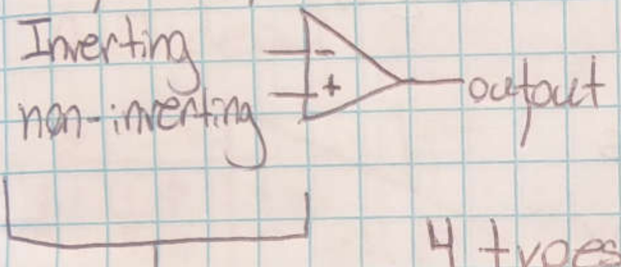
Operational Amplifier (linear)

Acts in conjunction with out side feed back from other components

Feedback: resistance, capacitive

Op-Amp is a 3 terminal device



output can sink or source either voltage or current

4 types of gain

Voltag - volt

Current - curr

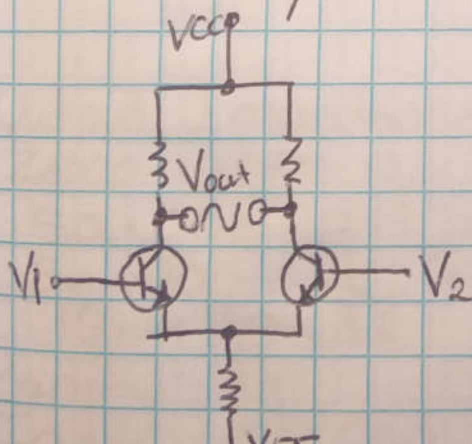
Transconductance - Volt

Transresistance - curr

- most common

Voltage output $= \beta(\text{Inv} - n\text{Inv})$

Diff amp



- a dual supply Vcc & VEE ensures constant supply
- The voltage that appears at the output is the difference between the two ~~tw~~ inputs
- inputs are antiphase

Inputs are identical
This is common mode of operation with common mode gain being gain when input is zero

Real life there is some variation CM RejectinoRatio

Voltage gain (A) = $\frac{V_{out}}{V_{in}}$

GBP = Gain x Bandwidth = A x BW

Convert gain to decibles

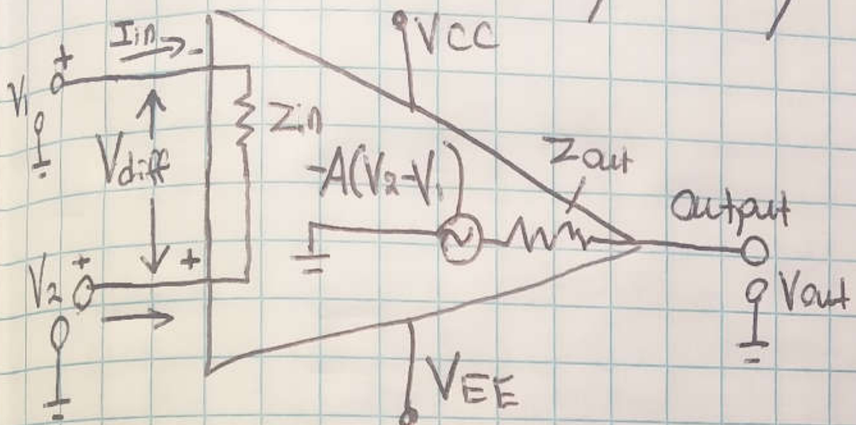
$20 \log (A)$ or $20 \log \frac{V_{out}}{V_{in}}$

an amplifiers band width
is inversly proportional to gain

Op-amps naturally have very high gain when open loop

gain can be controlled by adding negative feed back

An Ideal ~~Out~~ Op-Amp



A

Open loop gain (Infinite) gain without feed back (usually between 20,000 & 200,000) the higher the better

Input Impedance (Z_{in})
Ideally Infinite
prevent supply current from leaking into input circuitry).
real amps between a few pico-amps & a few milli-amps

Output Impedance (Z_{out})
zero acts as a perfect Internal voltage source allowing the load to be fully supported. in reality is between 100 - 20k Ω

Bandwidth
Infinite an Ideal Amp has an infinite freq response. In real amps it is limited to ~~the place~~ the Gain Bandwidth product which is the freq where the amps gain becomes unity.

