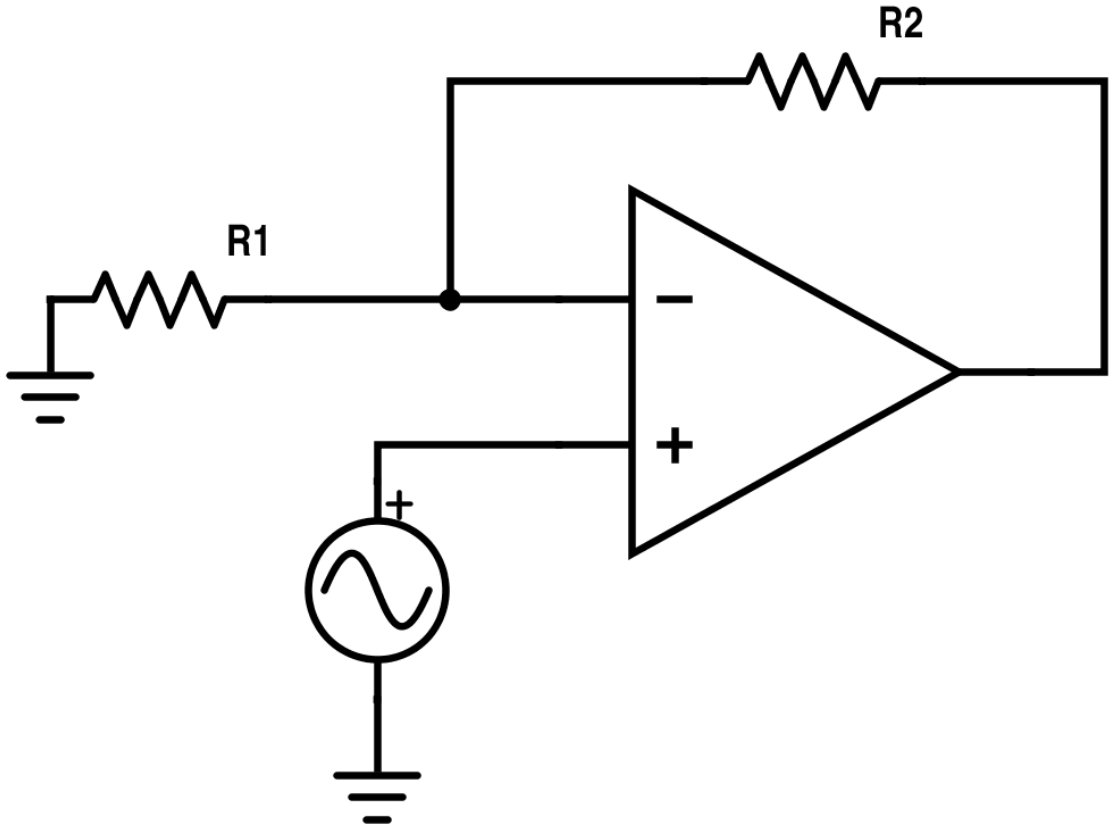
VOLUME CONTROL

- Humans hear in dB (logarithmically)
  - 2x interpreted volume means a 10x change in amplitude
- Need a circuit that change an input wave logarithmically
- Use a log potentiometer
- Gain is $\frac{R_2}{R_2+R_1}$
  - Always less than one!



GAIN

- Simple op amp circuit
- Non inverting amplifier



Can solve using KCL!

