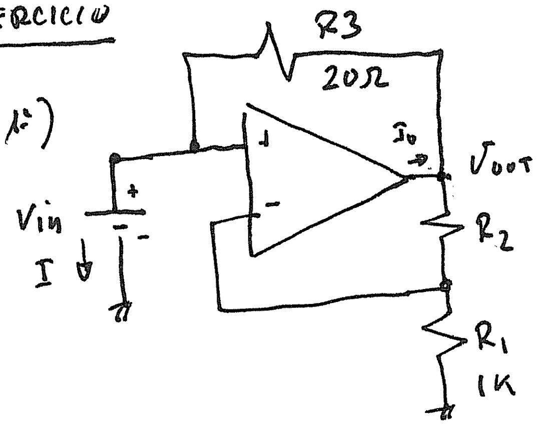
RESOLUCIÓN CUESTIONES Y EJERCICIOS EXAMEN 8-2-99 DE ELECTRÓNICA ANALÓGICA (EXAMEN COMPLETO)

1º EJERCICIO

1º)



$|I_o|_{máximo} = 200mA$

$|V_o|_{max} = 15V.$

Calculemos el valor de V_{OUT}, I_o e I en el caso de que el funcionamiento del A.O. sea lineal:

La configuración es la de un A.O. no inversor.
Es inmediato en en funcionamiento lineal se cumple:

$$V_{OUT} = \left(1 + \frac{R_2}{R_1}\right) V_{in}$$

NOTA: R3 no introduce realimentación si Vin es una fuente ideal.

$$I = \frac{V_{OUT} - V_{in}}{R_3}$$ Expresión cierta siempre que $|I_o| < 200mA$

Aplicando nudo en V_{OUT}, podemos deducir el valor de I_o

$$V_{OUT}(G_2 + G_3) - G_3 V_{in} - G_2 \cdot \frac{R_1}{R_1+R_2} V_{OUT} - I_o = 0$$

o lo que es lo mismo:

$$I_o = \frac{V_{OUT} - V_{in}}{R_3} + \frac{V_{OUT}}{R_1 + R_2} = V_{OUT}\left[\frac{1}{R_3} + \frac{1}{R_1+R_2}\right] - \frac{V_{in}}{R_3}$$

$$I_o = V_{OUT}\left[\frac{1}{R_3} + \frac{1}{R_1+R_2}\right] - \frac{V_{in}}{R_3}$$

Como $R_1 = 1K$ y $R_3 = 20Ω$, como se preveía desde el principio

$$I_o \simeq \frac{V_{OUT} - V_{in}}{R_3} \simeq I$$, ya que la corriente a través del divisor de tensión R_2 y R_1 es despreciable frente a la que circula por R_3

A) $R_2 = 1K\Omega \Rightarrow V_{OUT} = 2\,V_{in}$ $\quad I_0 = \frac{V_{OUT} - V_{in}}{20} \simeq I$

$V_{in} = 0 \Rightarrow V_{OUT} = 0 \quad I = 0$

$V_{in} = 1{,}5v. \Rightarrow V_{OUT} = 3v \quad I = \frac{3 - 1'5}{20} = 75mA$

$V_{in} = 6 \quad V_{OUT} = 12v \quad I = \frac{12 - 1'5}{20} = 525mA \rightarrow$ Protección $\Rightarrow I = 200mA$

$V_{in} = 12v \quad V_{OUT} = 24v. \Rightarrow$ SATURACIÓN $\Rightarrow V_{OUT} = 15v \Rightarrow I = \frac{15 - 12}{20} = 150mA.$

B) $R_2 = 500\Omega \Rightarrow V_{OUT} = 1'5\,V_{in}$ $\quad I_0 = \frac{V_{OUT} - V_{in}}{20}$

$V_{in} = 0 \quad V_{OUT} = 0 \quad I = 0$

$V_{in} = 1'5v. \quad V_{OUT} = 2'25v \quad I = 37'5\,mA$

$V_{in} = 6v \quad V_{OUT} = 9v \quad I = \frac{9 - 6}{20} = 150mA.$

$V_{in} = 12v \quad V_{OUT} = 18 \Rightarrow$ SAT. $\Rightarrow V_{OUT} = +15 \Rightarrow I = \frac{15 - 12}{20} = 150mA.$