Offset Voltage (V_{IO}) should be zero when
Zero - The output is zero
the Input difference

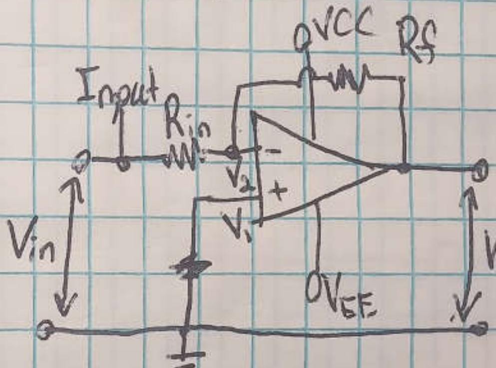
Inverting Op Amp

To reduce the substantial amount of gain the Amp must have feedback

Negative feed back is feeding a portion of the output to the negative or inverting input

To do this we use a feedback resistor this produces Closed-Loop Gain

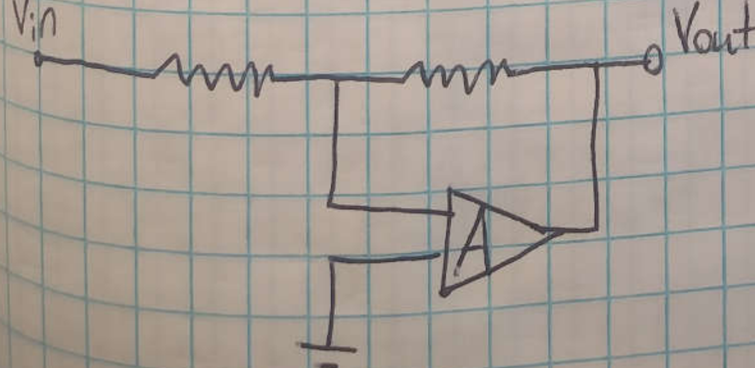
What goes into the amp is a sum of both input & some output



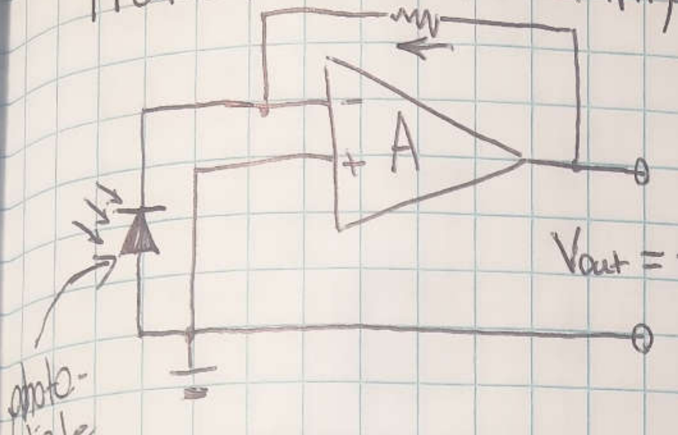
The input needs to be separated from the inverting pin by a resistor to limit the current that can flow back into the input

Rules: no current flows into the inputs & $V_2 = V_1$ always

$$\text{Gain }(A_v) = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}} \quad \text{or} \quad V_{out} = -\frac{R_f}{R_{in}} \cdot V_{in}$$



