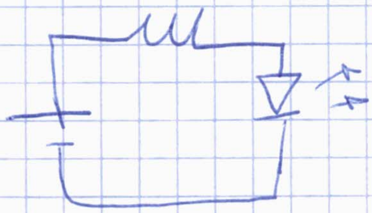
~~Problema 13:~~

Diodos: Segundo parcial.

- Cálculo R limitadora (LED)



Color: Rojo

$V_{AK\ umbral} = 1'6\ V$

$I_{max} = 20\ mA$

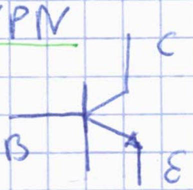
$$R_{lim} = \frac{V_{cc} - V_{AK}}{I} = \frac{5 - 2'4}{20 \cdot 10^{-3}} = 130\ \Omega$$

$$P_{LED} = I^2 \cdot R = (20 \cdot 10^{-3})^2 \cdot 130$$

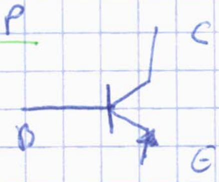
Tema 4:

$I_C = \beta I_B$ $\qquad$ $I_C = I_{colector}$; $I_B = I_{base}$; $\beta = 100$;

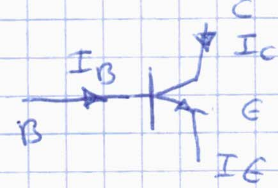
NPN

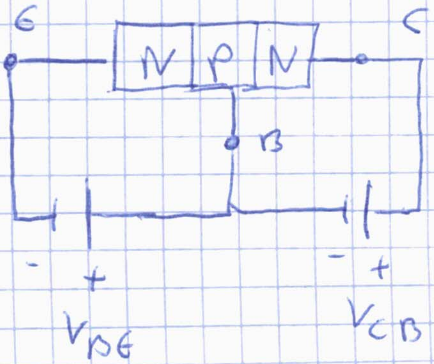


PNP



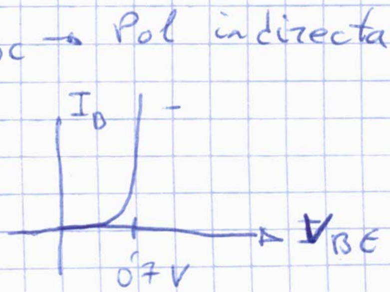
$$\boxed{\begin{array}{l} I_E = I_C + I_B \\ I_C = \beta I_B \end{array}} \rightarrow$$

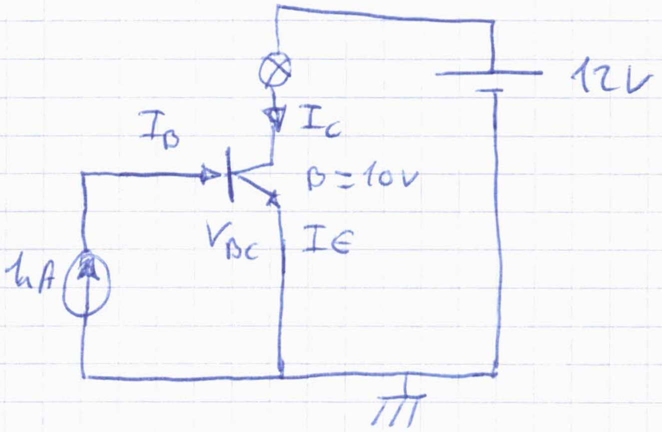


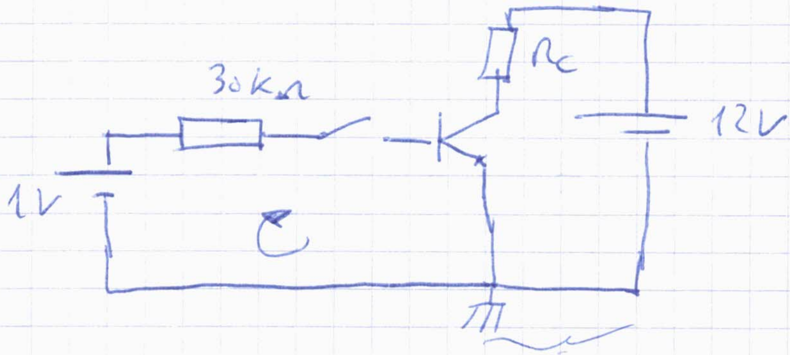


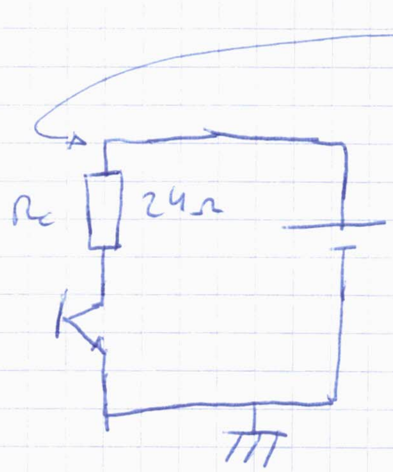
$I_{BE} \rightarrow$ Pol directa.