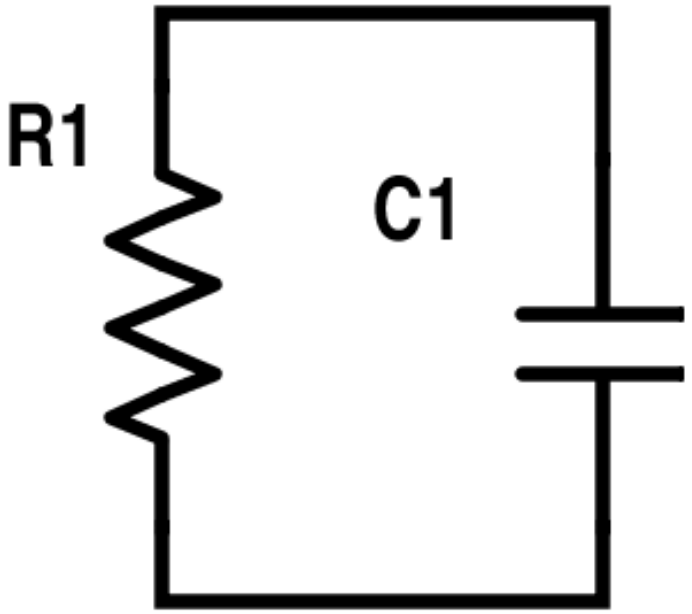
$$\frac{V_{out} - V_-}{R_2} = \frac{V_- - 0}{R_1}$$

$$V_- = V_{in}$$

$$V_{out} = \left(1 + {}^{R_2}/_{R_1}\right) V_{in}$$

LOW PASS FILTER

- Need an element that has a different response at low + high frequencies
- Solve with a parallel RC circuit

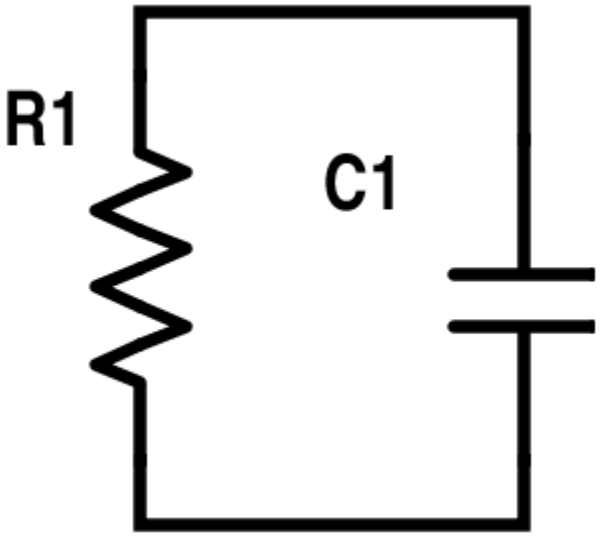


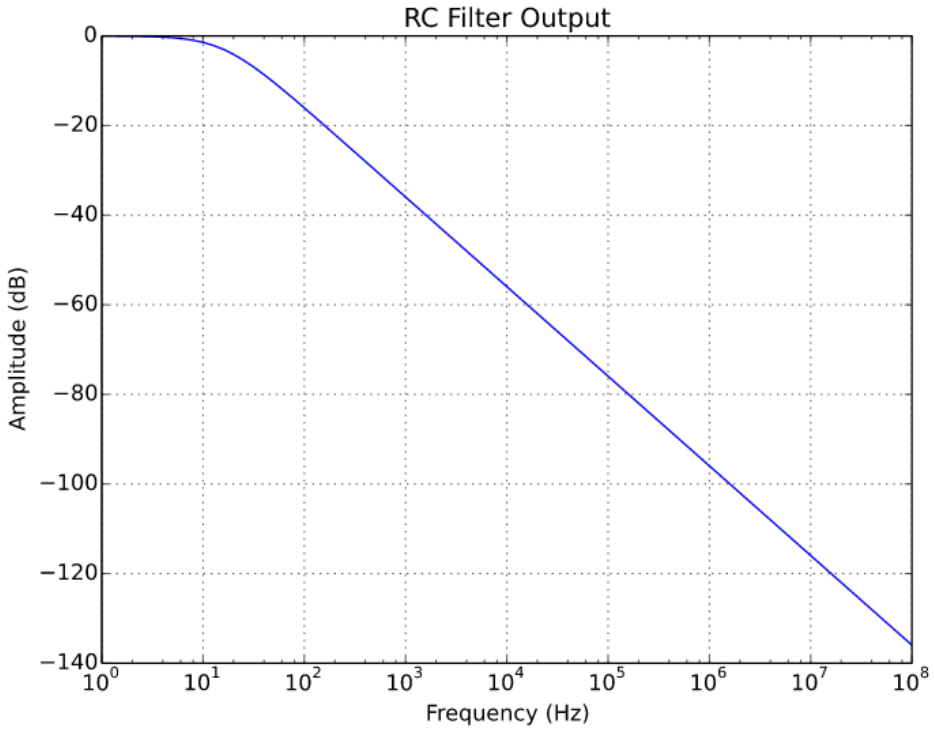
Impedance of circuit is :

$$Z_{RC} = R \| \frac{1}{jwC} = \frac{1}{\frac{1}{R} + jwC} = \frac{R}{1 + jwRC}$$

