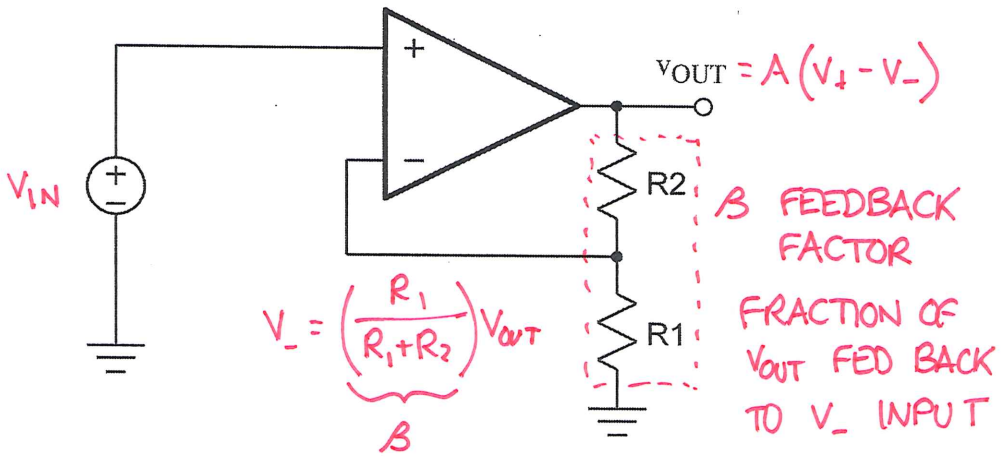
ECE3204 Lecture 4

Negative Feedback
Noninverting Gain (2.3)
Inverting Gain (2.2)
Bandwidth Limit (2.7)

Hand in: HW 1

HW 2 online

Noninverting gain op-amp circuit



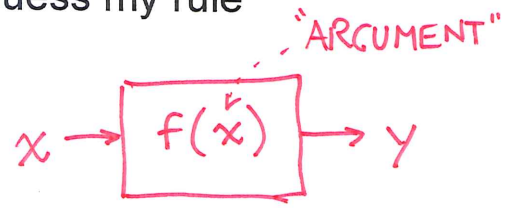
MATH $\Rightarrow$ $V_{OUT} = A(V_{IN} - \beta V_{OUT})$

$V_{OUT}(1 + A\beta) = A V_{IN}$

$\frac{V_{OUT}}{V_{IN}} = \underbrace{\frac{A}{1+A\beta}}_{A\beta \gg 1} \Rightarrow \frac{1}{\beta}$

DETERMINED BY FEEDBACK, NOT A ✓

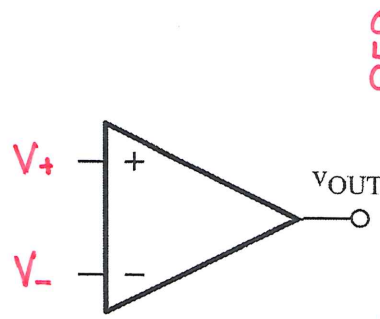
"Guess my rule"



x	y
32	1022
0	-2
100	9998
5	23
1	-1

$f(x) = x^2 - 2$

Op-amp's "rule"



ALL THE OP-AMP "KNOWS" ABOUT THE EXTERNAL WORLD

HOW DOES V_{OUT} CHANGE?

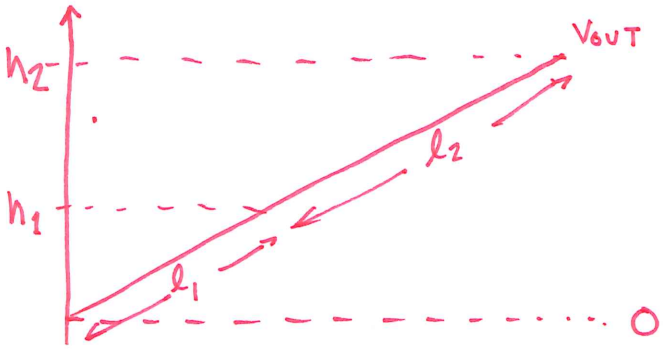
$V_+ > V_- \Rightarrow V_{OUT} \uparrow$

