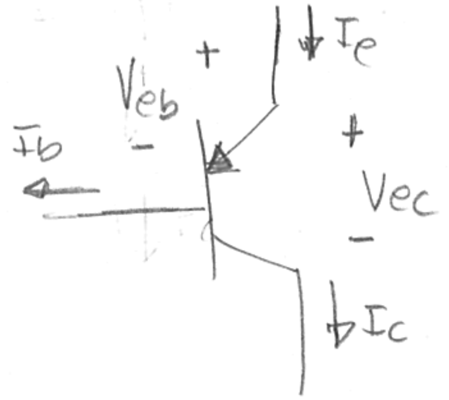
ANALOG SYSTEMS
22/3/2012 | (1)
BJT-

PNP BJT



⟹

- **ACTIVE ZONE**

$V_{eb} = 0'7$
$V_{ec} > 0'2$

$I_c = \beta I_b$
$I_e = (\beta + 1) I_b$

- **SATURATION ZONE**

$V_{ec} = 0'2$ Volt
$V_{eb} = 0'8$ Volt

$I_c < \beta I_b$
$I_e = I_c + I_b$

- **OFF ZONE**

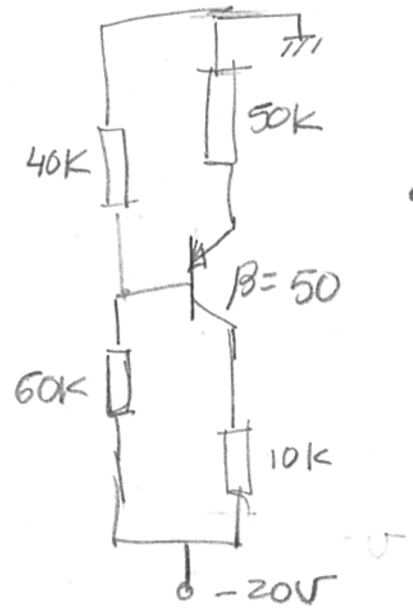
$V_{eb} < 0'5$. $I_b = 0$ $I_c = 0$ $I_e = 0$

$V_{ec} \geq 0$, but $V_{ec}|_{max}$ is obtained from datasheet.

ANALOG SYSTEMS

22/3/2012 | (2)

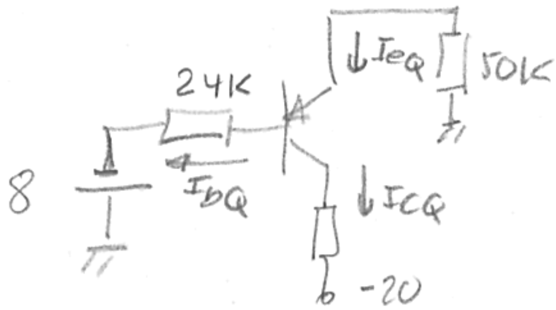
BJT



• FIND OUT

Q VOLTAGES AND CURRENTS

SOLUTION :



• BASE LOOP $\quad -8 + 24\, I_{bQ} + 0'7 + \underset{(\beta+1)}{51}\, I_{bQ} \cdot 50 = 0 \quad (1)$