LOW PASS FILTER

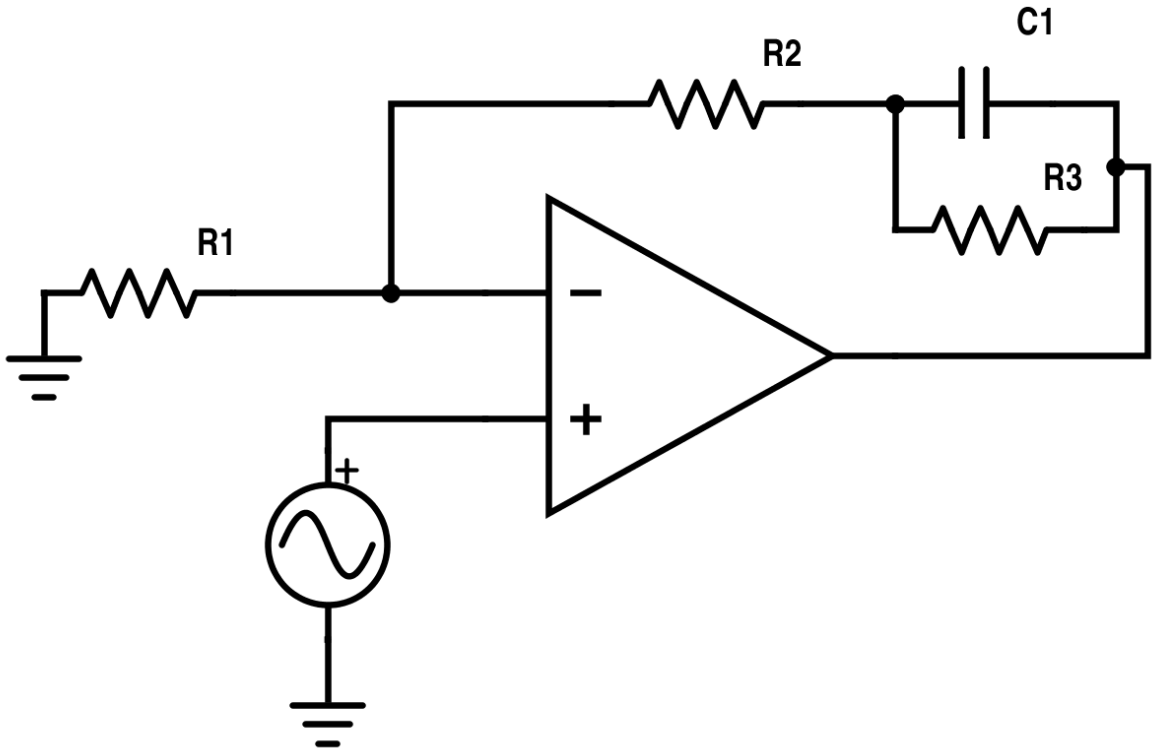
- See *R* at low frequencies, decreasing as *w* increases
- Can view as a filtering element!