C) $R_2 = 200\Omega \Rightarrow V_{OUT} = 1'2\,V_{in}$ $\quad I = \frac{V_{OUT} - V_{in}}{20}$

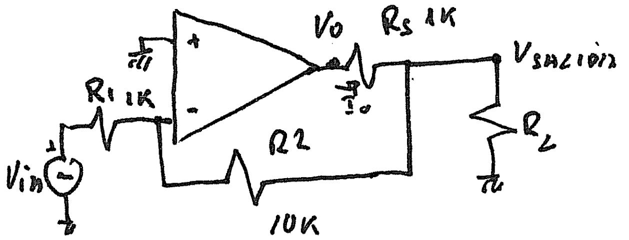
$V_{in} = 0 \quad V_{OUT} = 0 \quad I = 0$

$V_{in} = 1'5v \quad V_{OUT} = 1'8v. \quad I = 15\,mA.$

$V_{in} = 6v. \quad V_{OUT} = 7'2v \quad I = 60\,mA.$

$V_{in} = 12v \quad V_{OUT} = 14'4v. \quad I = \frac{14'4 - 12}{20} = 120\,mA.$

2º EJERCICIO



Siempre y cuando el A.O. sea ideal ($Ad \to \infty$) y V_0 no alcance las tensiones de saturación y la corriente $|I_0| < I_{MAX}$:

$$\boxed{V_{SALIDA} = -\frac{R_2}{R_1} V_{in}}$$

$$V_{SALIDA}\left(G_S + G_L + G_2\right) - G_S V_0 - G_L \cdot 0 - G_2 V^- = 0$$

Si se cumplen las condiciones de linealidad $V^+ = 0 \Rightarrow V^- = 0$

$$V_{SALIDA}\left(G_S + G_L + G_2\right) - G_S \cdot V_0 = 0$$

$$V_0 = \frac{G_S + G_L + G_2}{G_S} V_{SALIDA} = -\left(1 + \frac{R_S}{R_L} + \frac{R_S}{R_2}\right) \cdot \frac{R_2}{R_1} V_{in}$$

Como $\frac{R_2}{R_1} = 10$

$$V_0 = -10\left[1 + \frac{R_S}{R_L} + \frac{R_S}{R_2}\right] V_{in}$$

La anterior expresión es cierta en tanto $|V_0| < V_{SAT}$ $\quad |V_0| < 15v$

y e $|I_0|$ no supere los 25mA.

donde: $I_0 = \dfrac{V_0 - V_{SAL}}{1K}$

$V_{SAL} = -10\,V_{in}$

$V_0 = -21\,V_{in}$ $\qquad I = \dfrac{V_0 - V_{SAL}}{R_S} = \dfrac{-21V_{in} + 10V_{in}}{R_S} = -\dfrac{11}{1K} V_{in}$

A) $R_L = 1K$. $\Rightarrow$

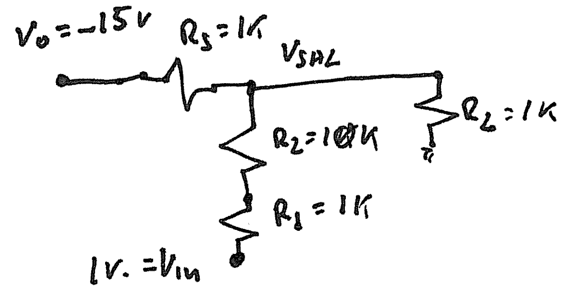
$V_{in} = 100mV \Rightarrow \quad V_0 = -10\left[1 + \dfrac{R_S}{R_L} + \dfrac{1}{10}\right] V_{in} = -10\left[1 + 1 + \dfrac{1}{10}\right] 0'1 = -2'1v.$

$V_{in} = 300mV \Rightarrow \quad V_0 = -21 \cdot 0'3 = -6'3v. \quad I_0 = \dfrac{-6'3 + 3}{1K} = -3'3mA.$

$\underline{V_{SAL} = -10V_{in} = -3v.}$

$V_{in} = 1v \Rightarrow \quad V_0 = -21 \cdot 1 = -21v. \Rightarrow SAT.$

CIRCUITO EQUIVALENTE:



$V_{SAL} \cdot \left[\dfrac{1}{1K} + \dfrac{1}{11K} + \dfrac{1}{1K}\right] - \left(\dfrac{1}{1K} \cdot -15\right) - \dfrac{1}{11K} \cdot 1 = 0$

$V_{SAL}\,[2'091] = -15$

$$\boxed{V_{SAL} = -\dfrac{15}{2'091} = \underline{\underline{-7'174v}}}$$

$|I_0| = \left|\dfrac{-15 + 7'174}{1K}\right| < I_{MAX}$

B) $R_L = 500\Omega$.

