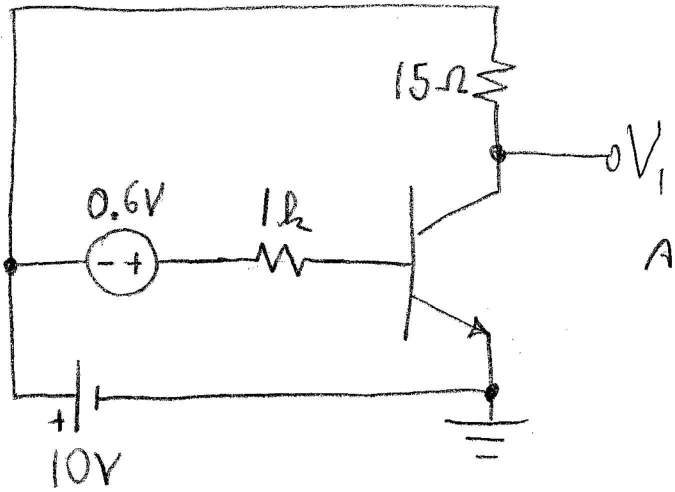
BJT Review

(a) FIND V_1.

(b) FIND i_e.



ASSUME $\beta = 100$, $V_T = 0.6\,V$

ASSUME ACTIVE MODE:

$$i_b = \frac{10V + 0.6V - 0.6V}{1k} = 10\,mA$$

$$i_c = \beta i_b = 1A$$

(IF THIS IS TRUE, $V_1 = 10V - 15\,\Omega \cdot 1A = -5\,V$.)

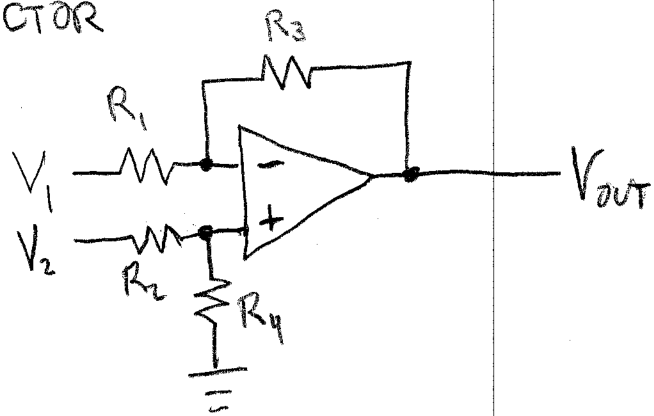
IS IT IN ACTIVE MODE?

- $i_b > 0$, SO NOT IN CUTOFF.
- MAX $i_c = \frac{10V}{15\Omega} = \frac{2}{3}A$. ← UH-OH! $< 1A$.

$\Rightarrow$ SATURATION. $i_c = 2/3\,A$. $\Rightarrow V_1 = 0$ (a)

(b) $i_e = 10mA + \frac{2}{3}A = 0.677A$.

SUBTRACTOR



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

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

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

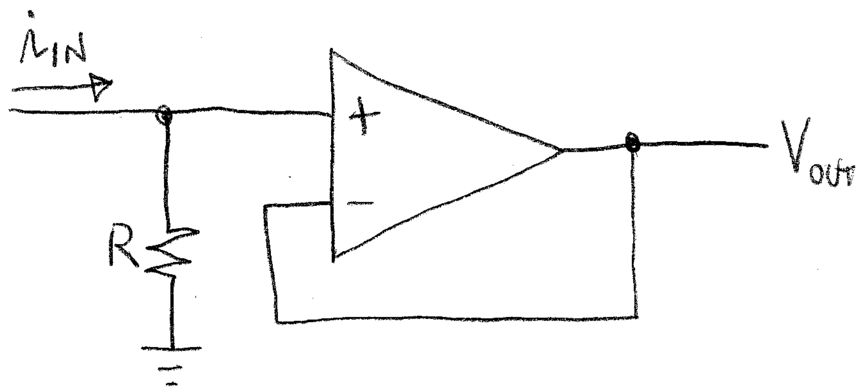
$$V_- = V_+ = \left(\frac{R_4}{R_2 + R_4}\right) V_2 \quad \text{(VOLTAGE DIVIDER)}$$

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

Q: HOW WOULD YOU GET

$$V_{OUT} = 2V_2 - 2V_1 \;?$$

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?)

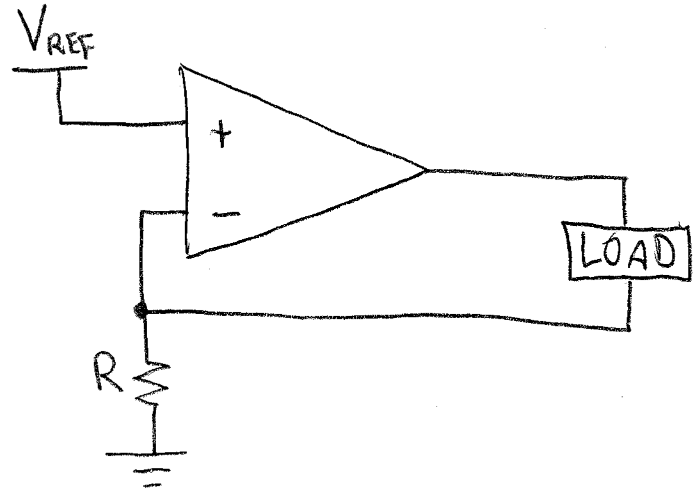
A: MAKE R SMALL, SAY 0.01 Ω

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

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

[CAN SKIP — THIS IS IN FAISSLER]

WHAT DOES THIS DO?



FIND i IN THE LOAD:

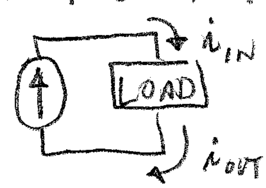
$$V_- = iR$$

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

$$\underline{\underline{SO}} \quad \boxed{i = \frac{V_{REF}}{R}}$$

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 $i_{IN} = i_{OUT}$.

Note on current-to-voltage amplifiers.

The foregoing example is not how current-to-voltage amplifiers are normally designed. You might find it interesting to learn why.

Problems with my naïve design

A typical application is measuring current from a photodiode. The ASIO x-ray radiometer for the NASA MUSE mission is a good example. We needed to measure photocurrents $i_{\text{in}} < 1\,\text{pA}$. For such a a small current, we require $R \sim 10^{12}\,\Omega$ to generate enough volage to make a good measurement. Consequently, even with the high input impedance of a good FET-based op amp, the current through the noninverting input could be significant compared to i_{in}.

You might suppose (based on the last discussion question on the previous page) that adding a voltage divider to ground on the inverting input to increase the gain of the amplifier would solve this problem. It would help, but probably not enough for precision measurement.

Inverting current amplifier

The inverting amplifier configuration below solves the issue. The noninverting imput is grounded, and negative feedback keeps the inverting input near $0\,\text{V}$. This minimizes parasitic current on the inputs to the op amp. The output is simply

$$V_{\text{out}} = -i_{\text{in}} R.$$

This is commonly called a *transimpedance amplifier.* The ASIO design required additional refinements, but this is the starting point.