

LAST TIME CH. 28

OP AMPS
NEGATIVE FEEDBACK
GOLDEN RULES

TODAY CH. 29 (THROUGH P. 260)

REVIEW GOLDEN RULES
LOTS OF EXAMPLES
ADDITION & SUBTRACTION OF SIGNALS
I-V CONVERTER
ETC.

COMPAD

GOLDEN RULES REVIEW

ASSUMPTIONS:

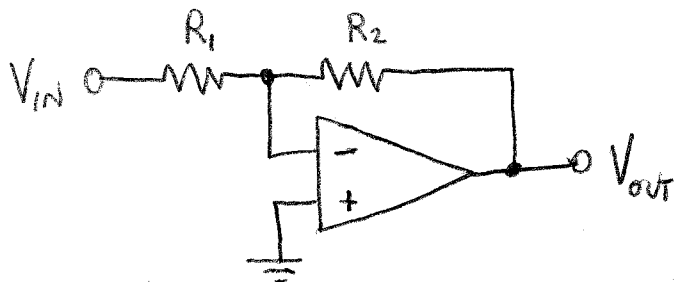
- IDEAL OP AMP
- ASSUME NOT SATURATED ($-V_s < V_{out} < V_s$, WITH MARGIN)
- NEGATIVE FEEDBACK

I. $V_+ = V_-$

II. $i_+ = i_- = 0$

EVERY CIRCUIT IN CH. 28 IS AN APPLICATION OF THESE RULES.

INVERTING AMPLIFIER (FAISSLER CH. 28)



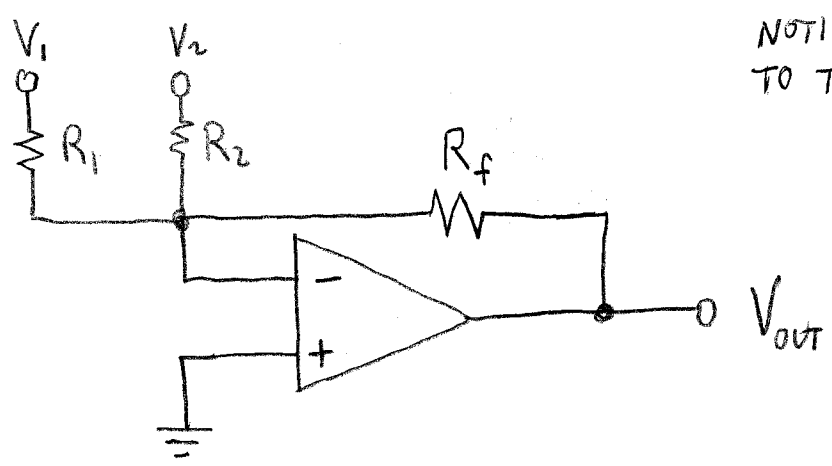
$$V_+ = V_- = 0$$

$$\frac{V_{IN} - 0}{R_1} + \frac{V_{OUT} - 0}{R_2} = 0$$

$$V_{OUT} = -\frac{R_2}{R_1} V_{IN}$$

BY THE WAY, THE RELATIONSHIP THAT GIVES A CIRCUIT'S OUTPUT(S) IN TERMS OF ITS INPUT(S) IS CALLED A TRANSFER FUNCTION.

INVERTING ADDER



NOTICE THE SIMILARITY TO THE INVERTING AMP!

AS WITH THE INVERTING AMP,

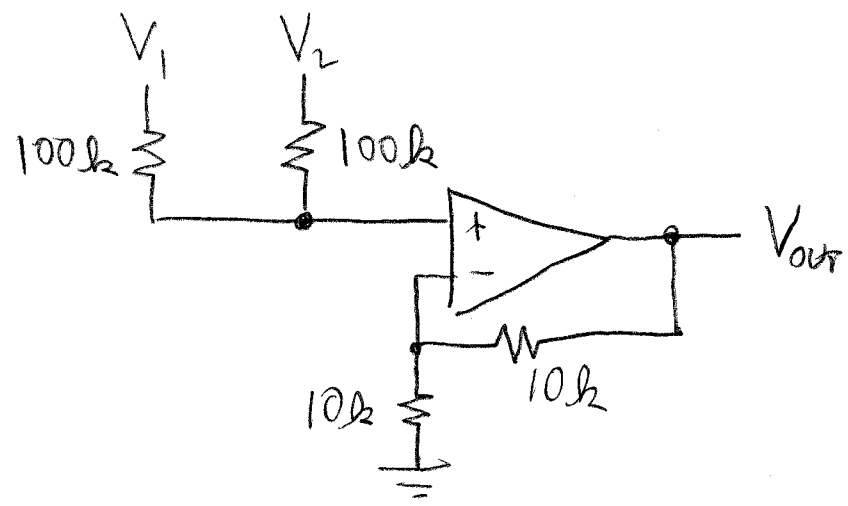
$$V_+ = V_- = 0.$$

KCL: $\frac{V_1 - 0}{R_1} + \frac{V_2 - 0}{R_2} + \frac{V_{out}}{R_f} = 0$

$$V_{out} = -\frac{R_f}{R_1} V_1 - \frac{R_f}{R_2} V_2$$

SRIPAD

AN ADDER THAT DOES NOT INVERT:



$$\frac{V_1 - V_+}{100k} + \frac{V_2 - V_+}{100k} = 0$$

$$\Rightarrow V_+ = \frac{1}{2}(V_1 + V_2)$$

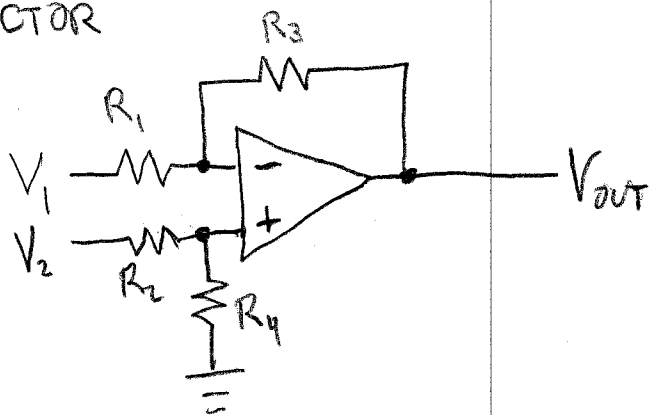
$$\frac{V_{out} - V_-}{10k} + \frac{0 - V_-}{10k} = 0$$

$$\Rightarrow V_{out} = 2V_-$$

SINCE $V_+ = V_-$,

$$V_{out} = V_1 + V_2$$

SUBTRACTOR



$$\frac{V_1 - V_-}{R_1} + \frac{V_{out} - V_-}{R_3} = 0$$

$$\Rightarrow (V_1 - V_-) \frac{R_3}{R_1} + (V_{out} - V_-) = 0$$

$$\Rightarrow V_{out} = V_- \left(1 + \frac{R_3}{R_1} \right) - V_1 \left(\frac{R_3}{R_1} \right)$$

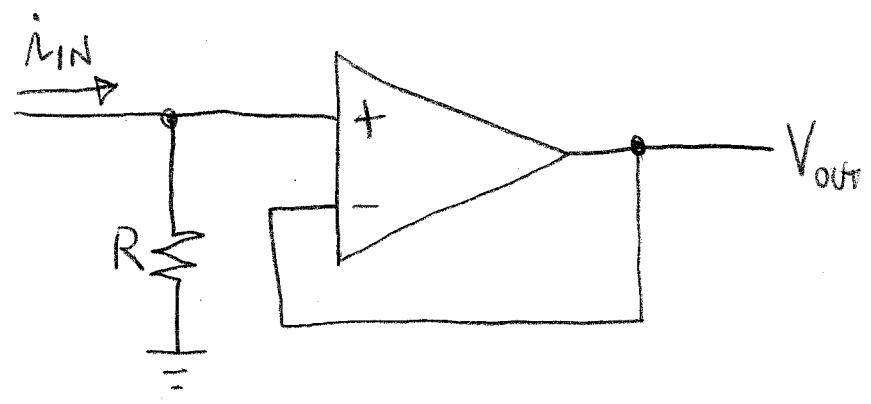
$$V_- = V_+ = \left(\frac{R_4}{R_2 + R_4} \right) V_2 \quad (\text{VOLTAGE DIVIDER})$$

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

Q: How would you get

$$V_{out} = 2V_2 - 2V_1 \quad ?$$

CURRENT TO VOLTAGE CONVERTER (DIFFERENT FROM FAISSLER'S VERSION)



$$V_{OUT} = V_- = V_+ = i_{IN} R$$

Q: HOW WOULD YOU MINIMIZE THE INPUT IMPEDANCE?
(CAN YOU SEE HOW THIS MAKES A MORE USEFUL CURRENT SENSOR?)

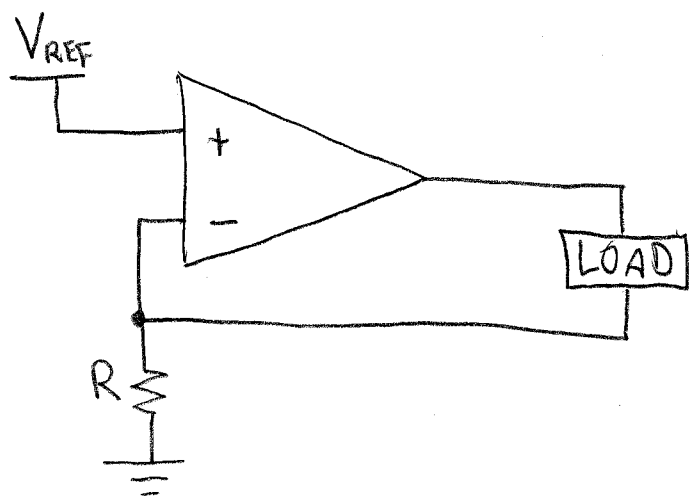
A: MAKE R SMALL, SAY 0.01Ω

Q: HOW WOULD YOU INCREASE THE SENSITIVITY, THAT IS, LET

$$V_{OUT} = CR i_{IN}, \quad C \gg 1 \quad ?$$

[CAN SKIP - THIS IS IN FAISSLER]

WHAT DOES THIS DO?



FIND i IN THE LOAD:

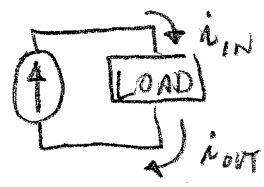
$$V_- = iR$$

$$V_- = V_+ = V_{REF}$$

$$\text{SO } i = \frac{V_{REF}}{R}$$

THIS IS INDEPENDENT OF WHAT IS IN THE LOAD.

Q: IS IT EQUIVALENT TO A CURRENT SOURCE?



A: ONLY IF $i_{IN} = i_{OUT}$. (DISCUSS)

NOTE THAT, IF THIS CURRENT SOURCE HAS ONLY 2 CONNECTIONS TO THE LOAD (NO HIDDEN CONNECTIONS, E.G. THROUGH GROUND, V_s , OR $-V_s$), THEN $i_{IN} = i_{OUT}$.