Siempre que se cumpla la hipótesis de funcionamiento lineal:

$$\boxed{\begin{aligned} V_{SAL} &= -10\,V_{in} \\ V_0 &= -31\,V_{in} \end{aligned}}$$

, y con $R_L = 500\Omega$: $\quad V_0 = -10\left[1 + \dfrac{1.000}{500} + 0'1\right] V_{in}$

$V_0 = -10\,[3'1]\,V_{in} = -31\,V_{in}$

$I_0 = (V_0 - V_{SAL})/1K$

$V_{in} = 100mV. \quad V_0 = -31 \cdot 0'1 = -3'1v. \Rightarrow V_{SAL} = -1v. \quad |I_0| < 25mA$

$V_{in} = 300mV \quad V_0 = -31 \cdot 0'3 = -9'3 \Rightarrow V_{SAL} = -3v. \quad |I_0| < 25mA$

$V_{in} = 1v. \quad V_0 = -31 \cdot 1 = -31v \Rightarrow$ SATURACIÓN. El circuito equivalente pasa a ser el mismo del caso anterior pero con $R_L = 500\Omega = 0'5K$.

$V_{SAL}\left[\dfrac{1}{1K} + \dfrac{1}{11K} + \dfrac{1}{0'5K}\right] - \left(-15 \cdot \dfrac{1}{1K}\right) - \dfrac{1}{11K} = 0$

$V_{SAL} = \dfrac{-15}{3'091} v. = -4'85v. \qquad |I_0| < 25mA$

$R_L = 100\Omega$.

$V_{SALIDA} = -10\, V_{in}$

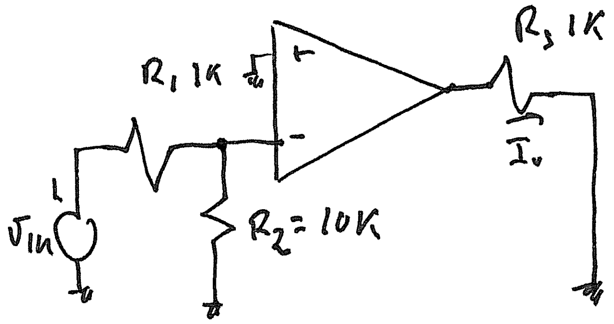
$V_0 = -10\left[1 + \frac{1K}{0'1K} + \frac{1}{10}\right] V_{in} = -10\left[1 + 10 + \frac{1}{10}\right] V_{in} = -10 \times 11'1\, V_{in}$

$V_0 = -111\, V_{in}$

$111\, V_{in} < 15 \Rightarrow \quad V_{in} < \frac{15}{111} = 0'135\,V.$

V_{in} maxima $=$ $\underline{135 mV}$

$R_L = 0$. EL CIRCUITO EQUIVALENTE ES AHORA:



No existe realimentación

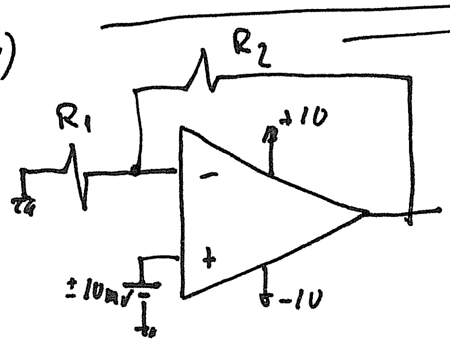
Con $V_{in} = +1V. \Rightarrow V^- > 0$

con $V^+ = 0 \Rightarrow$

$V^- > V^+ \Rightarrow \quad V_0 = -15V.$

$I_0 = -15\,mA$

3º)