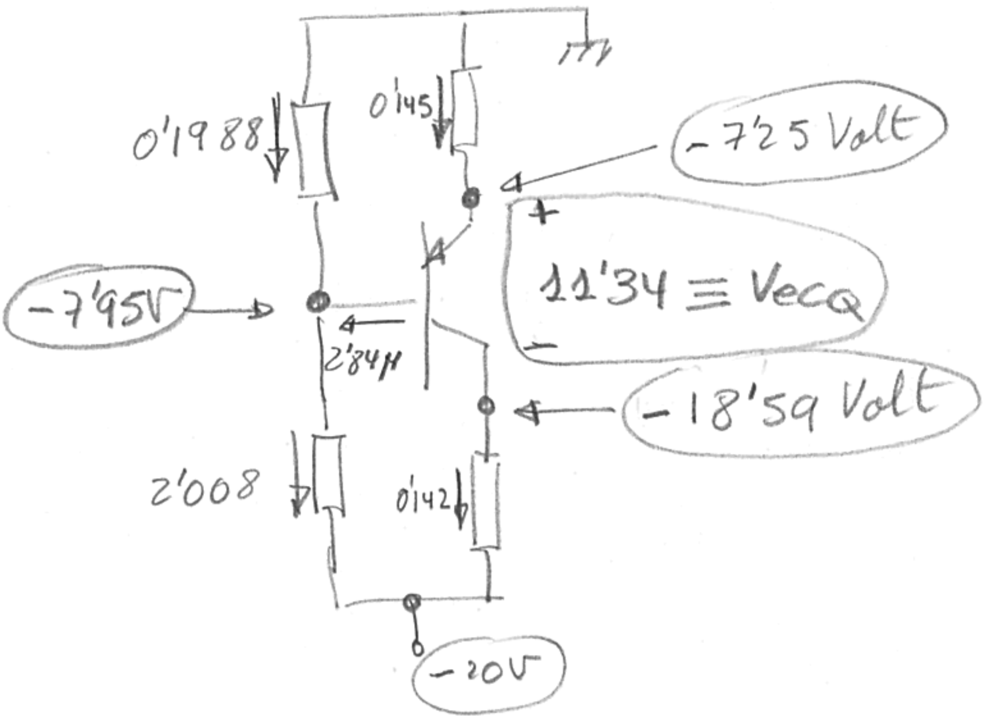
• COLLECTOR LOOP $\quad -20 + 10 \cdot 50 \cdot I_{bQ} + V_{ecQ} + 51\, I_{bQ} \cdot 50 = 0 \quad (2)$

From (1) $\quad I_{bQ} = 2'84\ \mu A \Rightarrow I_{CQ} = 0'142\ mA \Rightarrow$

$I_{eQ} = 0'145\ mA$

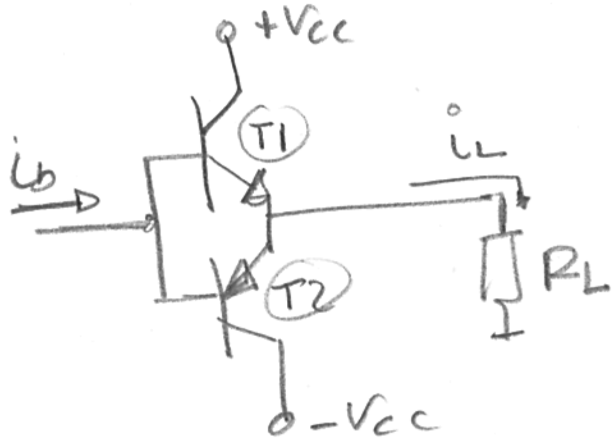
From (2) $\quad V_{ceQ} = 11'34\ Volt$

Finally:



PUSH-PULL CONFIGURATION

When the output current of a device must be increased, the push-pull configuration is suitable.



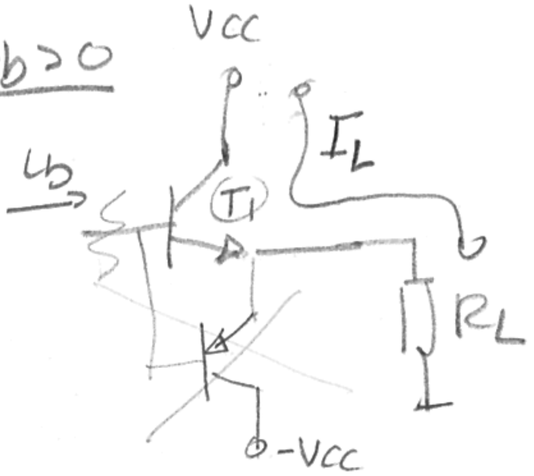
- $i_b > 0 \Rightarrow$ T_1 ON, T_2 OFF $\Rightarrow$ $i_L > 0$
- $i_b < 0 \Rightarrow$ T_1 OFF, T_2 ON $\Rightarrow$ $i_L < 0$