$I_{BC} \rightarrow$ Pol indirecta.









int abierto: $\begin{cases} I_C = 0\,A \\ I_C = \beta I_B \end{cases}$

int ON:

$$V_{BB} = I_B R + V_{BE}$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{1 - 0'7}{30\,k\Omega} = 0'1\,mA$$

$$V_{CC} = I_C R_C + V_{CE}$$

$$I_C = \beta I_B = 0'1 \cdot 100 = 10\,mA$$

$$V_{CE} = 12 - 10 \cdot 10^{-3} \cdot 24 = 11'76\,V$$

- Si necesitamos $+ I_C \rightarrow$ Aumentamos la I_B
- necesitamos que $V_{BB} \rightarrow$ mayor que V_γ 0'7
- Siempre poner: $V_{BB} \rightarrow V_{CC}$

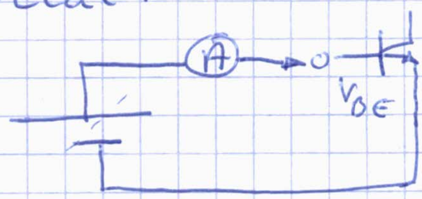
Pol. directa — Pol. indirecta

• Por el colector pasa 1 A, no puede, la máxima sería $I_C = \beta I_B \rightarrow$ lineal.

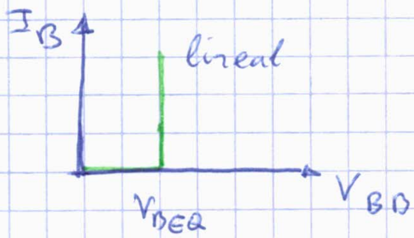
$V_{CE} < 0 \rightarrow$ saturación $\quad \beta_{sat} < \beta_{min}$.

- **Curvas BJT**

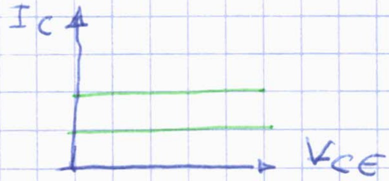
  - Ideal:



Circuito Base:

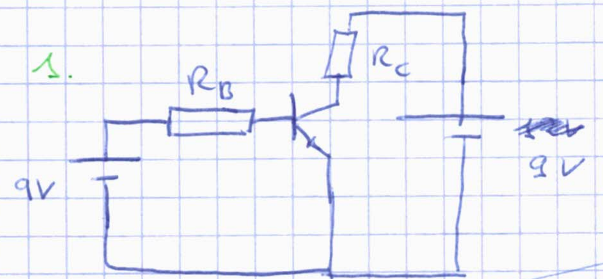


$I_C = \beta I_B$



- Análisis de circuitos BJT en EC.

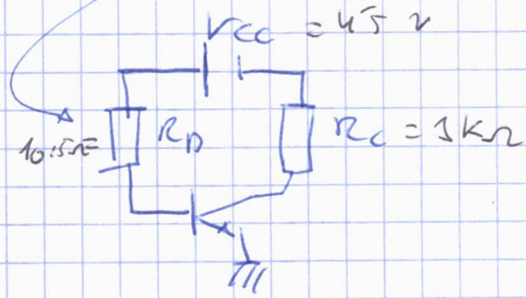
1.



Como $V_{BB} = V_{CC}$ → Puedo unir

$\equiv$

R_B y R_C no están paralelo porque sus bornes no están juntos.



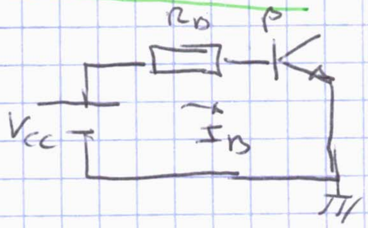
$\beta = 100$,

$V_{BE\gamma} = 0'6\ V$

$V_{CEsat} = 0'2\ V$

Pto Q (V_{CEQ}, I_{CQ}, V_{BEQ}, I_B)

Circuito base:



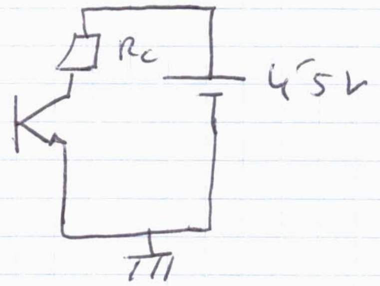
$$I_B = \frac{V_{CC} - V_\gamma}{R_B} = \frac{4'5 - 0'6}{10\ k\Omega}$$

$$I_B = 3'9 \cdot 10^{-4}\ A$$

$V_{BE} = 0'6\ V$

$I_B = 0'39\ mA$

Circuito de salida:



$I_C = 100 \cdot 0'39mA = 39mA$

$V_{CC} = V_{R_C} + V_{CE} = I_C R_C + V_{CE}$

$V_{CE} = V_{CC} - I_C R_C = 4'5 - 39mA \cdot 1K = -34'5V$

Como tengo $-34'5V \rightarrow V_{CE} < V_{CEsat}$

Al estar en saturación: $\cancel{I_C \neq \beta I_B}$

$\cancel{I_C \neq 39mA}$

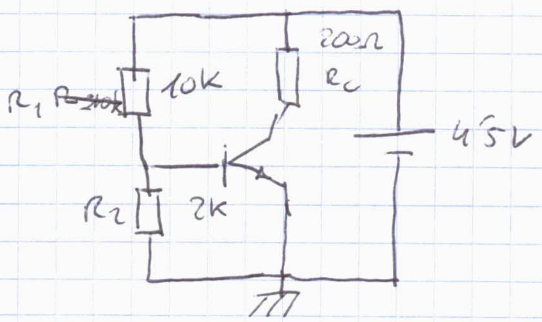
$V_{CEsat} = 0'2V$

$V_{CC} = V_{RB} + V_{CEsat} = I_{Csat} R_C + V_{CEsat}$

$I_{Csat} = \frac{V_{CC} - V_{CEsat}}{R_C} = \frac{4'5 - 0'2}{1K\Omega} = 4'3mA$

$I_{Csat} = \beta_{sat} I_B$; $\beta_{sat} = \frac{4'3mA}{0'39mA} = 11'02$

− β varía con la temperatura:

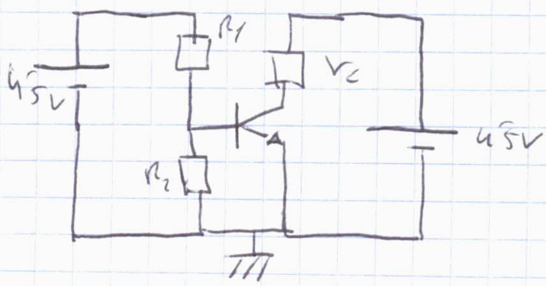


$\beta_{lin} = 100$

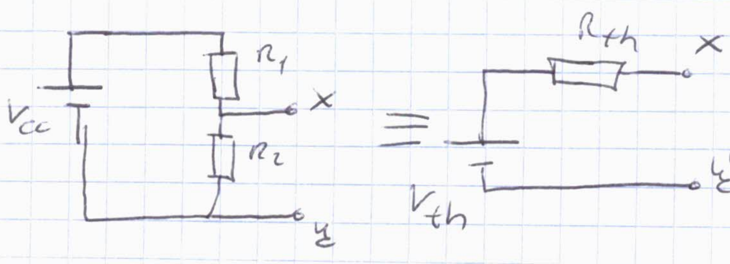
$V_{BE\gamma} = 0'6V$

$V_{CEsat} = 0'2V$

Equivalente:



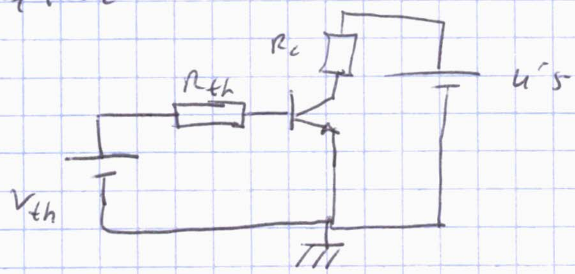
Thevenin:



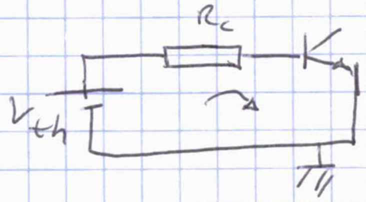
$$V_{th} = V_{R2} = \frac{R_2 V_{CC}}{R_1 + R_2} = 0'7V$$

R_{th} → cortocircuito las fuentes de V y V_{CC}, R_1 y R_2 en paralelo: $R_{th} = \frac{R_1 R_2}{R_1 + R_2} = 1'6\,k\Omega$

y se me queda:

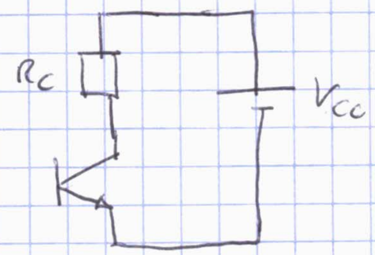


Circuito base:



$$I_B = \frac{V_{th} - V_{BE}}{R_{th}} = \frac{0'7 - 0'6}{1'6\,k\Omega} = 90\,\mu A$$

Circuito colector:



$$V_{CC} = V_{RC} + V_{CE} = I_C R_C + V_{CE}$$

$$V_{CC} - I_C R_C = V_{CE}$$

$$I_C = \beta I_B = 9\,mA$$

$$4'5 - 9mA \cdot 200 = 2'7\,V$$

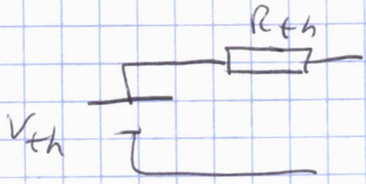
$V_{CE} > V_{CEsat}$ funciona lineal.

Si $V_{CE} < V_{CEsat}$ → saturado.

Corte:

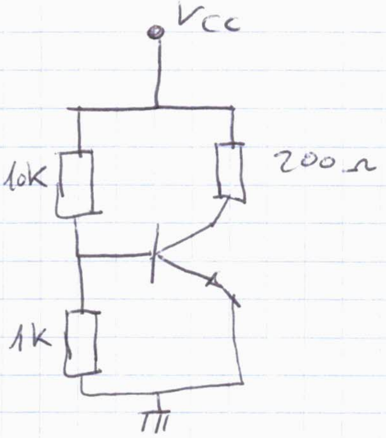
- Trabajamos con la I_b: si $R_2 = 1k$; $V_T = V_{R2} = 4'5 \frac{1k}{1k+10k} = 0'4V$

Entonces $0'4 < 0'6 = V_{BE}$ corte.



$V_{th} = 0'4\,V$

$R_{th} = R_1 // R_2 = 909\,\Omega$

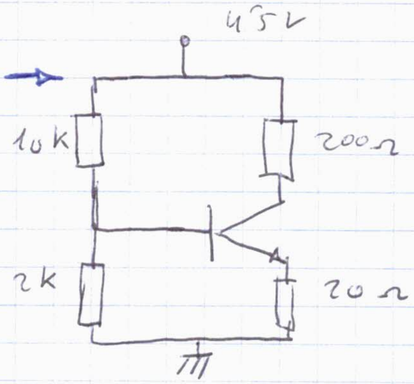


$V_{th} = 0'4 \rightarrow$ circuito base.