Transresistance Amp

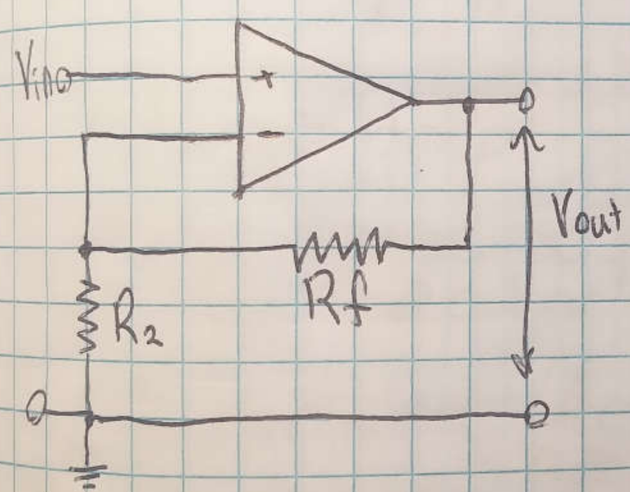


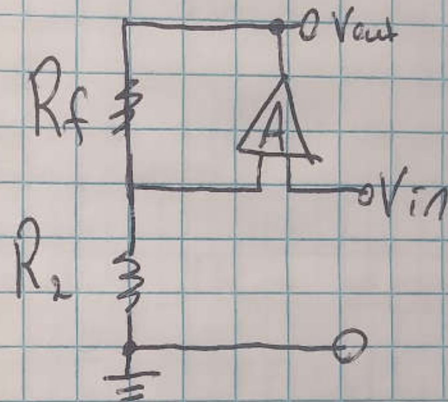
$V_{out} = -I_s \times R_f$

Converts a small current into a measurable voltage

Voltage output is proportional to the current generated

Non-Inverting





$A = 1 + \frac{R_f}{R_2}$

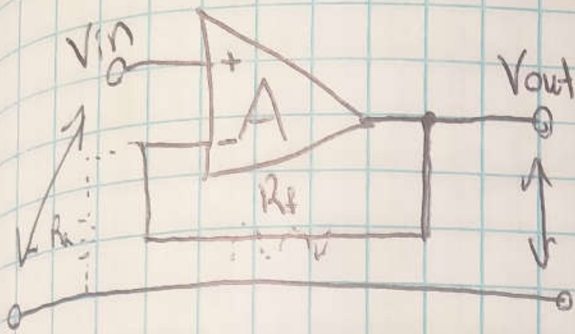
The gain will always be greater than one and if the Rf is zero then the gain will always be at unity (1)

as R_2 decreases the amplification ~~is~~ increases towards infinity.

if R_2 = infinity & $R_f = 0$ this produces a Voltage follower or Unity gain Buffer

allows for circuit isolation and increasing availible current without changing voltage.

Unity Gain Buffer



$R_f = 0$
$R_2 =$ infinity

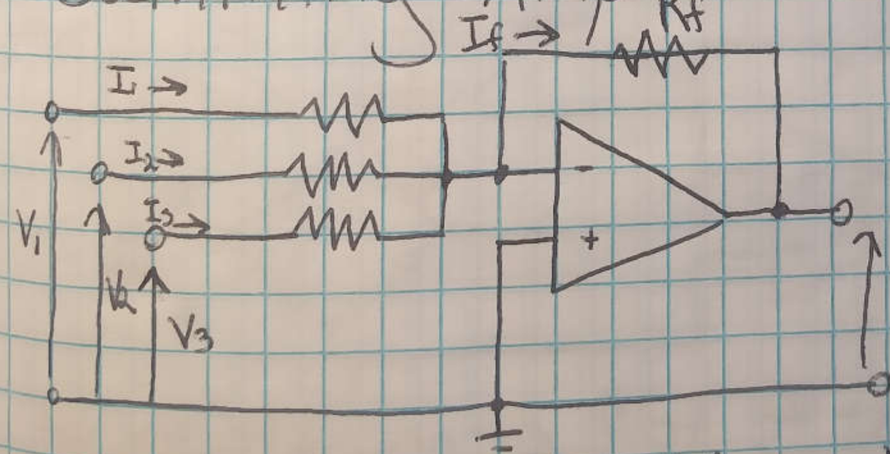
Can provide substantially more power at at a consilstent voltage

used to isolate circuits from each other especially in high-order state variable or active filters to separate filter stages (Sallen-Key type ~~buffers)~~ filters)

