Operational Amplifiers
Op-amp for short

Pat Arnott 360 ATMS

'History'

1928 Harold Black invents feedback amplifier.

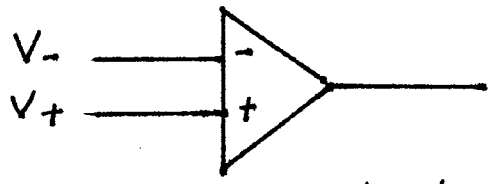
1947 Ragazzini first uses the term Operational Amplifier in print.
Bardeen, Brattain, and Shockley of Bell LABS discover the transistor effect.
< Transfer of Resistance

1953 First commercially available vacuum tube op-amp.

1958 Jack Kilby of Texas Instruments invents the integrated circuit.

1963 Bob Widlar of Fairchild designs the first monolithic IC op-amp ⇒ Single chip.

Basic Op-Amp

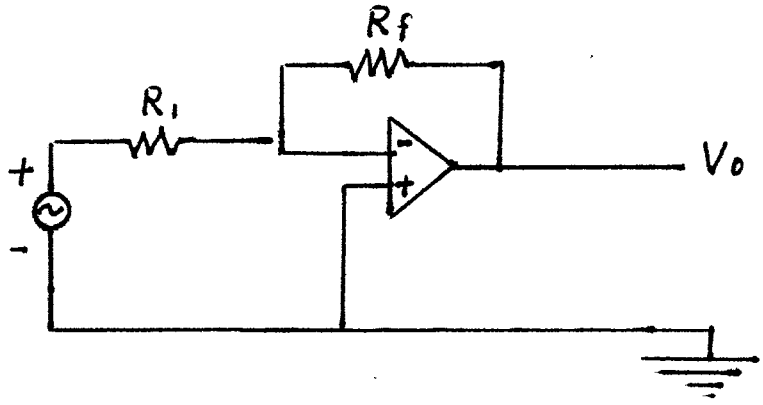


Inputs:
V_+ & V_-

Output:
$A(V_+ - V_-)$
↑
Huge

A = Gain ≈ 100,000

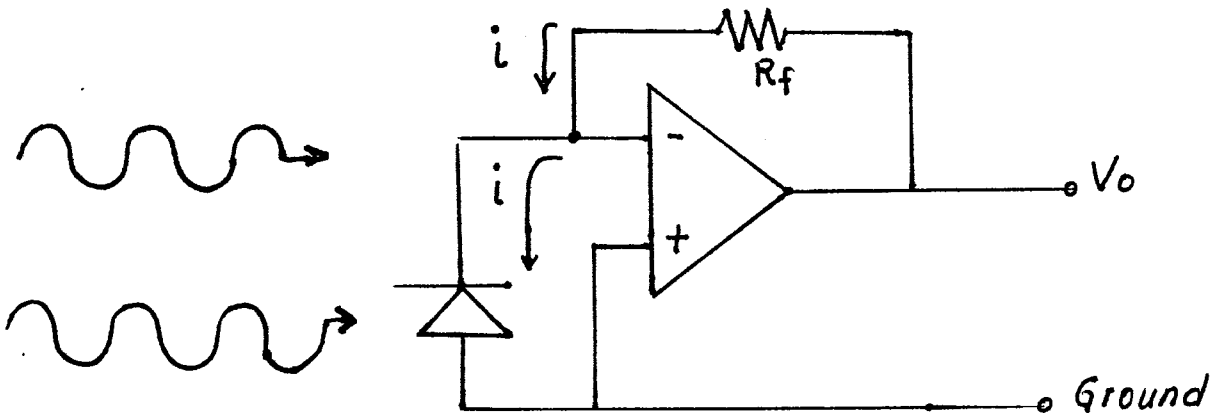
Need to clobber the gain a bit to reduce the instability:



Feedback some of the output to the input to reduce instability.

Transimpedance Amplifier

(Turn the current produced by an LED with light shining on it, into a measurable voltage).



Analyze this circuit using the Op-amp golden rules

1) V_o feedback keeps the voltage the same at the - and + terminals of the Op-amp.

2) The - and + terminals have extremely high input impedance: No current flows into either terminal.

Analysis: i = current generated by the LED when light shines on it.

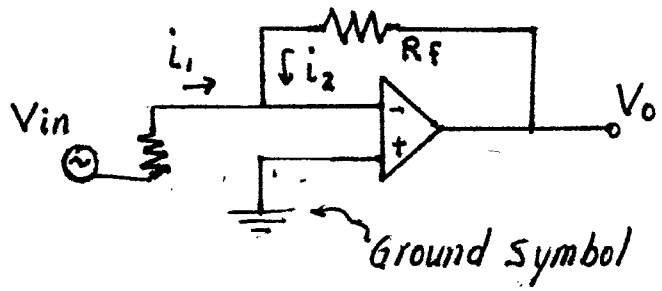
From rule 2, i is the current flowing through R_f also.

From rule 1, - and + terminals are both at ground voltage.

Ohms Law gives $V_o = iR_f$ or $i = 1\,\mu a$, $R_f = 1\,M\Omega$
$V_o = 1$ volt

Simple Circuits

1) Inverting Amplifier:



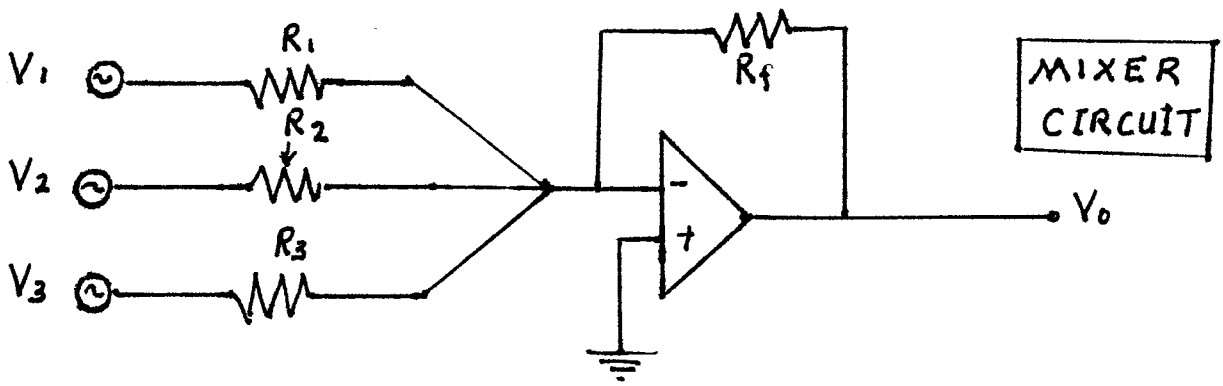
Output is measured from Vo to ground.
Goal: Amplify Vin by turning it into Vout

Vo is the output voltage
Vin is the input voltage

- Sign inversion ⇒
Gain = R_f / R_1

Rule 2: $i_1 + i_2 = 0$

Rule 1 & Ohm's Law: $\frac{Vin}{R_1} + \frac{V_o}{R_f} = 0$, So $\boxed{\frac{V_o}{Vin} = -\frac{R_f}{R_1}}$



$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \frac{V_o}{R_f} = 0$ With $R_1 = R_2 = R_3$

$$\boxed{V_o = -(V_1 + V_2 + V_3)\left(\frac{R_f}{R_1}\right)}$$

Gain = R_f / R_1

Input voltages are summed & amplified