$V^-(G_1 + G_2) - G_1 \cdot 0 - G_2 \cdot V_0 = 0$

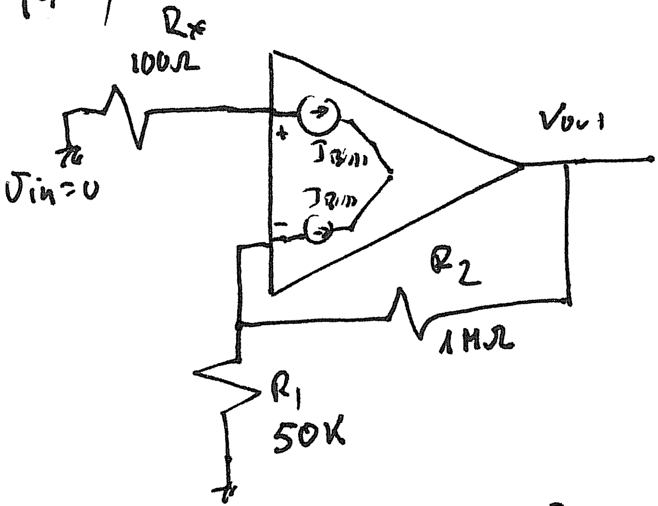
$V^- = V^+ \Rightarrow \quad V^- = \pm 10 mV$

$\pm 10mV\,(G_1 + G_2) = G_2\, V_0$

$V_0 = \pm 10mV.\left[1 + \frac{G_1}{G_2}\right] = \pm 10mV\left[1 + \frac{R_2}{R_1}\right] =$

$V_0 = \pm 10mV.\,[1 + 200] = 201 \cdot 10mV = \underline{2'01V}$

(4°)



En ausencia de señal, ($v_{in}=0$) si el A.O. está funcionando linealmente $v^+ = v^-$

$$v^+ = 0 - R_x I_{BIAS} = -R_x I_{BIAS}$$

En el nudo ⊖:

$$v^-(G_1+G_2) - G_2 V_{OUT} + I_{BIAS} = 0$$

$$V_{OUT} = I_{BIAS} \cdot R_2 + v^- \left[\frac{G_1+G_2}{G_2}\right]$$

$$V_{OUT} = R_2 I_{BIAS} + \left(1+\frac{R_2}{R_1}\right) v^- = R_2 I_{BIAS} + A \cdot v^-$$

$$V_{OUT} = R_2 I_{BIAS} + A(-R_x I_{BIAS})$$

$$\boxed{V_{OUT} = [R_2 - A R_x] I_{BIAS}}$$

$R_2 = 1M\Omega$

$R_x = 100\Omega$

$A = 21$

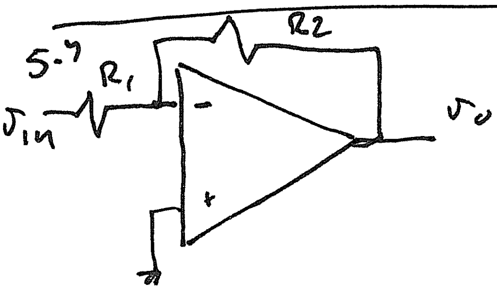
$$V_{OUT} = [1M\Omega - 21 \cdot 100] \cdot 1\mu A$$

$$V_{OUT} = [1M\Omega - 2'1K] \cdot 1\mu A \simeq \underline{1V}$$

Si deseamos que $V_{OUT} \simeq 0 \Rightarrow$

$$R_2 = A R_x \Rightarrow R_x = \frac{R_2}{A} = \frac{1M\Omega}{21} = 47'6K$$

$R_x = 47'6K \Rightarrow$ Resistencia adicional $47'6K - 100\Omega \simeq \underline{47'5K}$



$$v_0 = -\frac{100K}{2K} v_{in} = -\frac{R_2}{R_1} v_{in} = -50 v_{in}$$

$$v_{in} = (10mV) \cdot \text{sen}\,\omega t$$

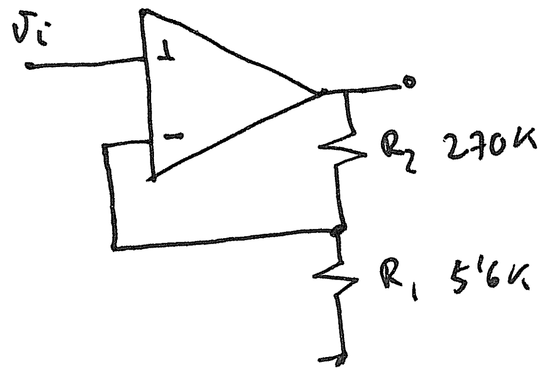
$$v_{out} = -0'5v \cdot \text{sen}\,\omega t$$

$$\left.\frac{dv}{dt}\right|_{MAX}\Big|_{\omega t=0} = 0'5 \cdot \omega = 0'5 \cdot 2\pi f < 1V/\mu s$$

$$f < \frac{10^6}{0'5 \cdot 2\pi} = 318'3KHz$$

5

6.)