requires zero current & thus zero voltage drop

often times a 1k resistor will be placed in the feedback loop to limit current

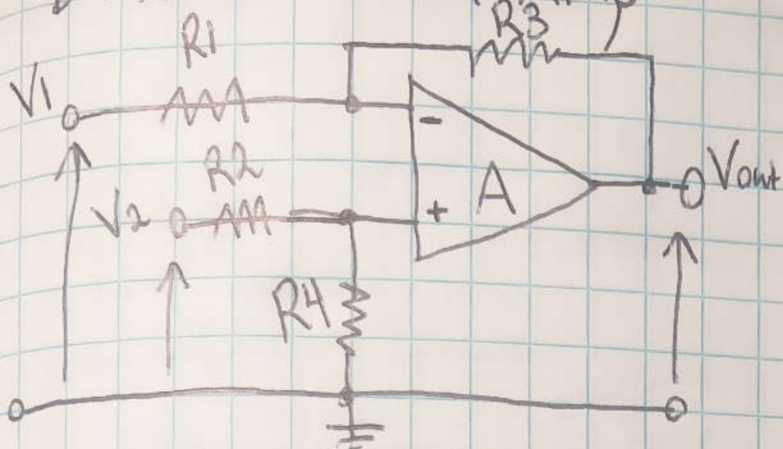
Summing Amp



$I_f = I_1 + I_2 + I_3$ $\qquad$ $-V_{out} = \dfrac{V_1 R_f}{R_1} + \dfrac{V_2 R_f}{R_2} + \dfrac{V_3 R_f}{R_3}$

applications as an audio mixer, digital to analog converter summing things and choosing their weight before summing

Differential Amp



all amps are esentially differential amps as the output is proportional to the difference between inputs

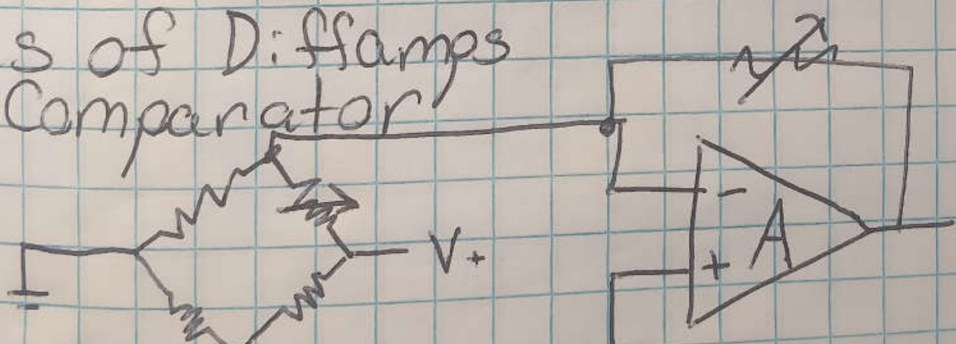
$$V_{out} = -V_1\left(\frac{R_3}{R_1}\right) + V_2\left(\frac{R_4}{R_2+R_4}\right)\left(\frac{R_1+R_3}{R_1}\right)$$