Analog Systems

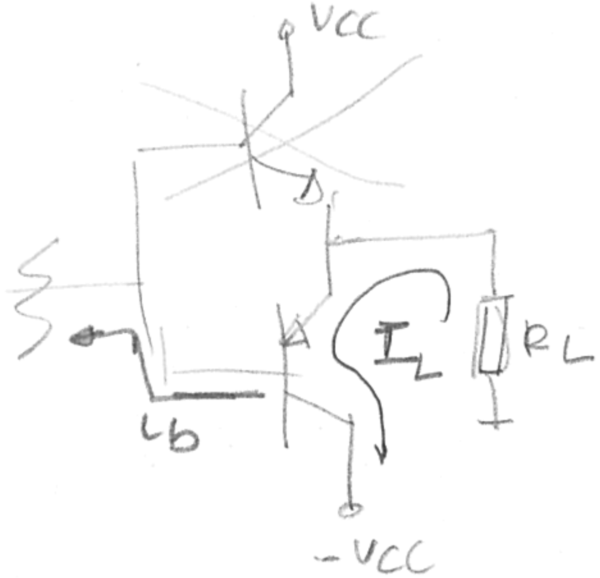
22/3/2012 | (4)

BJT

$i_b > 0$



$i_b < 0$

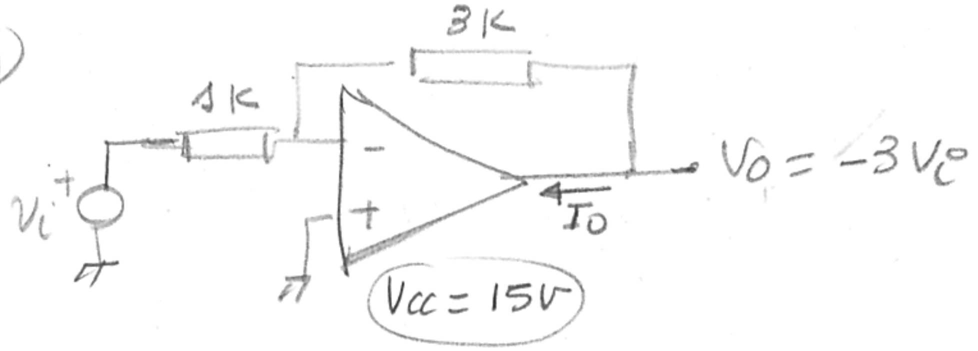


- $I_L = \beta I_b$

Analog Systems
22/3/2012 | (5)
BJT

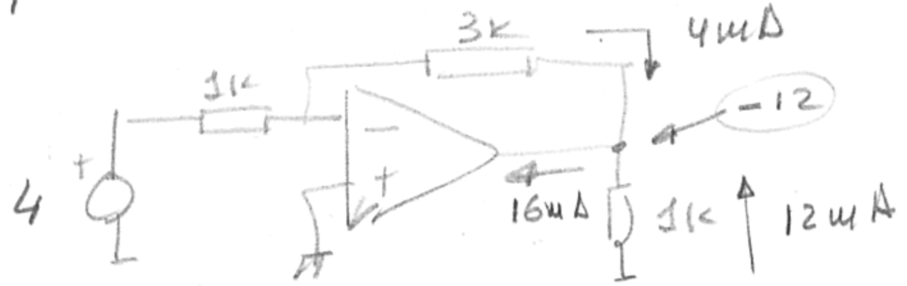
· When the current output of an OA is not large enough :