BASS BOOST

- Now let's combine the last two ideas!
- We now have a amplifier with variable gain based on the frequency!



$$V_{out} = \left(1 + \frac{R_2 + Z_{RC}}{R_1}\right) V_{in}$$

GAIN BANDWIDTH

- Have a tuning knob to change that resistor, but…
- Nothing in life is free!
- If we want to boost more bass, we get less boost
- If we want to have stronger boost, we boost less bass

WHY

GAIN BANDWIDTH

- Gain is proportional to resistance
  - More gain, higher R

$$V_{out} = \left(1 + \frac{R_2 + Z_{RC}}{R_1}\right) V_{in}$$

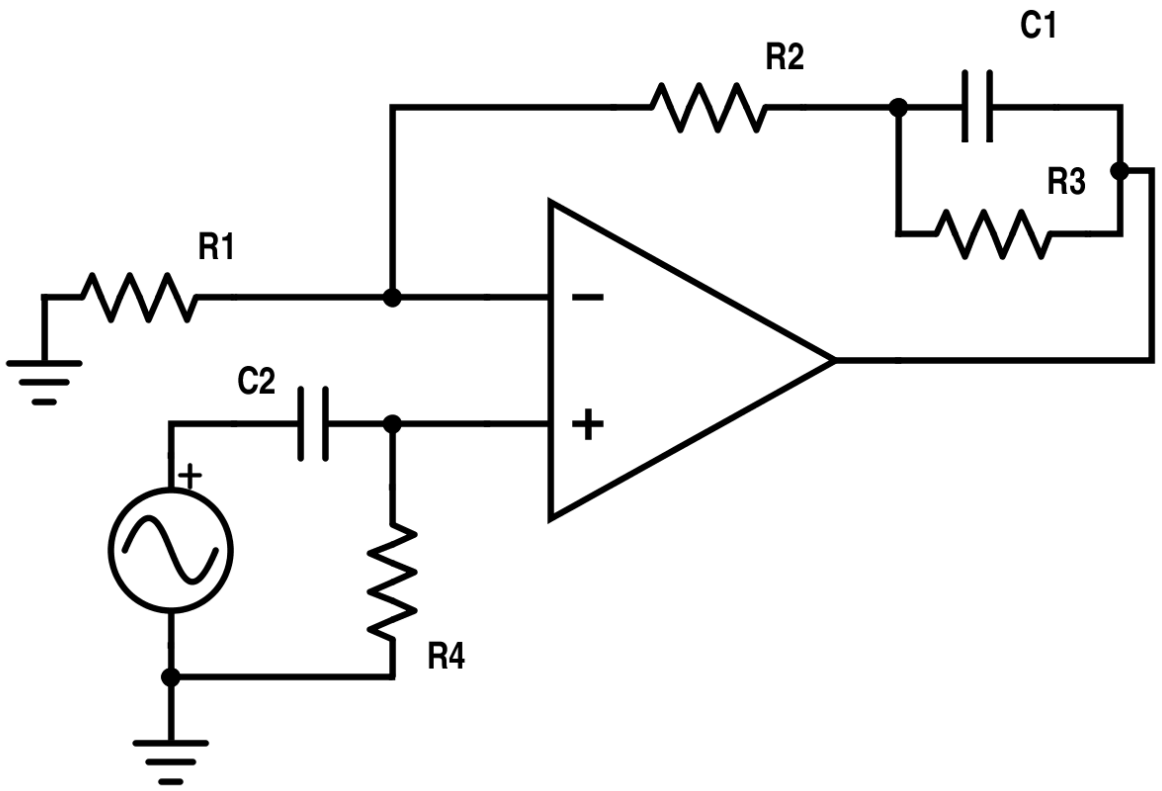
- Bandwidth is inverse to resistance
  - More frequencies, lower R

$$Z_{RC} = \frac{R}{1 + jwRC}$$

- Relationship called Gain-Bandwidth Product (can prove with integrals)

INPUT SIDE

- High pass filter into op amp
- Don't want any DC going to the output/headphones
- Opposite of parallel RC
- Has "rising" effect with frequency
  - Blocks low frequencies
  - Leaves high frequencies alone
  - Choose cutoff as 2-5 Hz