$V_- > V_+ \Rightarrow V_{OUT} \downarrow$

$\Rightarrow$ WHICHEVER INPUT (+ OR −) IS HIGHER (MORE POSITIVE) IN VOLTAGE TELLS ↑ OR ↓ OF OUTPUT

Analog Stick of Knowledge

Height - Voltage analogy

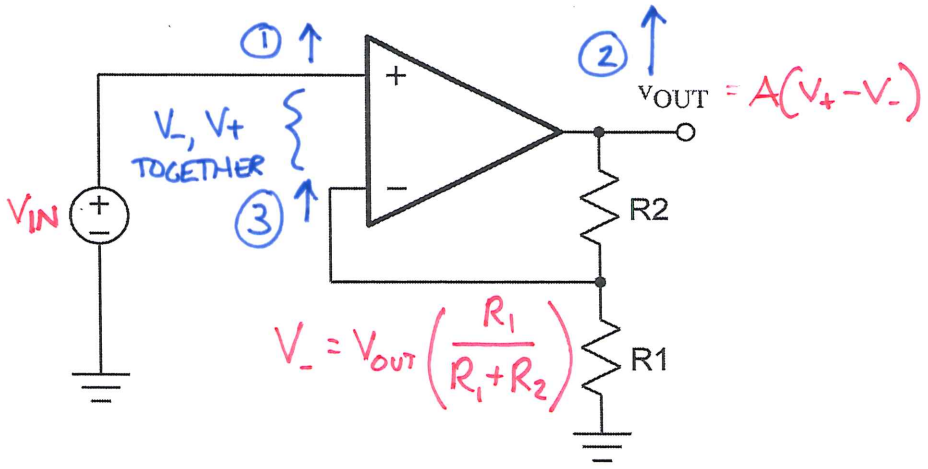


SIMILAR TRIANGLES

$$\frac{h_1}{l_1} = \frac{h_2}{l_1+l_2}$$

$$h_1 = h_2\left(\frac{l_1}{l_1+l_2}\right)$$

Noninverting gain op-amp circuit



① V_{IN} ↑

② RULE: V_{OUT} ↑

③ VOLTAGE DIVIDER: V_- ↑ BY SOME FRACTION $\frac{R_1}{R_1+R_2}$

$$V_{OUT} = A(V_+ - V_-)$$

$$V_+ - V_- = \frac{V_o}{A}$$ IF IN LINEAR REGION

Op-Amp Analysis

FIRST: CHECK NEGATIVE FEEDBACK
1. Change v_{IN}
2. Follow change around loop
3. Does v_{OUT} change to keep v_-, v_+ together?
   If yes: negative feedback

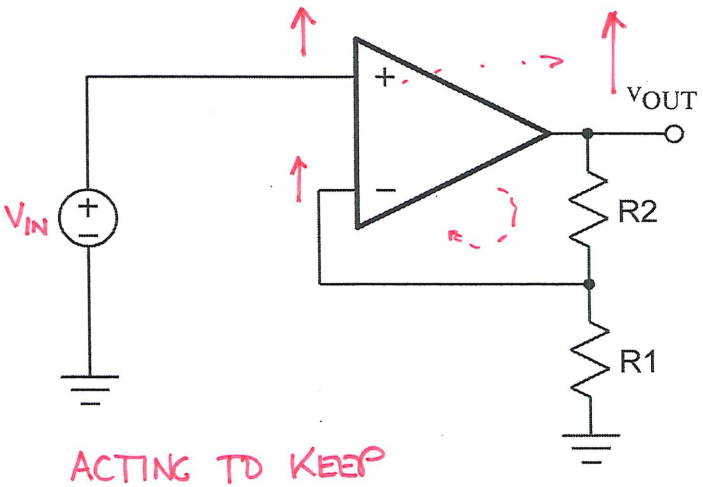
THEN $v_- \approx v_+$

(How ≈ ? Depends on A large)

$A = 200000$

$V_{OUT} = \pm 14V$ / 200000 $\quad \pm 70\mu V$

Simpler analysis of noninverting gain op-amp circuit



ACTING TO KEEP V_-, V_+ TOGETHER:

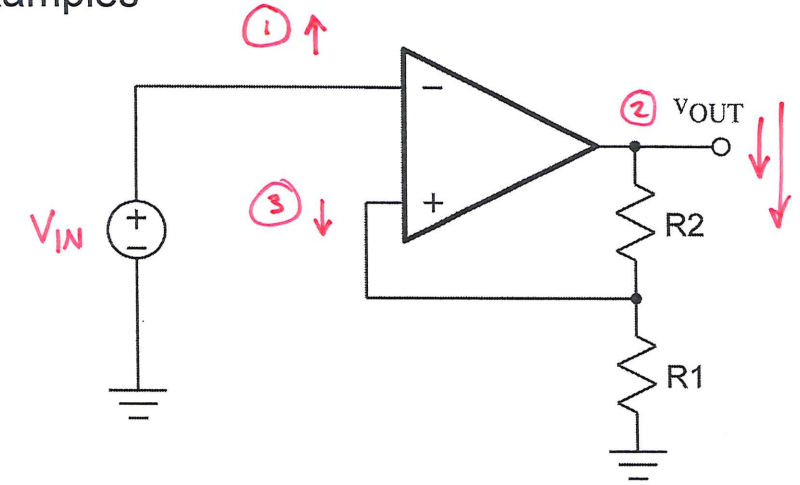
NEGATIVE FEEDBACK

$V_- = V_+$ $\quad A \to \infty$

$$\left(\frac{R_1}{R_1+R_2}\right) V_{OUT} = V_{IN}$$

$$V_{OUT} = \left(\frac{R_1+R_2}{R_1}\right) V_{IN}$$

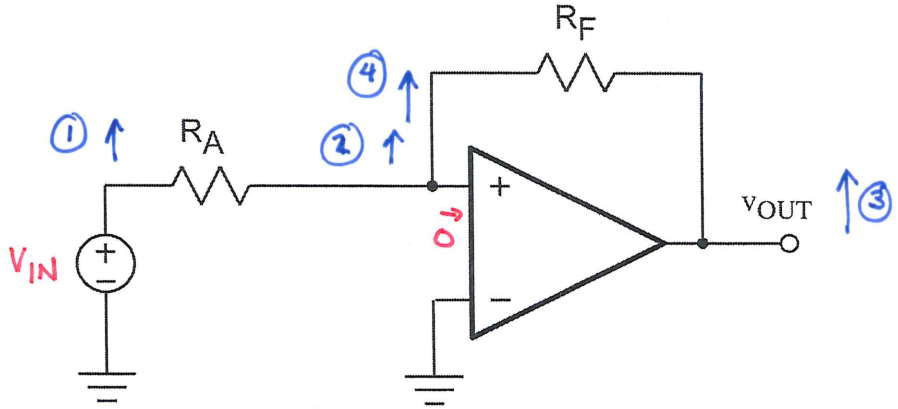
Examples



NEGATIVE FEEDBACK? NO!

V_-, V_+ APART!

$V_- \neq V_+$



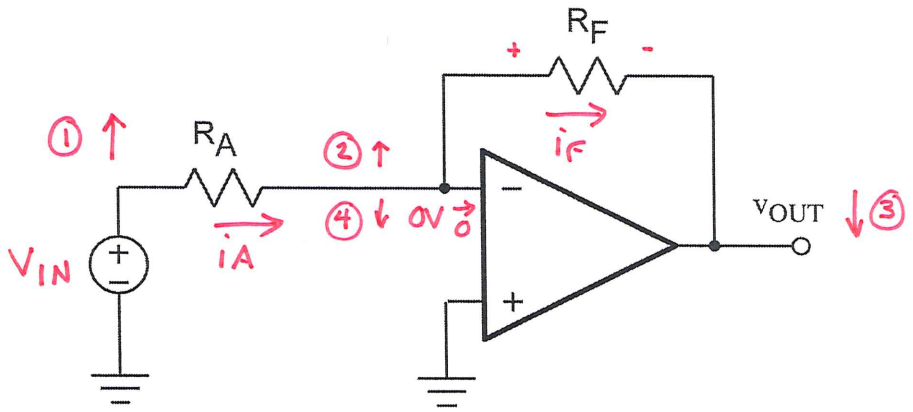
SUM = 1

$$V_+ = \left(\frac{R_F}{R_A + R_F}\right) V_{IN} + \left(\frac{R_A}{R_A + R_F}\right) V_{OUT}$$

PULLS V_+ AWAY FROM V_-

NOT NEGATIVE FB!