①



If $V_i|_{max} = \pm 4$ Volt ⇒ $V_o|_{max} = \mp 12$ Volt ⇒ $I_O = 4mA$

② If $R_L = 1K$ →

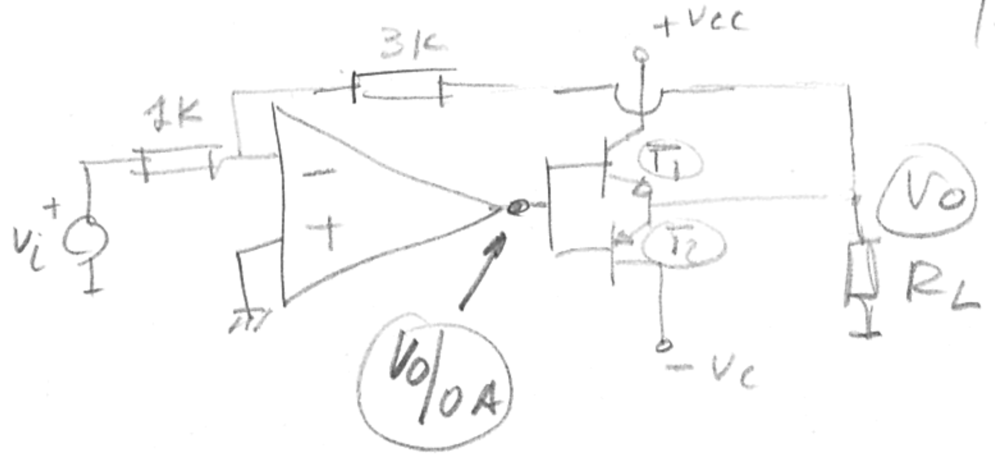


$I_O = 16mA$. The OA can handle it

③ If $R_L = 0'1$ ⇒ $I_O = 124mA$. The O.A can't handle it! ⇒ PUSH-PULL IS NEEDED

Analog Systems
22/3/2012 | 6
BJT

• {OA + PUSH-PULL}



The negative feedback guarantees $V_0 = -3V_i$ as in the previous circuit.

The voltage output of the OA is

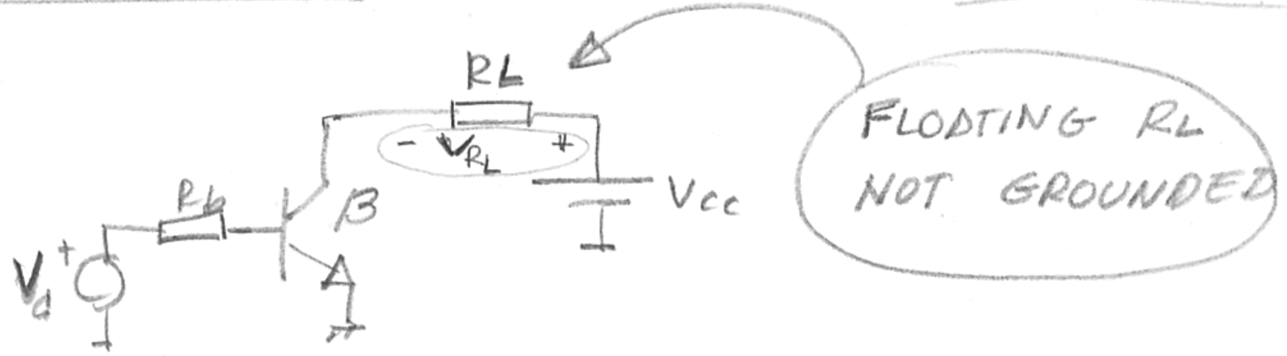
$$V_0|_{OA} = V_0 + 0'7 \quad \text{if} \quad V_0 > 0$$