$V_{th} < V_{BE} \rightarrow$ Corte

diodo $\rightarrow$ —• •— circuito abierto.

$$\boxed{\begin{array}{l} I_B = \emptyset A \rightarrow I_C = 0 A \\ V_{BC} = V_{th} = 0'409 V \\ V_{CE} = V_{CC} = 4'5 V \end{array}}$$



$V_{BE\gamma} = 0'6 V$

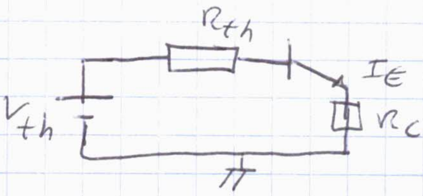
$V_{CEsat} = 0'2 V$

$\beta_{lin} = 100$

$$R_{th} = \frac{R_1 \cdot R_2}{R_1 + R_2} = 1'6 k\Omega$$

$V_{th} = 0'75 V$

· Circuito base:



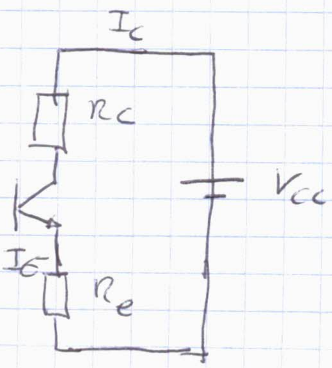
$V_{th} = V_{RT} + V_{BE} + V_{RE}$

$I_E = I_C + I_B = \beta I_B \cdot I_B$

$V_{th} = I_b R_{th} + V_{BE} + I_b R_E + \beta I_b R_E$

$$I_b = \frac{V_{th} - V_{BE}}{R_{th} + R_E(\beta + 1)} = 40'69 \mu A$$

- Circuito colector:

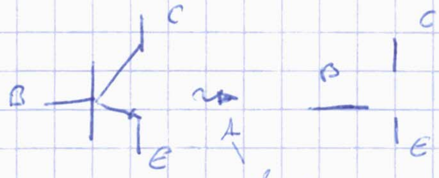


$V_{CC} = I_C R_C + V_{CE} + I_E R_e$

$V_{CE} = 3'6 = V_{CC} - (I_b \beta R_C + I_b R_e + \beta I_b R_e)$

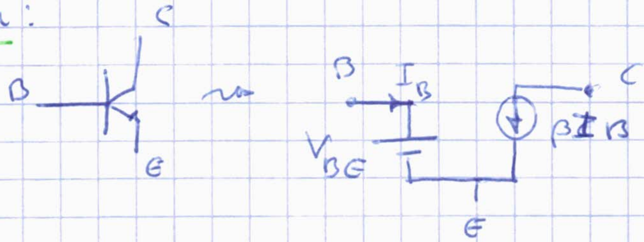
PtoQ:
$$\boxed{\begin{array}{l} I_C = \beta I_b = 4'069 mA \\ I_e = I_C + I_b = 4'109 mA \\ I_b = 40'69 \mu A \\ V_{CE} = 3'6 V \\ V_{BE} = 0'6 V \rightarrow \text{diodo} \end{array}}$$

- Transistor en corte:

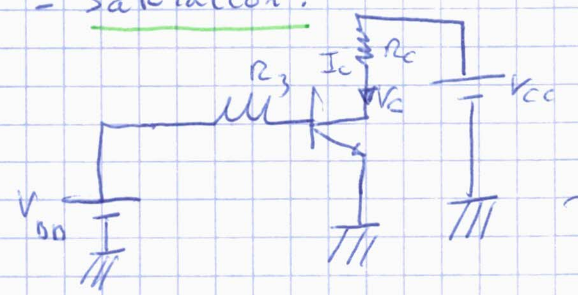


⇝ polarización inversa

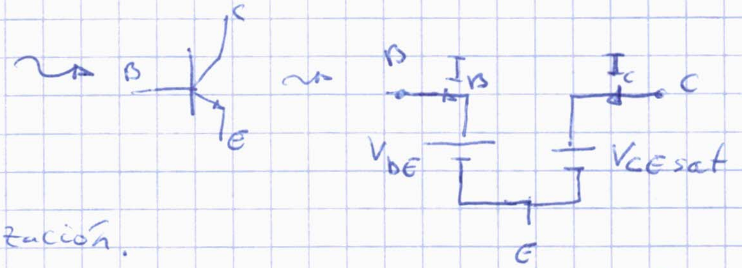
- Transistor en activa:



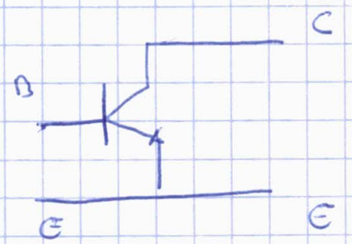
- Saturación:



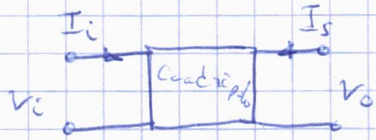
$V_C = V_{CC} - I_C R_C$



- Configuración de polarización.