When $R_1 = R_2$ & $R_3 = R_4$

$$V_{out} = \frac{R_3}{R_1}(V_2 - V_1)$$

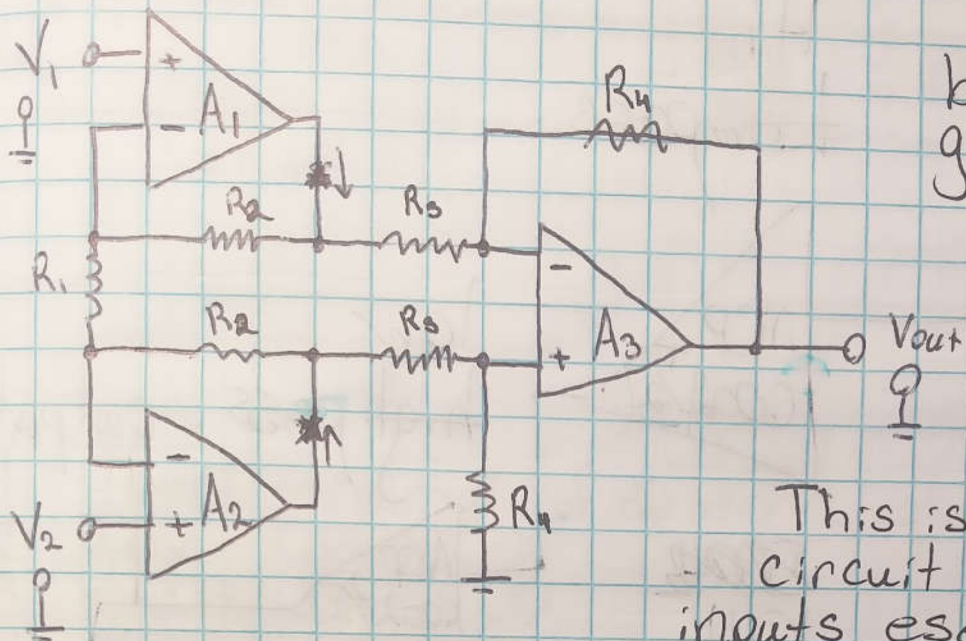
If all resistors are equal the system becomes a unity gain diff amp and $V_{out} = V_2 - V_1$

Types of Diffamps
Comparator



by replacing a foot of the bridge with some type of variable resistor like a thermistor or a Light dependent resistor the output can be as sensative as the bridge + feedback allow

High input impedance Instrumentation Amp



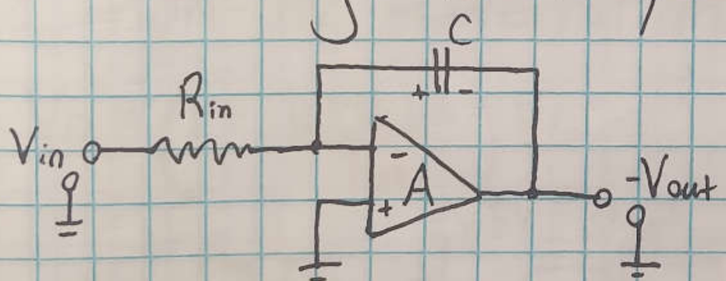
A1 & A2 act as buffers with a gain of

$$1 + 2R_2/R_1 = \beta(A)$$

$$V_{out} = (V_2 - V_1)\left[1 + \frac{2R_2}{R_1}\right]\left(\frac{R_4}{R_3}\right)$$

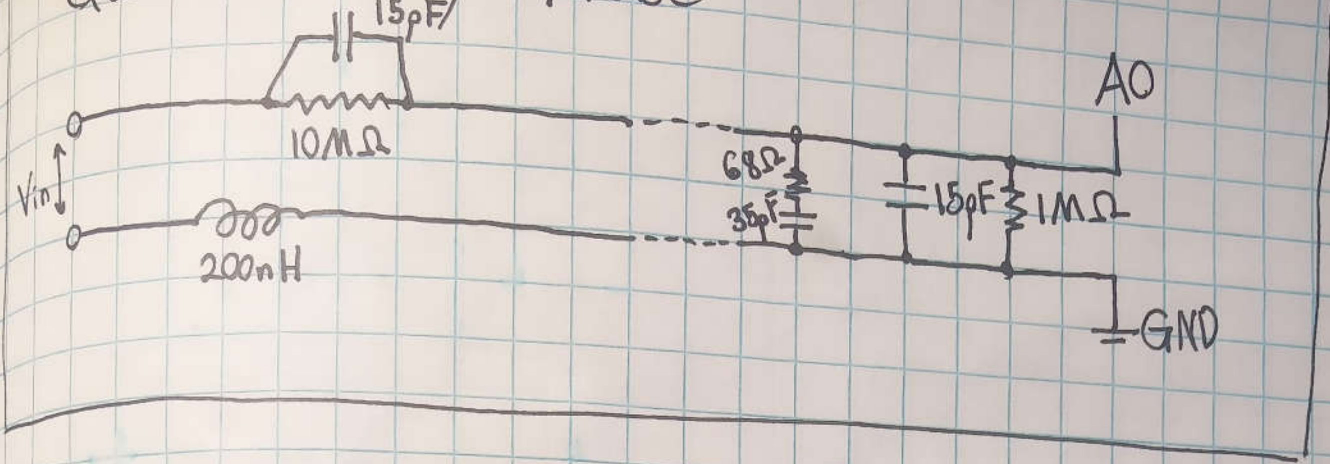
This isolates the circuit by making the inputs esentially infinitly higher impedence than the unity buffer amps