$$V_0|_{OA} = V_0 - 0'7 \quad \text{if} \quad V_0 < 0$$

Analog Systems
22/3/2012 (2)
BJT-SWITCH

BJT ⟷ SWITCH

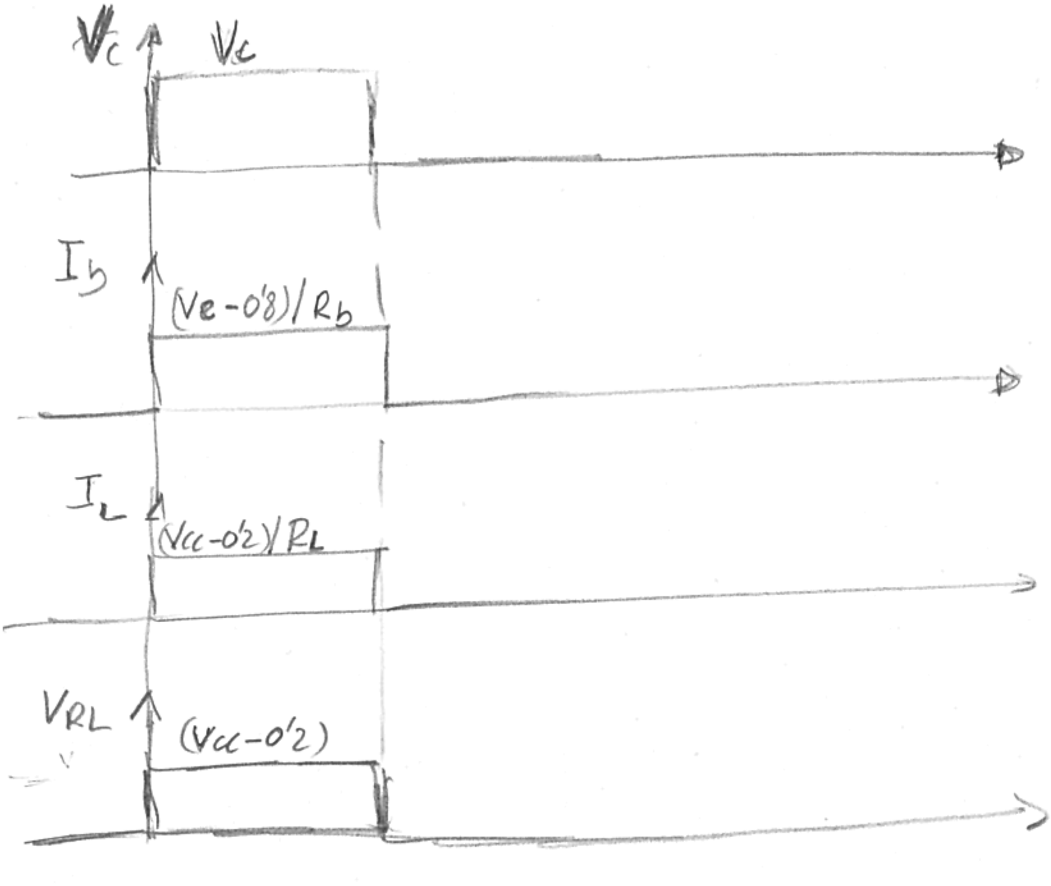
• BASIC CIRCUIT



If $V_G = 0 \Rightarrow I_b = 0 \Rightarrow \begin{cases} I_L = 0 \\ V_{ce} = V_{cc} \end{cases}$ (BJT OFF)

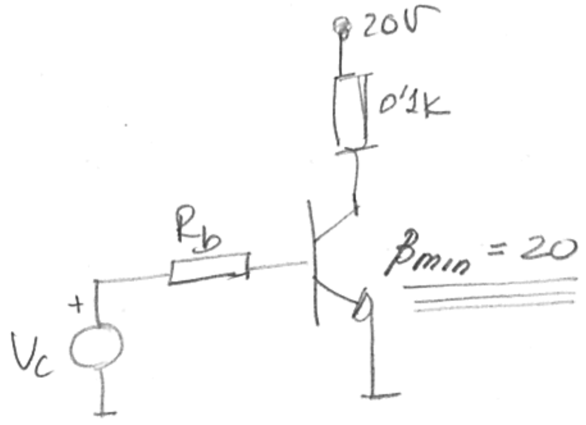
If $V_G = \uparrow\uparrow \Rightarrow I_b = \dfrac{V_c - 0'8}{R_b} \Rightarrow \begin{cases} V_{ce} = 0'2 \\ I_L = \dfrac{V_{cc} - 0'2}{R_L} \end{cases}$

(BJT SATURATED)



- EXAMPLE

Analog Systems
22/3/2012 | 8
BJT - SWITCH



If $V_c(ON) = 5V$, $V_c(OFF)\ 0'2V$ } find out R_b for a proper operation

$V_c = 5 \Rightarrow$ BJT ON (SAT)

$$I_b = \frac{5-0'8}{R_b} = \frac{4'2}{R_b}$$

$$I_c = \frac{20-0'2}{0'1} = 198mA$$

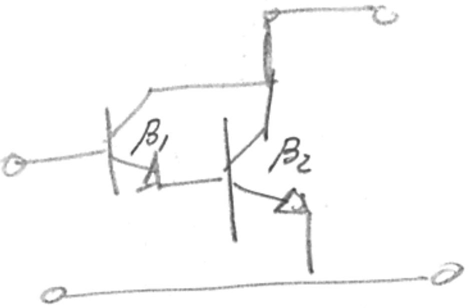
} $198 < \beta I_b \Rightarrow$

$198 = 20 \cdot I_{b_{min}} \Rightarrow I_{bmin} = 9'9mA \Rightarrow R_{b_{max}} = 0'424K$