Inverting Gain Op-Amp Circuit



LOOP TRIES TO KEEP $V_- = V_+$: NEGATIVE FEEDBACK ✓

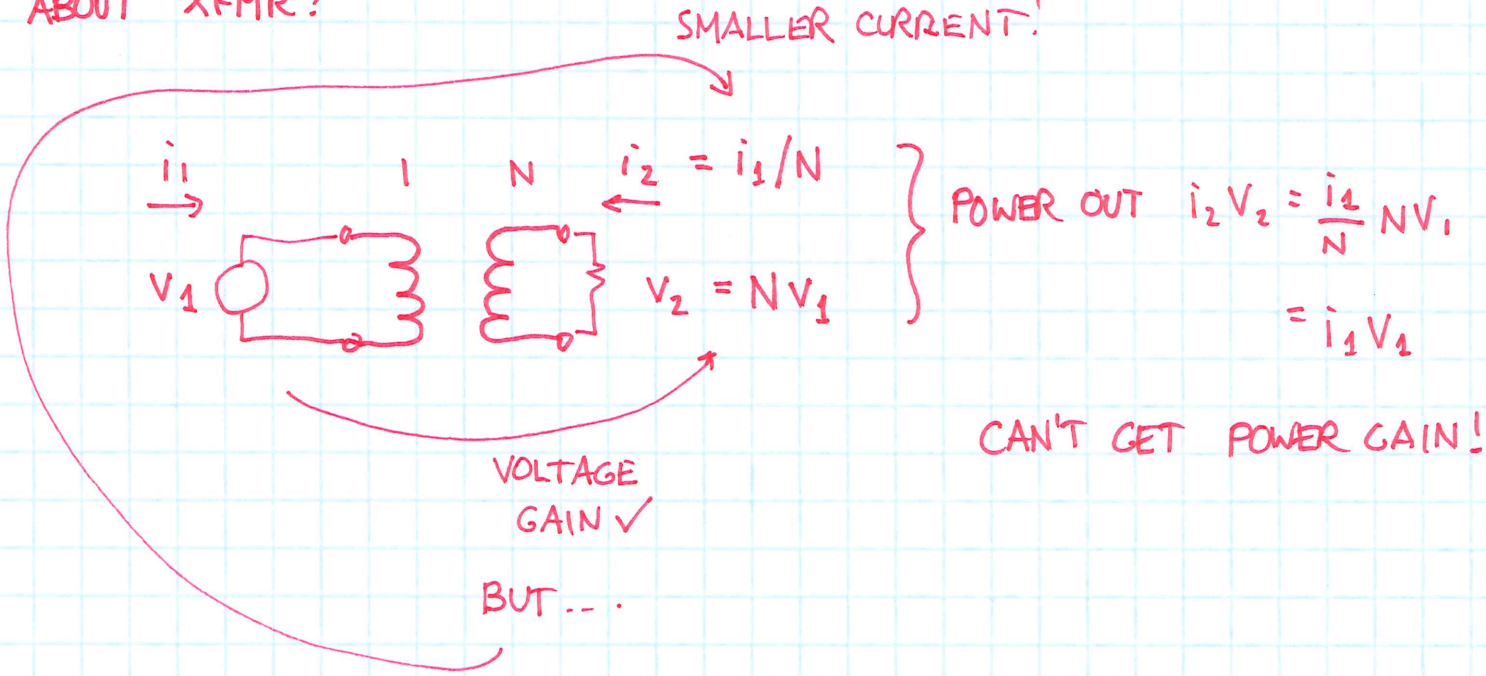
$\Rightarrow V_- = V_+ = 0V$

"VIRTUAL GROUND"

KCL AT V_- INPUT: $I_A = i_F$

OHM'S LAW $\frac{V_{IN}}{R_A} \quad \frac{-V_{OUT}}{R_F}$ $\Rightarrow V_{OUT} = \left(\frac{-R_F}{R_A}\right) V_{IN}$

WHAT ABOUT XFMR?



POWER OUT $i_2 V_2 = \frac{i_1}{N} NV_1$

$= i_1 V_1$

CAN'T GET POWER GAIN!