The integrator Amp



replaces the R_f of an inverting amp with a Cap

Quick Oscilloscope Probe

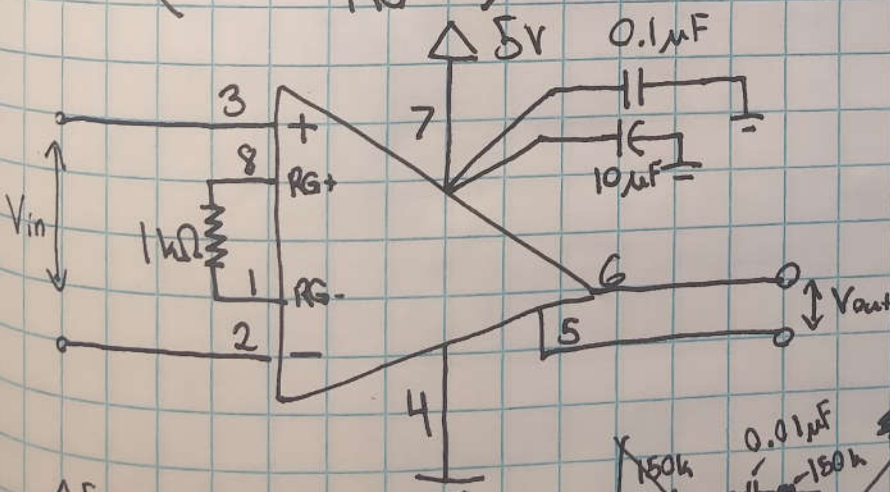


AD623

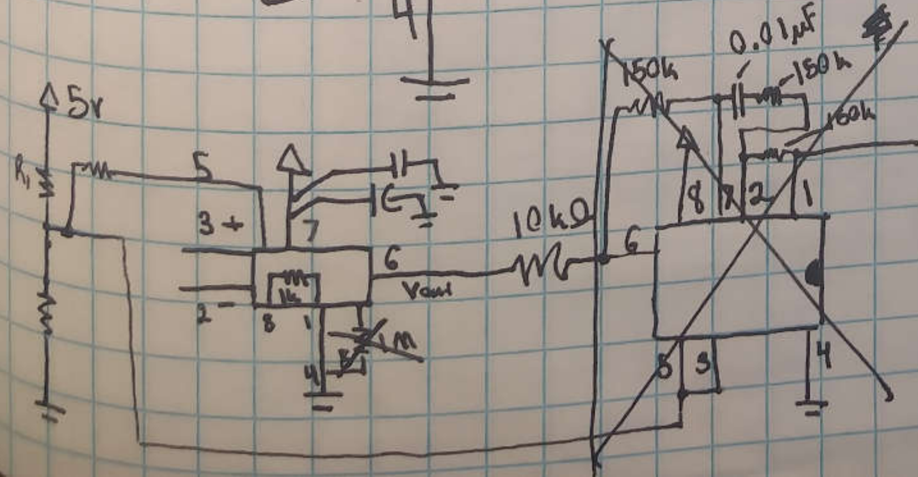
1 Invert terminal of external gain setting resistor
2 Inv - Input (−)
3 n-Inv Input (+)
4 VEE −
5 Ref input establishes common mod voltage
6 Output
7 Vcc +
8 non-inv external gain setting