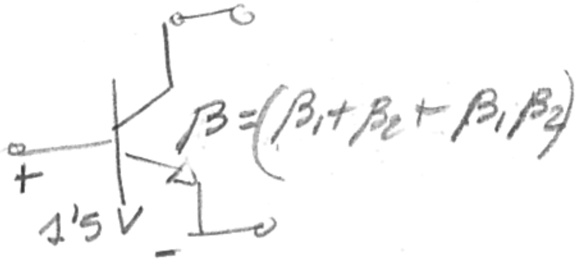
↑ β_{min}

- A greater β will improve the performance of the circuit $\Longrightarrow$

- DARLINGTON ASSEMBLY



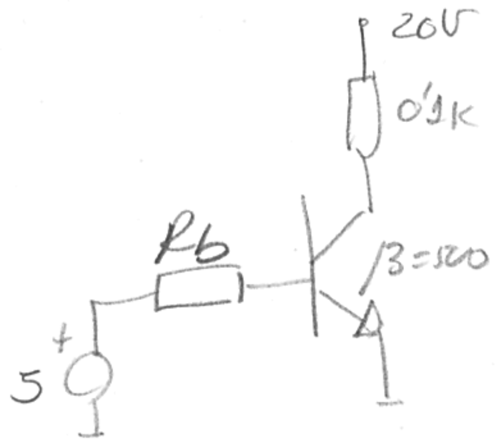
$\Longleftrightarrow$



If saturated: $V_{be}|_2 = 0'8$ (SAT)

$V_{be}|_1 = 0'7$ (ACT) $\rightarrow$ (Notice that $V_{ce_1} > 0'2$)

If a Darlington ($\beta = 500$) is used:



$I_b = \dfrac{5-1'5}{R_b} = \dfrac{3'5}{R_b}$

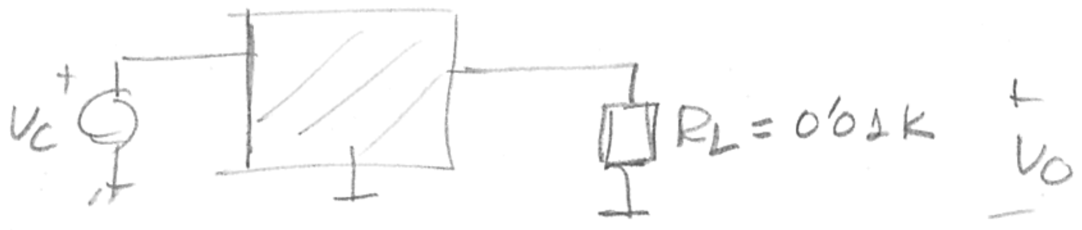
$I_c = \dfrac{20-0'2}{0'1} = 198$ mA

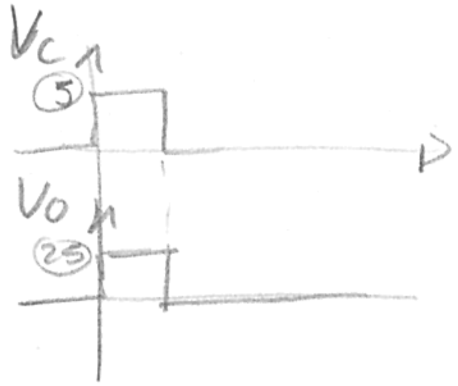
$198 < 500 \cdot I_{b_{min}} \Rightarrow$

$I_{b_{min}} = 0'396$ mA $\Rightarrow R_{b_{max}} = \dfrac{5-1'5}{0'396} = 8'84$ K.

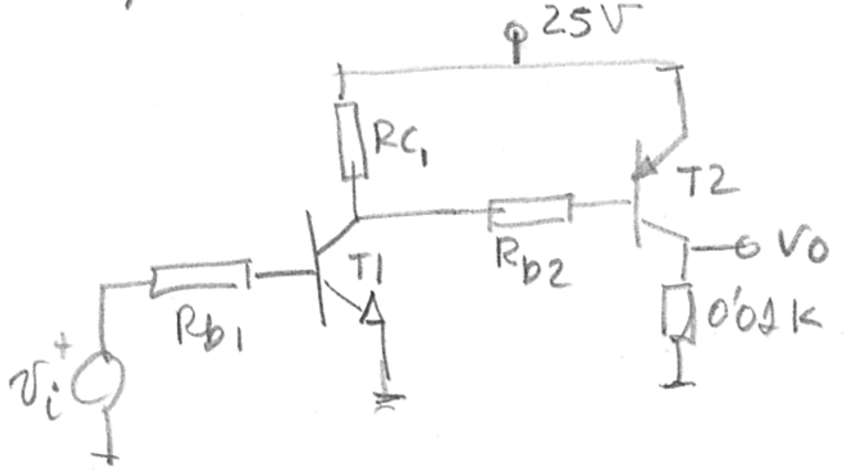
(better than previous circuit)