ADVANCED – INPUT BIAS

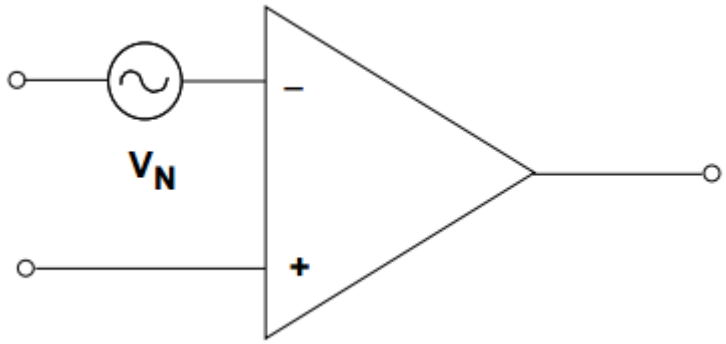
- Ideally, op amp inputs are the same voltage
- Not always that lucky, often get a term called “input bias” or “offset voltage”
- Shows up as a linear distortion term

$$V_{out} = \left(1 + \frac{R_2 + Z_{RC}}{R_1}\right)(V_{in} + V_{OS})$$

Our op amp has maximum offset voltage of 75uV – not bad!

ADVANCED - NOISE

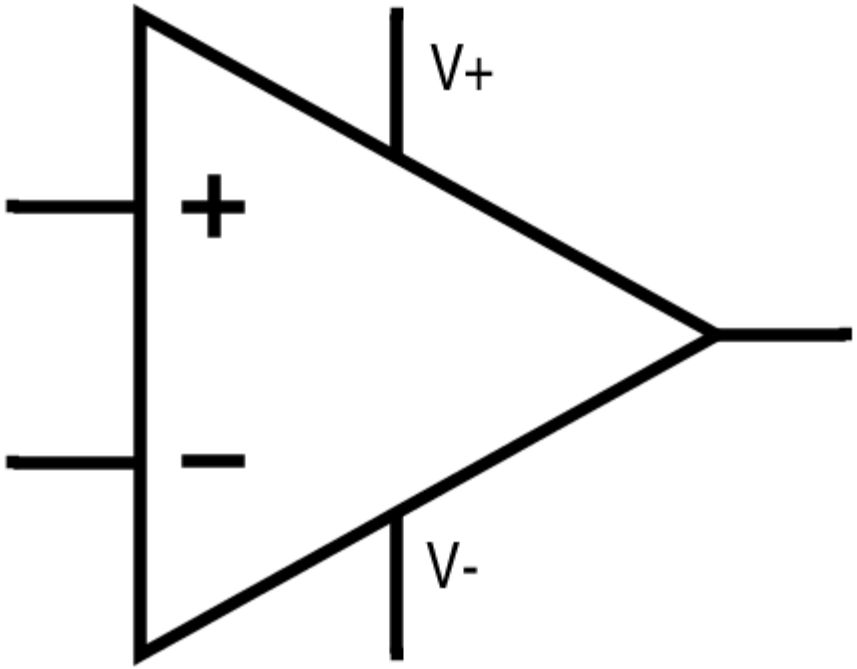
- Every amplifier has some noise input
- Get noise across all frequencies!



- Define noise as V/rt-Hz (voltage per square root Hertz)
- Plug in bandwidth of circuit -> get noise power
- Ours has 3nV/rt-Hz -> 3nV/rt-Hz * sqrt(20kHz) = 0.42uVrms

ADVANCED - PSRR

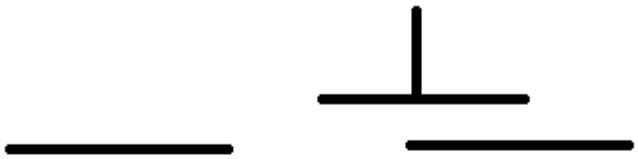
- Op amps don't have three terminals, they have FIVE
- If the supply voltage changes, how much should the output change?
- Ideally none, but of course it's dependent



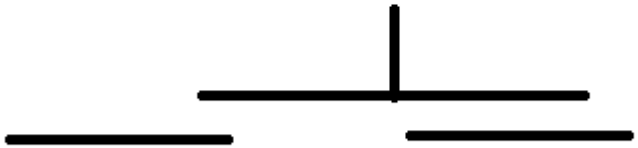
- Called "Power Supply Rejection Ratio" – PSRR
- Ours has 0.5uV/V (output/supply)

SWITCHES

- All switches can be characterized into types
  - MBB (Make Before Break)
  - BBM (Break Before Make)