$$V_0 = \left(1 + \frac{100k\Omega}{R_G}\right) V_c$$

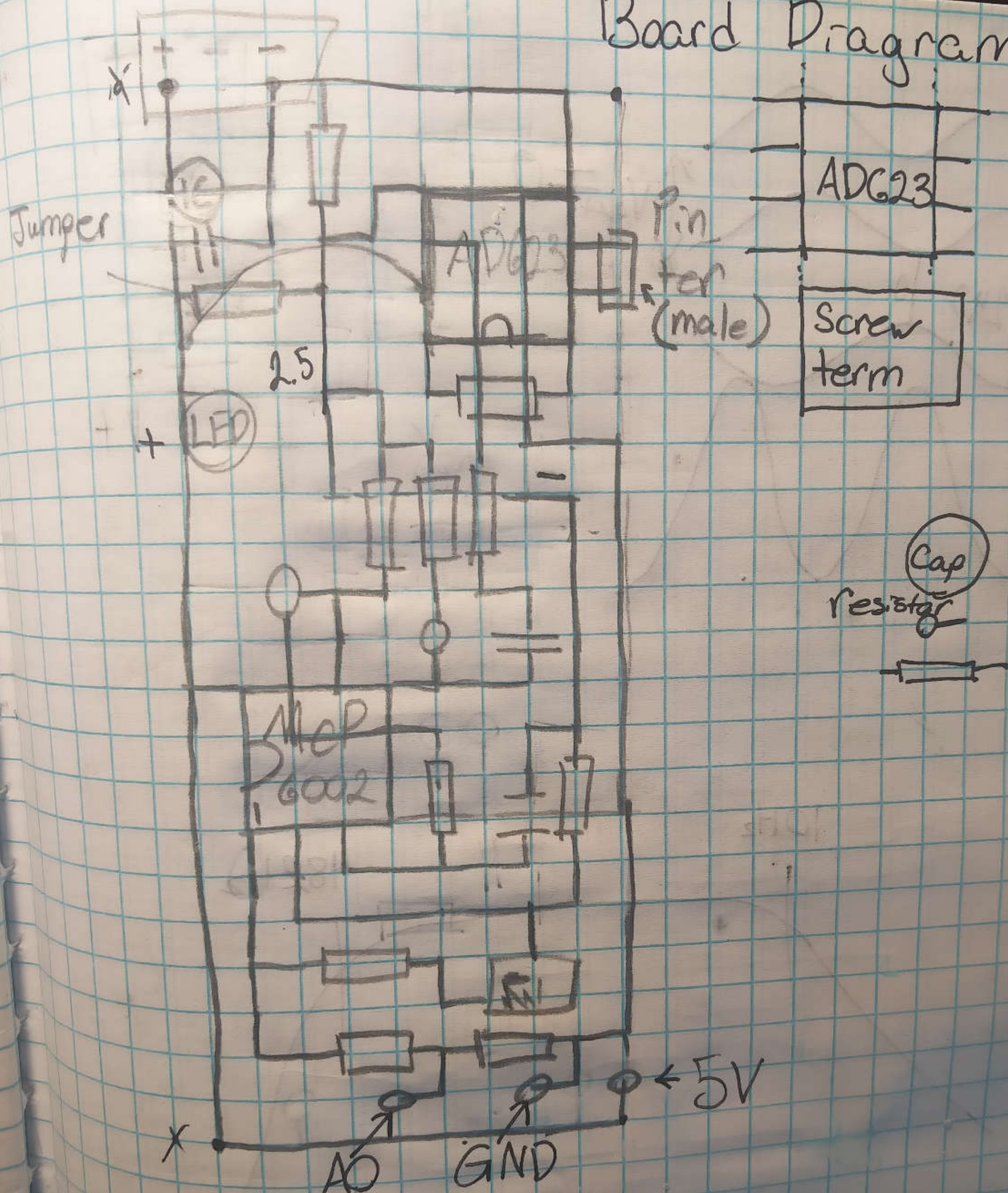
→ Signal aq



Gain = ~100

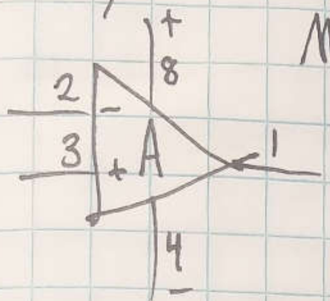


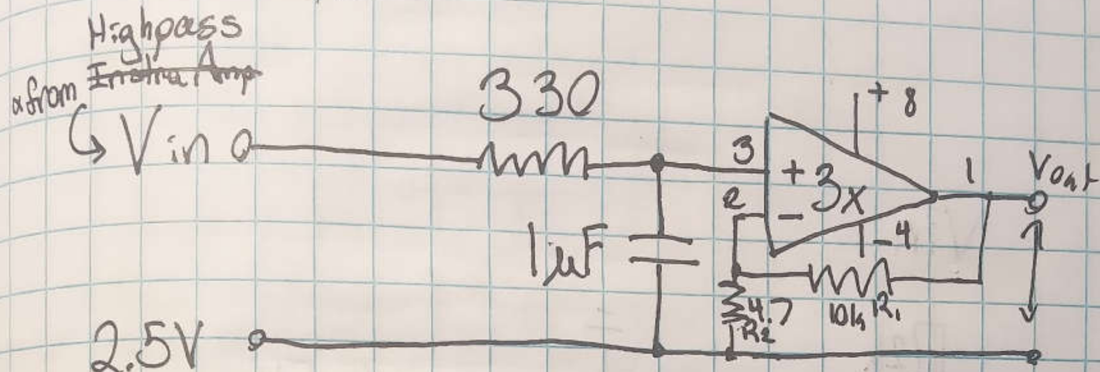
Board Diagram



low pass filter

MCP6002(½)





$1 + \frac{R_1}{R_2}$