- A switch based circuit must be designed:





- Proposed circuit



$\beta_1(min) = 20$
$\beta_2(min) = 20$

- $\{R_{b1}, R_{b2}, R_{C1}\}$ have to be found out:

- If $V_C \downarrow\downarrow$ ($V_C < 0'5$) $\Rightarrow$ T1 OFF $\Rightarrow$ T2 OFF $\Rightarrow$ $V_O = 0$

If $V_C = 5V \Rightarrow T_1$ ON (SAT) $\Rightarrow$ T2 ON (SAT) $\Rightarrow$
$V_O = 25 - 0'2 = 24'8$ volt

• $V_i = 5V$ (ANALYSIS)

$$I_{e2} = \frac{25 - 0'2}{0'01} = 2480\ mA$$

$$I_{b2} = \frac{25 - 0'8 - 0'2}{R_{b2}} = \frac{24}{R_{b2}}$$

• $\beta_{min} I_{b2} > 2480$ (T2 ON (SAT)) $\Rightarrow$

$$20 \cdot \frac{24}{R_{b2}} > 2480 \Rightarrow R_{b2} < 0'193\,K \Rightarrow \boxed{R_{b2} = 0'18}$$

$$\boxed{I_{b2} = 133\,mA}$$

• $$I_{b1} = \frac{5 - 0'8}{R_{b1}} = \frac{4'2}{R_{b1}}$$

• $$I_{C1} = \frac{25 - 0'2}{R_{C1}} + 133 = \frac{24'8}{R_{C1}} + 133$$

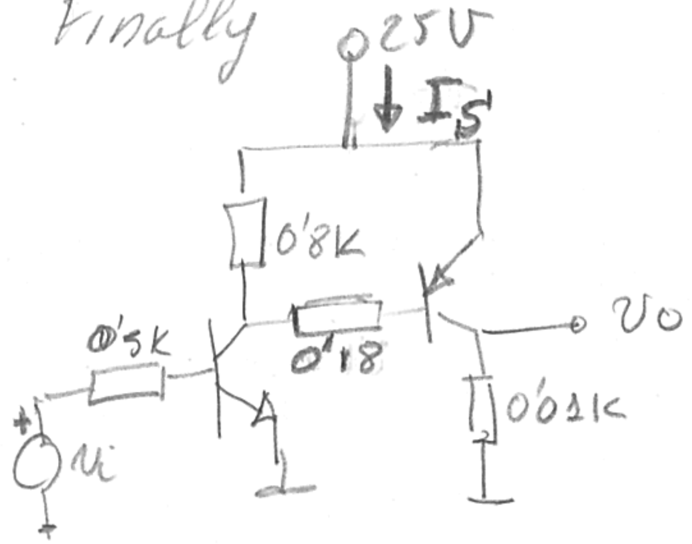
• $$\beta_{min} \cdot I_{b1} > I_{C1} \Leftrightarrow \frac{20 \cdot 4'2}{R_{b1}} > \frac{24'8}{R_{C1}} + 133$$

$$\Rightarrow \frac{84}{R_{b1}} > 133 + \frac{24'8}{R_{C1}} \Rightarrow \text{e.g.:}$$

$$\boxed{R_{b1} = 0'5K} \rightarrow \boxed{I_{b1} = 8'4\ mA}$$

$$R_{C1} \geq 0'708 \Rightarrow \boxed{R_{C1} = 0'8K}$$

Finally



- If a Darlington ($\beta_{min} = 500$) is used (T2)

$I_{e2} = 2480$; $I_{b2} = \dfrac{25 - 1'5 - 0'2}{R_{b2}} = \dfrac{23'3}{R_{b2}}$