$$A_d(j\omega) = \frac{A_{do}}{1 + j\frac{\omega}{\omega_B}}$$

$$A_{do} = \left(1 + \frac{R_2}{R_1}\right) = 49'21$$

GANANCIA × ANCHURA DE BANDA = cte = $A_{do_{\text{LAZO ABIERTO}}}$ × anchura banda lazo ab.

$= 2 \times 10^4 \times 12 = 24 \times 10^4$

$24 \times 10^4 = 49'21 \; f_B \Rightarrow f_B = \frac{24 \times 10^4}{49'21} = 4.877 \, Hz.$

7.)

$$I_d = I_s\left(e^{v_d/V_T} - 1\right) = 10^{-15}\left[e^{v_d/25mV} - 1\right]$$

$$3mA \simeq 10^{-15} e^{v_0/25m}$$

$$\frac{v_0}{25mV} = \ln \frac{3 \times 10^{-3}}{10^{-15}} = 28'73$$

$$v_0 = 25mV \times 28'73 = \underline{\underline{0'718 \, V}}$$

8.)

$$I_s(T) = I_s(T_R) \cdot 2^{\frac{T - T_R}{5}}$$

a $t = 0°C$ (273°K) $\quad I_s(273°K) = I_s(27°C) \cdot 2^{\frac{(273-300)}{5}}$

$$I_s(0°C) = 10^{-15} \cdot (\;) = 2'367 \times 10^{-17}$$

$$V_d = V_T(0°C) \cdot \ln \frac{3 \times 10^{-3}}{2'367 \times 10^{-17}}$$

300°K $\quad V_T(27°C)$ — 25mV

273 — x

$x = \frac{273}{300} \cdot 25mV = 22'75mV.$

$$v_d(t = 0°C) = \underline{\underline{0'738 \, V.}}$$

⑥

$I_S(100°C) = 10^{-15} \cdot 2^{\frac{373-300}{5}} = 2'473 \cdot 10^{-11}$

$V_T(100°C) = 25mV \cdot \frac{373}{300} \quad 31'1 mV.$

$i_D = 2'473 \cdot 10^{-11} \cdot e^{Vd/V_T} = 3mA$

$Vd = 31'1mV \cdot \ln \frac{3 \cdot 10^{-3}}{2'473 \cdot 10^{-11}} =$

$Vd = 578'8 mV.$

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9) $rd = \frac{V_T}{I_{DQ}} = \frac{25mV}{3mA} = 8'33\,\Omega$

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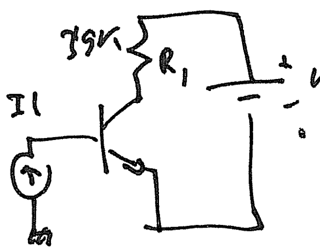
10)



$I_{CQ} = \beta_F \cdot I_1 = 50 \cdot 20\mu A. = 1mA.$

$V_{CEQ} = 12 - 3'9K \cdot 1mA = 8'1v.$

$0'2 = 12 - 3'9K\, I_{CMAX} \Rightarrow$ $\quad I_{CMAX} = \frac{12-0'2}{3'9K} = 3'0256mA \Rightarrow$

$I_{BMAX} = 60'5\mu A.$

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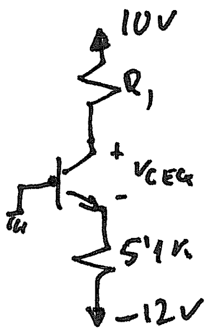
11)



$V_{CEQ} \simeq 22 - (R_1 + 5'1K)\, I_{CQ}$

Pero $I_{CQ} \simeq \frac{-0'7+12}{5'1K} \simeq 2'2mA$

$V_{CEQ} = 22 - (R_1 + 5'1K) \quad 2'2mA = 5$

(2'24mA)

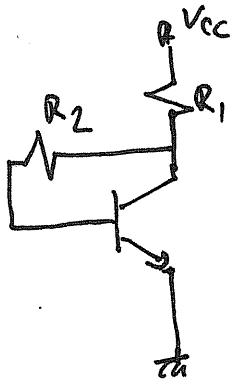
$17 = 2'2(R_1 + 5'1K) \Rightarrow$

$R_1 + 5'1K = 7'73K$

$\boxed{R_1 \simeq 2'63K}$ para $V_{BEQ} = 0'7v.$

$R_1 = 2'49K$ para $V_{BEQ} = 0'6v.$

12).