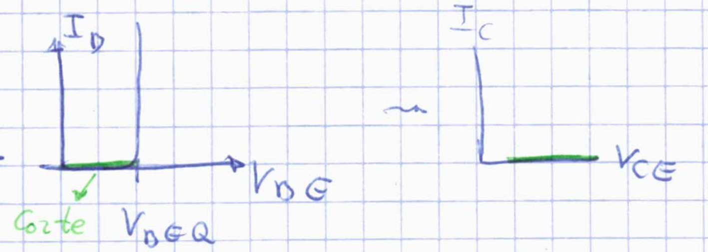


⇝ Emisor común

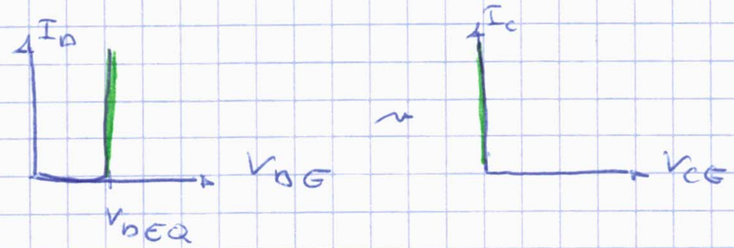


- Curvas:

en corte ⇝

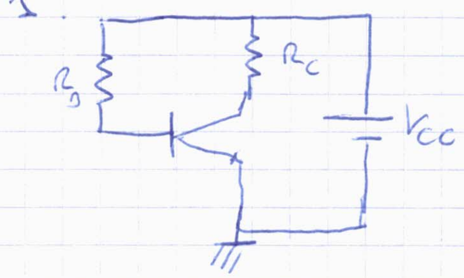


Saturación ⇝



- Estabilización por realimentación en el emisor:

1.



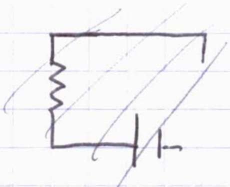
$R_C = 1000\,\Omega$; $V_{CC} = 20V$

$R_E = 0\,\Omega$; $\beta = 100$

$R_B = 180\,K\Omega$; $V_{BE} = 0'7V$

$V_{CEsat} = 0'2V$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{20 - 0'7}{180\,K} = 0'107\,mA$$

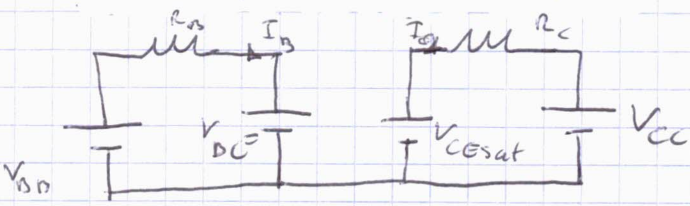


$I_C = \beta I_B = 10'7\,mA$

$V_{CE} = V_{CC} - I_C R_C = 20 - 10'7_{m} \cdot 1000$

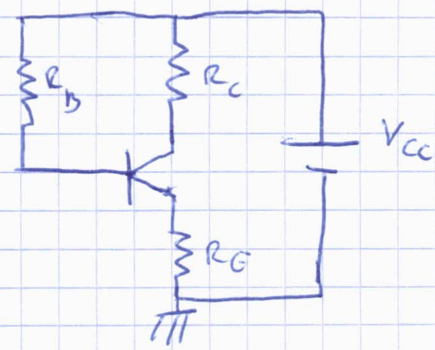
- $\beta = 300$ Está en saturación.

$I_B = 0'107\,mA$



$$I_C = \frac{V_{CC} - V_{CEsat}}{R_C} = 0'0198\,mA$$

2.



$R_C = 1000\,\Omega$; $V_{CC} = 20\,V$;

$R_E = 100\,\Omega$; $\beta = 100$;

$R_B = 180\,k\Omega$; $V_{BE} = 0'7\,V$;

$V_{CEsat} = 0'2\,V$.

$$\to I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1)R_E} = \frac{20 - 0'7}{180k + (\beta+1)\,180k} = \frac{19'3}{180k + 101 \cdot 180k} = 1'05 \cdot 10^{-6}\,A$$

$$\to I_C = I_B \cdot \beta = 1'05 \cdot 10^{-4}\,A = 0'105\,mA$$

$$\to V_{CE} = V_{CC} - I_C\left(R_C + \left(\frac{\beta+1}{\beta}\right)R_E\right) =$$

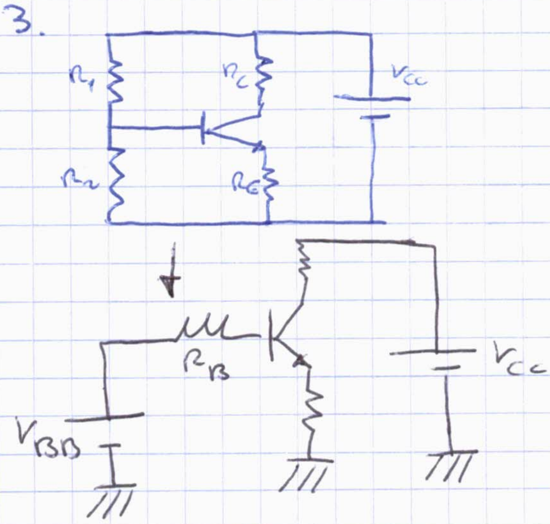
$\beta = 300$

$I_B = 0'097\,A$

$I_C = 17'991\,A$

$V_{CE} = 0'2\,V$

3.