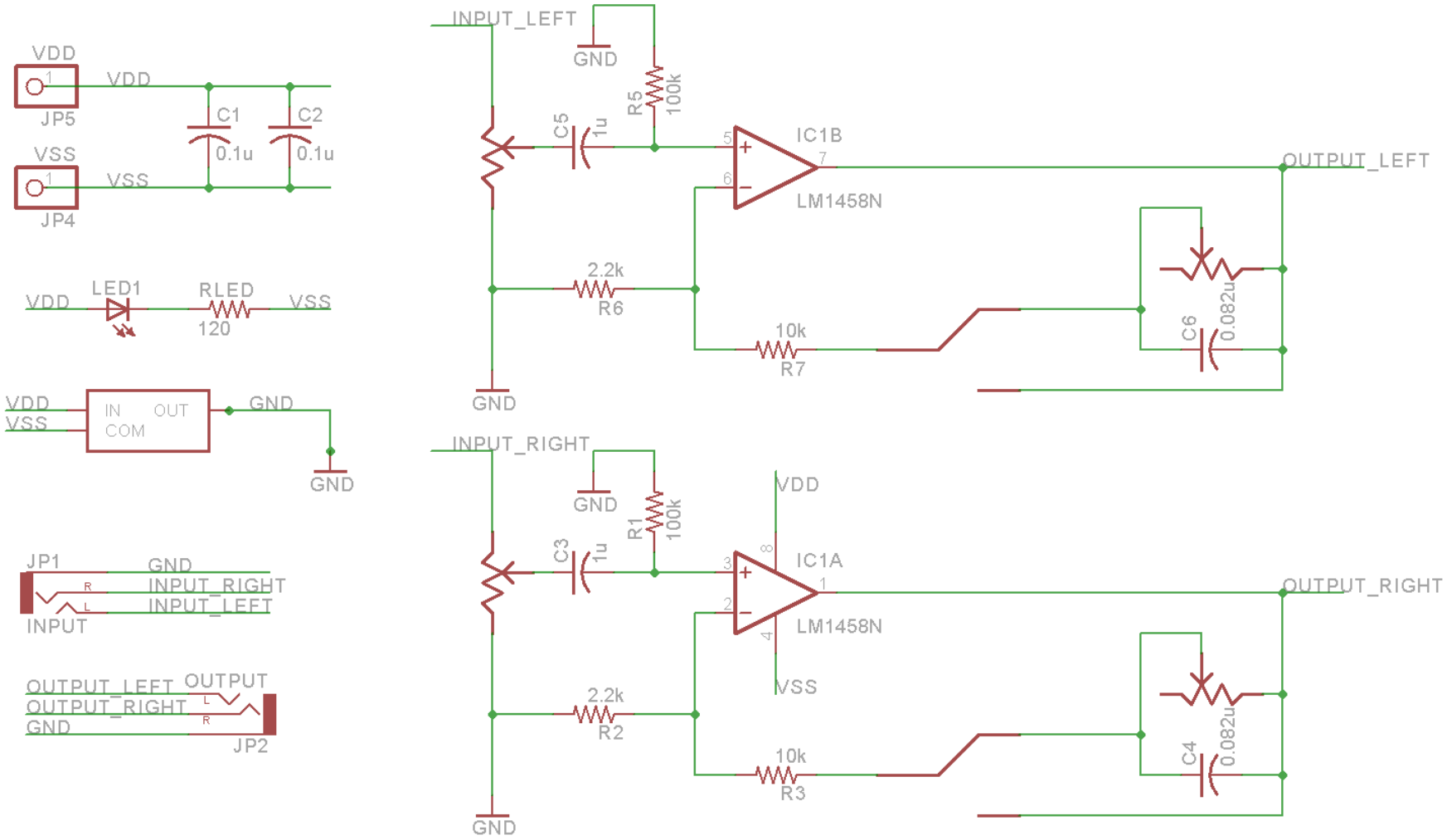


- Which one is better?
  - Depends on application

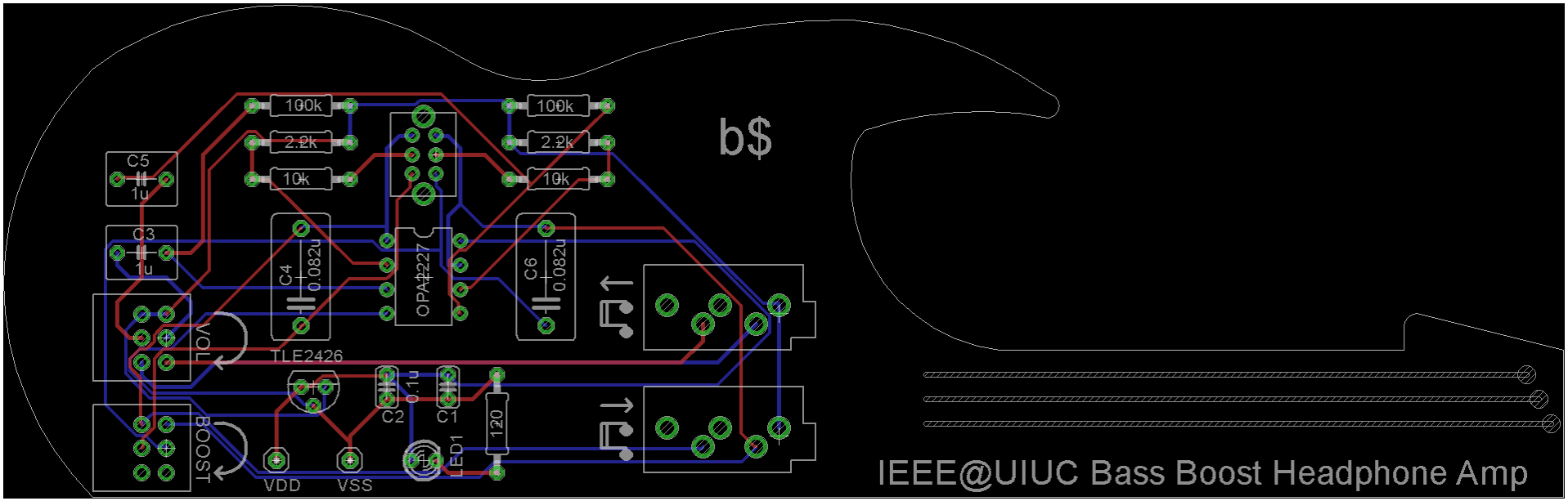


- For this circuit, we use BBM to prevent short circuits

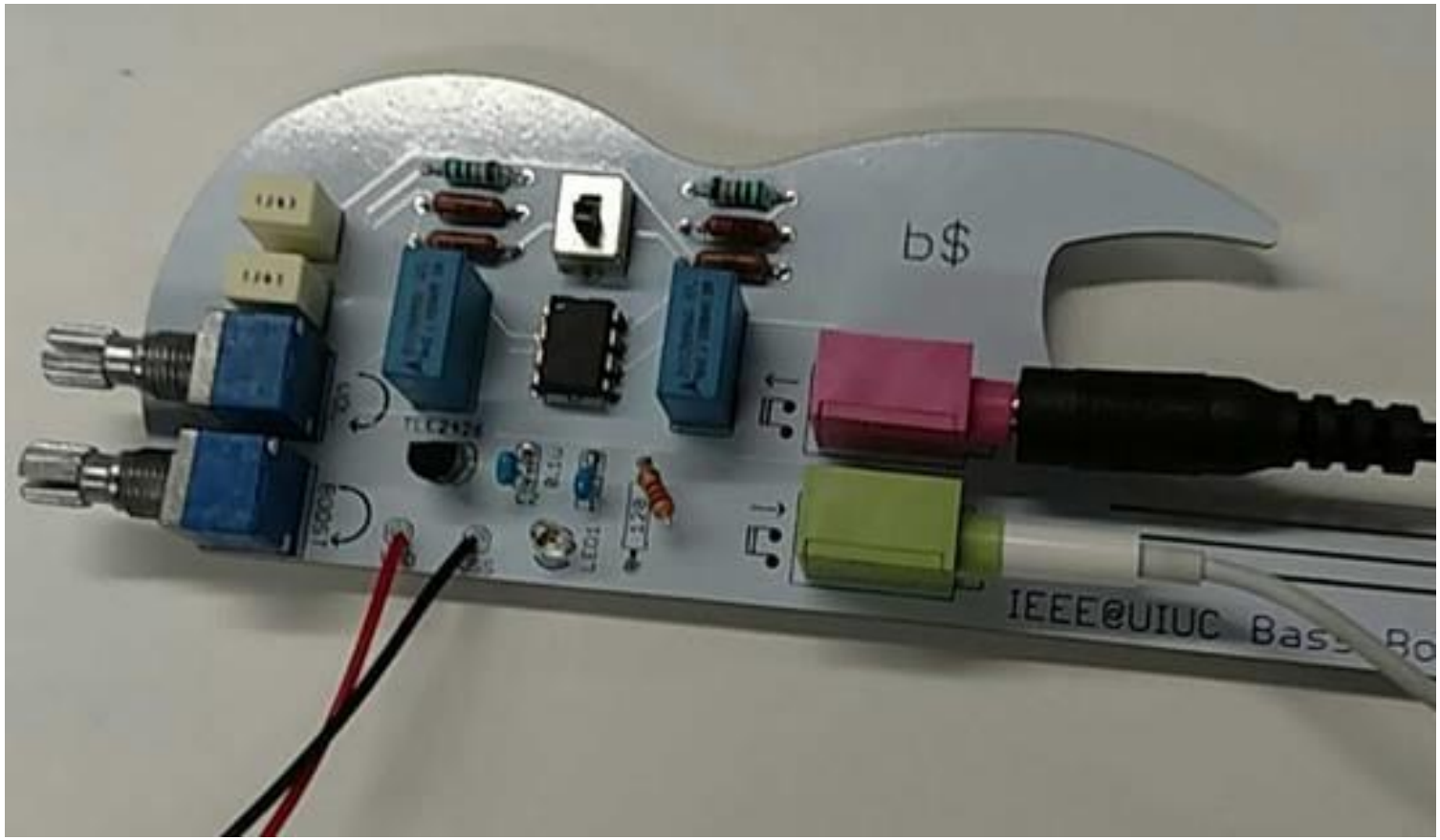
SCHEMATIC


VDD
VDD
JP5
C1
0.1u
C2
0.1u
VSS
VSS
JP4
VDD
LED1
RLED
120
VSS
VDD
VSS
IN
OUT
COM
GND
GND
JP1
GND
INPUT_RIGHT
INPUT_LEFT
INPUT
OUTPUT_LEFT
OUTPUT_RIGHT
GND
OUTPUT
JP2
INPUT_LEFT
GND
R5
100k
C5
1u
IC1B
LM1458N
