Solutions: part 4

Largest area? I_o = 10 uA.

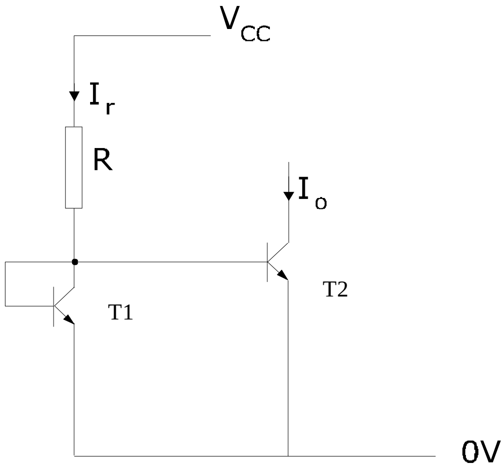
Consider T_1 biggest, then I_r = 50 uA

$$R = \frac{30-0.7}{50uA} = 586k\Omega$$

if T_2 biggest, I_r = 10uA/5 = 2uA

giving $R = \frac{30-0.7}{2uA} = 14.7M\Omega$!!

- enormous for an I.C.

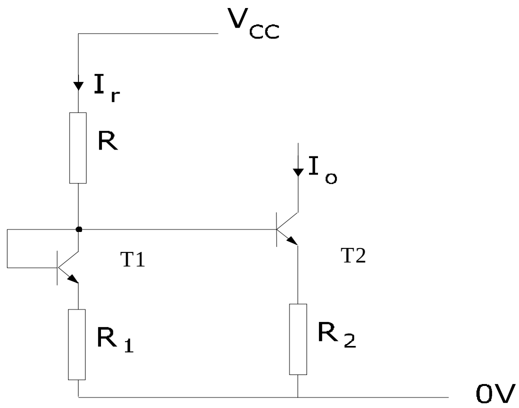


Make T_1 biggest.

R is still very large for an I.C. (would take up a massive area).

<u>Second circuit (</u>Resistors must be < 50k)

Ignore base currents ($I_C \sim I_E$)



$$I_r R_1 + V_{BE1} = I_o R_2 + V_{BE2}$$

$$I_o R_2 - I_r R_1 = V_{BE1} - V_{BE2}$$

$$\frac{I_o R_2}{I_r R_1} - 1 = \frac{1}{I_r R_1}\left(V_{BE1} - V_{BE2}\right) \quad (1)$$

$$I_r = I_S \exp\left(\frac{V_{BE1}}{V_T}\right)$$

$$I_O = I_S \exp\left(\frac{V_{BE2}}{V_T}\right)$$

$$\text{so } \frac{I_o R_2}{I_r R_1} - 1 \approx \frac{V_T}{I_r R_1}\ln\left(\frac{I_r}{I_o}\right) \qquad (2)$$

Given that I_r = 1 mA, I_o = 10uA, which resistor biggest (R_1or R_2) ?

Looking at Eqn.1, expect V_{BE} difference to be small so expect $\frac{I_o R_2}{I_r R_1} - 1 \approx 0$

$\frac{I_o}{I_r} \approx \frac{R_1}{R_2}$, $\frac{10uA_o}{1mA} \approx \frac{R_1}{R_2}$, $R_1 \sim 0.01\ R_2$ so consider making R_1 the smaller.

Want resistors less than 50k, make R_2 = 25k (say) so R_1 ~ 250Ω.

Get more accurate values: set R_1 = 250Ω, **R_1 = 250Ω,**

Use Eqn.2, $R_2 \approx \frac{V_T}{I_o} \ln\left(\frac{I_r}{I_o}\right) + \frac{I_r}{I_o} R_1$ = 11,512 + 25,000 = 36.5kΩ **R_2 = 36.5kΩ**

Finally need to find R: volt drop across R_1 is $I_r R_1$ = 0.25V so voltage at collector/base node of T_1 is 0.7V + 0.25V = 0.95V

$R = \frac{30 - 0.95}{1mA} \sim 30k\Omega$ **R = 30kΩ**

ALL RESISTORS LESS THAN 50kΩ

Note this is a DESIGN so there are other answers that will satisfy the given requirements (specification).