$R_C = 1000\,\Omega$; $V_{CC} = 20\,V$

$R_E = 100\,\Omega$; $\beta = 100$

$R_1 = 18\,k\Omega$; $V_{BE} = 0'7\,V$

$R_2 = 1'8\,k\Omega$; $V_{CEsat} = 0'2\,V$

$$R_B = \frac{R_1 R_2}{R_1 + R_2} = 1636'36\,\Omega.$$

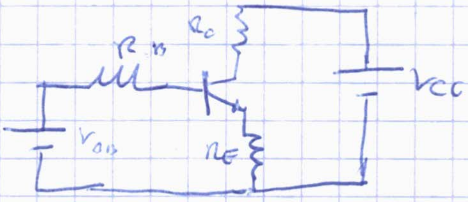
$$V_{th} = V_{BB} = \frac{V_{CC} R_2}{R_1 + R_2} = 1'8\,V$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B + (\beta+1)R_E} = 9'37 \cdot 10^{-5}\,A = 0'00937\,mA$$

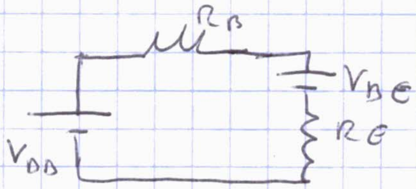
$$I_C = \beta I_B = 9'37 \cdot 10^{-3}\,A \approx 0'00937\,A$$

$$V_{CE} = V_{CC} - I_C\left(R_C + \left(\frac{\beta+1}{\beta}\right)R_E\right) =$$

- Análisis por recta de carga.

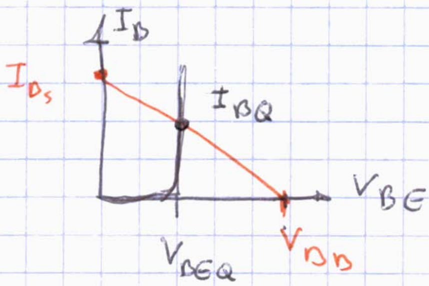


- analizamos el circuito base:



$$V_{BB} = I_B R_B + V_{BE} + I_E R_E \, ;$$

$$I_E = (\beta + 1) I_B$$



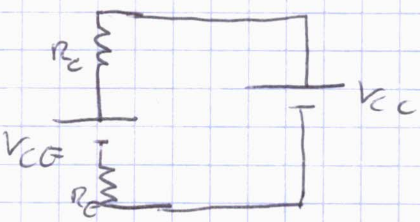
$$V_{BB} = V_{BE} + I_B (R_B + (\beta+1) R_E)$$

$$I_B = 0 \; ; \quad V_{BB} = V_{BE}$$

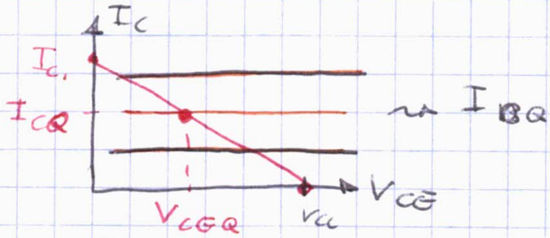
$$V_{BE} = 0 \; ; \quad V_{BB} = I_B (R_B + (1+\beta) R_E) \, ;$$

$$I_{B_s} = \frac{V_{BB}}{R_B + (1+\beta) R_E}$$

- analizamos circuito colector-emisor.



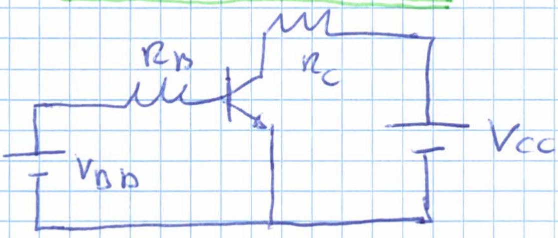
$$V_{CC} = I_C R_C + V_{CE} + I_E R_E \simeq V_{CE} + I_C (R_C + R_E)$$



$$I_C = 0 \; ; \quad V_{CC} = V_{CE}$$

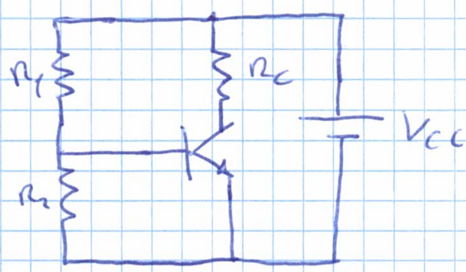
$$V_{CE} = 0 \; ; \quad I_{C_s} = \frac{V_{CC}}{R_C + R_E}$$

- Diseño de circuitos



$$V_{CC} = I_C R_C + V_{CE} \; ; \; R_C = \frac{V_{CC} - V_{CE}}{I_C}$$

$$V_{BB} = I_B R_B + V_{BE} \; ; \; R_B = \frac{V_{BB} - V_{BE}}{I_B}$$



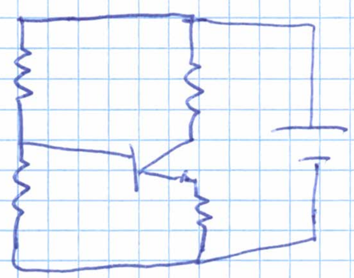
$$R_C = \frac{V_{CC} - V_{CE}}{I_C} \; ; \; I_B = \frac{I_C}{\beta}$$

- Elección del factor n:

$20 \geq n \geq 5$ (típico 10)

$$\left.\begin{array}{l} V_{R_2} = V_B = V_{BE} \\ I_{R_2} = n I_B \\ V_{R_2} = R_2 I_{R_2} \end{array}\right\} R_2 = \frac{V_{BE}}{I_{R_2}}$$

$$R_1 = \frac{V_{R1}}{I_{R1}} = \frac{V_{CC}}{I_{R1}} \cdots$$



V_{CC}

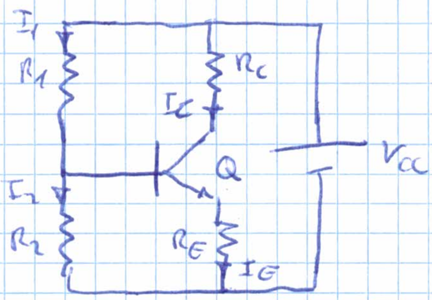
Ejercicio: Diseñar el circuito de polarización con 4 resistencias.