OUTPUT_LEFT
2.2k
R6
10k
R7
C6
0.082u
GND
INPUT_RIGHT
GND
R1
100k
C3
1u
VDD
IC1A
LM1458N
VSS
OUTPUT_RIGHT
2.2k
R2
10k
R3
C4
0.082u
GND

PCB


100k
2.2k
10k
100k
2.2k
10k
C5
1u
C3
1u
C4
0.082u
OPA227
C6
0.082u
b$
VOL
TLE2426
BOOST
C2
0.1u
C1
LED1
120
VDD
VSS
IEEE@UIUC Bass Boost Headphone Amp

BOARD



CITATIONS

- "CMoy Pocket Amplifier" by Warren Young
  http://tangentsoft.net/audio/cmoy/

- OPA2227 Datasheet
  http://www.ti.com/lit/ds/symlink/opa2227.pdf

- "Op Amp Noise" – Analog Devices
  http://www.analog.com/media/en/training-seminars/tutorials/MT-047.pdf

- "Op Amps for Everyone" – Ron Mancini
  http://123.physics.ucdavis.edu/week_1_files/opamps.pdf

HOW TO USE

- Turn volume, boost to ZERO (CCW)
- Maximize input source volume (laptop, phone, etc)
- Slowly turn up volume to acceptable level
- Slowly turn boost to acceptable level
  - If not apparent, hit the switch
- ENJOY
- P.S. It's a preamp, not an amp!