$500 \cdot \dfrac{23'3}{R_{b2}} > 2480 \Rightarrow R_{b2} < 4'69K \Rightarrow$

$\boxed{R_{b2} = 4'5K} \Rightarrow \boxed{I_{b2} = 5'18\,mA}$

- $I_{b1} = \dfrac{4'2}{R_{b1}}$

- $I_{c1} = \dfrac{24'8}{R_{c1}} + 5'18$

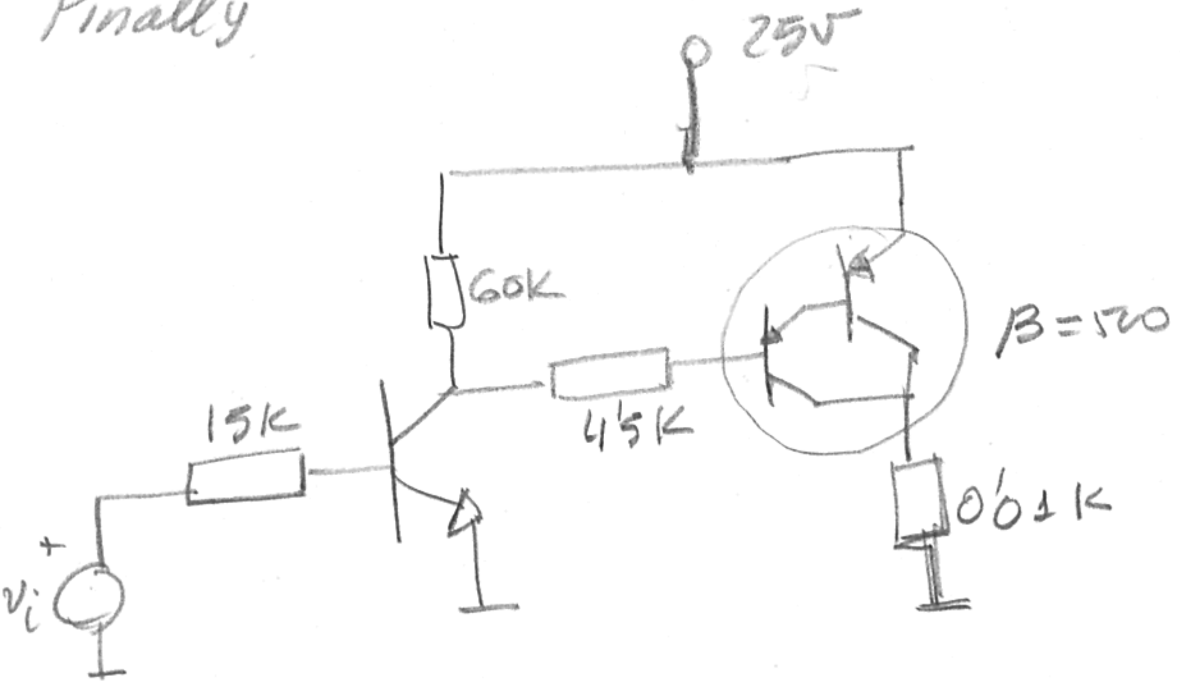
β_{min} ↓

$20 \cdot \dfrac{4'2}{R_{b1}} > 5'18 + \dfrac{24'8}{R_{c1}}$

$R_{b1} = 15K \Rightarrow R_{c1} > 59K \Rightarrow$

$R_{c1} = 60K$

Finally



Which is best?

Power loses are the key:

$P = v_i \cdot I_i + 25 \cdot I_s$, is the power supplied by the sources

· CIRCUIT ①

• ON STATE ($V_i = 5V$)

$$P = 5 \cdot I_{b1} + 25 \left(I_{0'8K} + I_{e2} \right) = 65'37 \text{ W}$$

NOTICE: $P_{LOAD} = 0'01 \cdot (2480)^2 = 61'50 \text{ W}$

$$I_{0'8K} = \frac{25 - 0'2}{0'8} = 31$$

$$I_{e2} = I_{c2} + I_{b2} = 2480 + 133 = 2.613$$

$$I_{b1} = 8'4$$

Power losses $= 65'37 - 61'50 = 3'87 \text{ W}$

• OFF STATE

$I_{b1} = 0$, $I_{e1} = 0$ $I_{0'8K} = 0$ $\Rightarrow$ $P = 0$

CIRCUIT ② (DARLINGTON)

- ON STATE ($V_L = 5V$)

$$P = 5 \cdot I_{b_1} + 25(I_{60k} + I_{e_2})$$

$$P = 5 \cdot 0'28 + 25(0'413 + 2485'18) = 62'14W$$

$$I_{b_1} = \frac{4'2}{15} = 0'28$$

$$I_{60K} = \frac{25 - 0'2}{60} = 0'4133$$

$$I_{e_2} = 2480 + I_{b_2} = 2480 + 5'18 = 2485'18$$

$$P_{LOSSES} = 62'14 - 61'50 = 0'64W.$$

BEST: DARLINGTON ASSEMBLY!