$I_C = 1\,mA$; $V_{CE} = V_{CC}/2$; $V_{BE} = 0'6V$; $\beta = 100$

Criterios:

$R_C = 10 \cdot R_E$

$I_2 = 10\, I_B$



$$V_{CC} = I_C R_C + I_E R_E + V_{CE}$$

$$\left.\begin{array}{l} I_E = \frac{\beta+1}{\beta} I_C \\ R_E = \frac{R_C}{10} \end{array}\right\} V_{CC} = V_{CE} + I_C \left(R_C + \frac{\beta+1}{\beta} \frac{R_C}{10} \right) \rightarrow$$

$$V_{CC} = V_{CE} + R_C I_C \left(1 + \frac{\beta+1}{\beta\, 10}\right)$$

$$R_C = \frac{V_{CC} - V_{CE}}{I_C\left(1+\frac{\beta+1}{\beta \cdot 10}\right)} = 5'449\ k\Omega \ ; \quad R_E = \frac{R_C}{10} = 0'5450\ k\Omega$$

$$V_B = V_E + V_{BE} = I_E R_E + 0'6 = \frac{\beta+1}{\beta} I_C R_E + 0'6 = \left(\frac{101}{100} \cdot 1 \cdot 10^{-3} \cdot 545\right) + 0'6 = 1'15\ V$$

$$V_B = I_2 R_2 = 10 I_B R_2 \ ; \quad R_2 = \frac{V_B}{10 I_B} = \frac{1'25}{10 \cdot \frac{10^{-3}}{100}} = 11'50\ k\Omega$$

$$I_B = \frac{I_C}{\beta} = \frac{1 \cdot 10^{-3}}{100}$$

$$\frac{V_{CC} - V_B}{11 I_B} = R_1 = \frac{12 - 1'15}{11 \cdot \frac{10^{-3}}{100}} = 98'63\ k\Omega$$

- Transistor como amplificador.

1. $V_g(t) = 0'4 \operatorname{sen} \omega t$: En ese momento está en corte porque no le llega tensión suficiente.

2. $V_g(t) = 0'4 \operatorname{sen} \omega t$

$$V_{BB} = 1'6\ V$$

$$V_{BB} + V_g(t) = I_B R_B + V_{BE}$$

$$\frac{V_{BB} + V_g(t) - V_{BE}}{R_B} = I_B \ ;$$

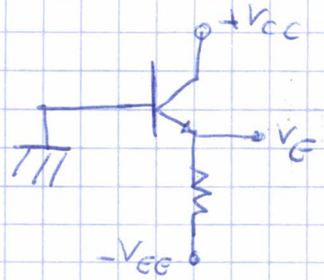
$$I_B = \frac{1'6 + 0'4 \operatorname{sen} \omega t - 0'6}{40} = \frac{1 + 0'4 \operatorname{sen} \omega t}{40}\ mA$$

$$I_C = \beta I_B = 2'5 + \operatorname{sen} \omega t \quad mA$$

$$V_C = V_{CC} - I_C R_C = 5 - 2 \operatorname{sen} \omega t\ V$$

La señal de 0'4 V_p se convierte en una de 2 V_p invertida.

Ejercicio 7: Circuito de polarización con FA simétrica.



$V_{BE}=0'7V$; $\beta=150$; $V_{CC}=5V$; $-V_{EE}=-5V$; $R_E=3'9k\Omega$

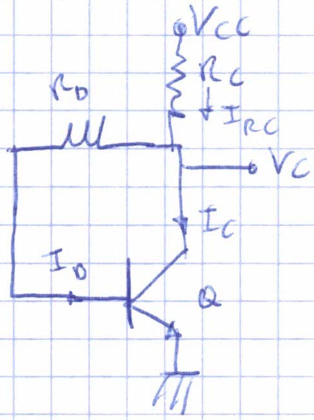
$V_B=0$; $V_E=-0'7V$

$$I_E=\frac{V_{EE}+V_E}{R_E}=\frac{+5-0'7}{3'9}=\frac{+4'3}{3'9}=+1'102mA$$

$$I_B=\frac{V_{EE}-V_{BE}}{(\beta+1)R_E}=\frac{5-0'7}{151\cdot 3'9}=7'3\mu A$$

$$I_C=1'095mA$$

Ejercicio 8:



$R_C=6k8\Omega$; $R_B=100k$

$\beta=150$; $|V_{BE}|=0'7V$

$V_{CC}=15V$

$I_B+I_C=I_{RC}$

$I_B+\beta I_B=I_{RC}$; $I_{RC}=I_B(1+\beta)$

$V_E=0V$; $V_B=0'7V$

$$V_{CC}=I_{RC}R_C+I_BR_B+V_{BE}$$

$$15-0'7=I_B(1+\beta)R_C+I_BR_B$$

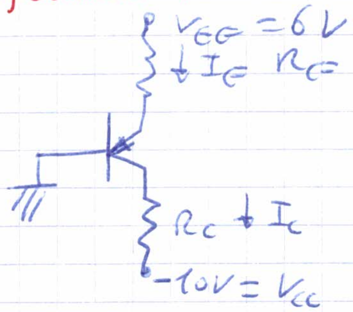
$$14'3=150\cdot 6'8\ I_B+100I_B$$

$$I_B=12'69\mu A//$$

$$I_C=\beta I_B=150\cdot 12'69=\ldots\mu A$$

$$V_C=V_{CC}-I_{RC}R_C=15-[12'69+150\cdot 12'69]6'8=1'97V//$$

Ejercicio 9:



$R_E = 6'8 k\Omega$ $\quad -V_{CC} = -10V$

$R_C = 4'7 k\Omega$ $\quad V_{EE} = 6V$

$\beta = 500$ $\quad V_{EB} = 0'8V$

$$V_{EE} = I_E R_E + V_{EB}$$

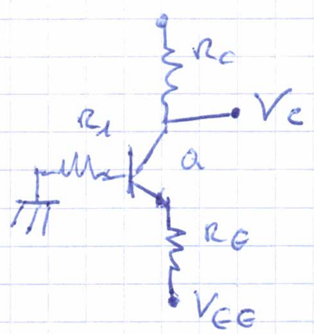
$$I_E = \frac{V_{EE} - V_{EB}}{R_E} = \frac{6 - 0'6}{6'8} = \frac{5'4}{6'8} = 0'794 \ mA //$$

$$I_E = \frac{\beta + 1}{\beta} I_C \ ; \ I_C = \frac{I_E \beta}{\beta + 1} = \frac{500 \cdot 0'794}{501} = 0'7925 \ mA //$$

$$V_C = -V_{CC} + I_C R_C = -10 + 0'7925 \cdot 4'7 = -6'275 \ V //$$

$$V_{CE} = V_C - V_E = -6'875 V //$$

Ejercicio 6:



$I_C = \beta I_B$ $\quad I_E = (\beta + 1) I_B = 1'515 \ mA //$

$1'5 mA //$

$$0 = I_B R_1 + V_{BE} + I_B (1 + \beta) \cdot R_E + V_{EE}$$

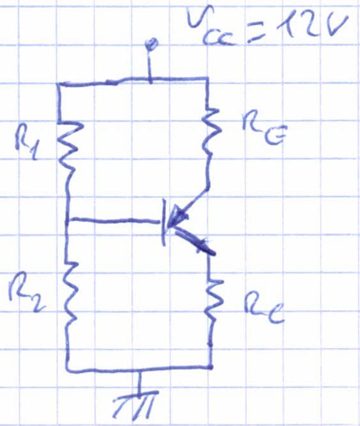
$$-V_{EE} - V_{BE} = I_B (R_1 + (\beta + 1) R_E) \ ; \ I_B = \frac{-V_{EE} - V_{BE}}{R_1 + (\beta + 1) R_E}$$

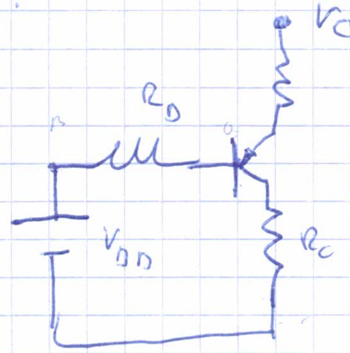
$'' \ 13'5V //$

$$\left.\begin{array}{l} V_C = V_{CC} - I_C R_C \\ V_E = V_{EE} + I_E R_E \end{array}\right\} V_{CE} = V_C - V_E > V_{CE\,sat} = 14'985 V //$$

$'' \ -1'485V //$

Ejercicio 10: Circuito de polarización con cuatro resistencias y transistor BJT pnp.



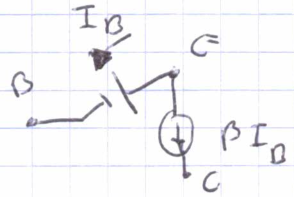


$|V_{BE}| = 0'6V$, $\beta = 100$

$R_1 = 22k\Omega$; $R_2 = 68k\Omega$

$R_E = 1k\Omega$; $R_C = 3'9k\Omega$

$$I = \frac{V_{CC}}{R_1+R_2} \; // \; 1'989mA \quad ; \quad V_{BB} = I R_2 = V_{CC}\frac{R_2}{R_1+R_2} = 9'06V$$



$$R_B = \frac{R_1 R_2}{R_1+R_2} = 16'62k$$

$$I_E = (\beta+1) I_B$$

$$I_C = \beta I_B$$

$$V_{CC} = I_E R_E + V_{EB} + I_B R_B + V_{BB}$$

$$V_{CC} - V_{EB} - V_{BB} = I_B(R_B + (1+\beta)R_E)$$

$$I_B = \frac{V_{CC} - V_{EB} - V_{BB}}{R_B + (1+\beta)R_E} = \frac{12 - 0'6 - 9'06}{16'62 + (101)} = 19'89\mu A$$

$I_E = (\beta+1) I_B = 2'009 mA$

$V_E = 9'99V = V_{CC} - I_E R_E$

$V_C = I_C R_C = 7'75V$

$V_{CE} = V_C - V_E = -2'23V$