$3.128 = 1 + \left(\frac{10k}{4.7k}\right) = A$

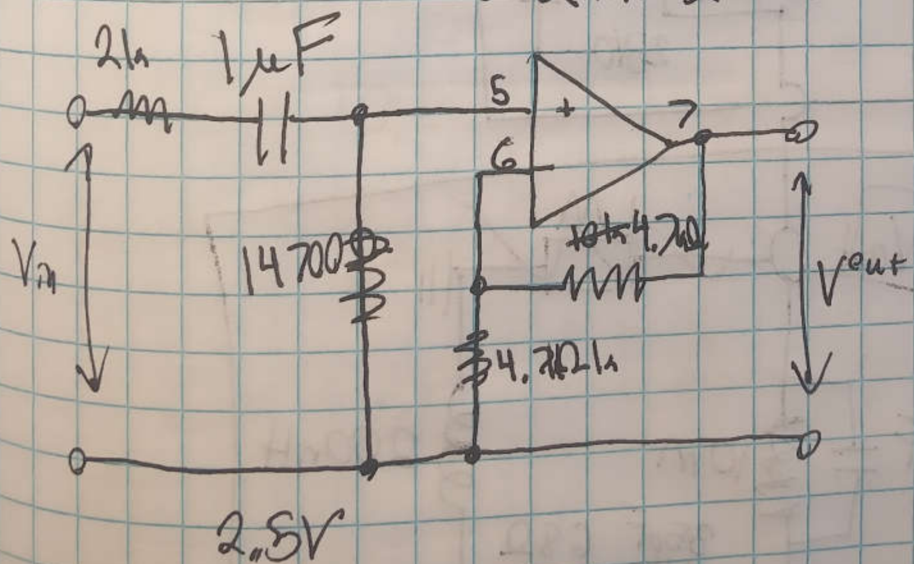
$f_c \approx 500\text{ Hz}$

$$\frac{1}{2\pi(330)(1\times10^{-6})} = \boxed{482\text{ Hz}}$$

Highpass filter

$f_c \approx 10\text{ Hz}$

$$\frac{1}{2\pi(1\times10^{-6})(14700)} = \boxed{10.83\text{ Hz}}$$



$\frac{10k}{4.7}$