$E_{BE} = V_{CC}$

$E_{CE} = V_{CC}$

$R_B + R_E = R_1 + R_2$

$R_C + R_E = R_1$

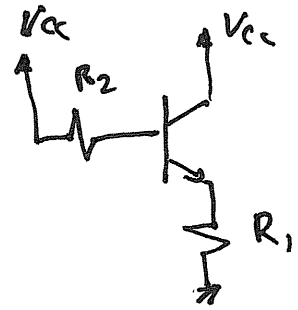
$R_B + R_C = R_2$

$$R_B = \frac{1}{2}\left[(R_B+R_E) + (R_B+R_C) - (R_C+R_E)\right] = \frac{1}{2}\left[R_1+R_2+R_2-R_1\right]$$

$$R_C = \frac{1}{2}\left[(R_B+R_C) + (R_C+R_E) - (R_B+R_E)\right] = \frac{1}{2}\left[R_2+R_1-R_2-R_1\right] = 0$$

$$R_E = \frac{1}{2}\left[(R_B+R_E) + (R_C+R_E) - (R_B+R_C)\right] = \frac{1}{2}\left[R_1+R_2+R_1-R_2\right] = R_1$$

$$\boxed{\begin{aligned} R_B &= R_2 \\ R_C &= 0 \\ R_E &= R_1 \end{aligned}} = 100k$$



$R_B + R_E = R_1 + R_2 = 101\,k\Omega$

$R_C + R_E = R_1 = 1\,k\Omega$

$R_B + R_C = R_2 = 100K$

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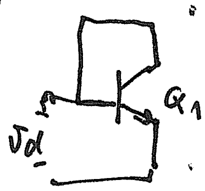
13)

$$I_{Cq} = \frac{E_{BE} - V_{BEq}}{\frac{R_B}{\beta} + R_E(1+\frac{1}{\beta})} = \frac{10 - 0'7}{\frac{100k}{\beta} + 1k(1+\frac{1}{\beta}}$$

$$I_{Cq\,\beta\to\infty} = \frac{10-0'7}{1k} = 9'3\,mA.$$

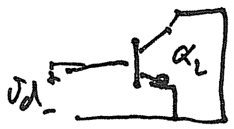
$$I_{Cq\,\beta=100} = \frac{100-0'7}{1k + 1k} \simeq 4'65\,mA$$

14)



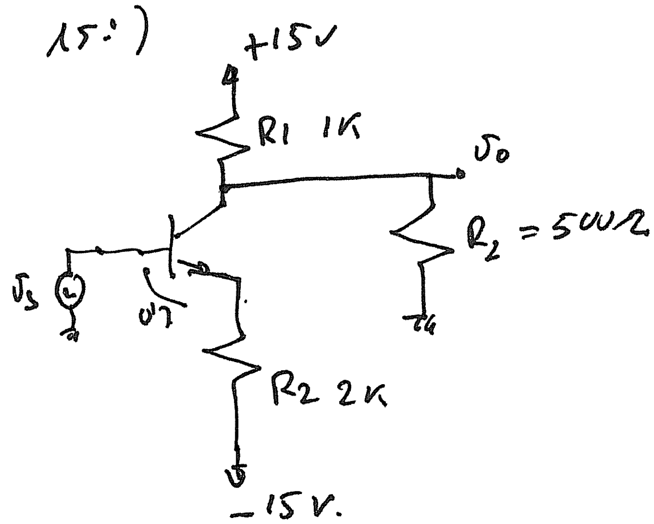
TRANSISTOR NPN.

$V_{BE} = v_d > 0$ U. BE DIRECTA } = R. A. N
$V_{BC} = 0 < V_\gamma$ ⇒ U. BC INVERSA



$V_{BE} = v_d > 0$ U. BE DIRECTA } R. SATURA.
$V_{BC} = v_d$ ⇒ U BE. DIRECTA

15.)



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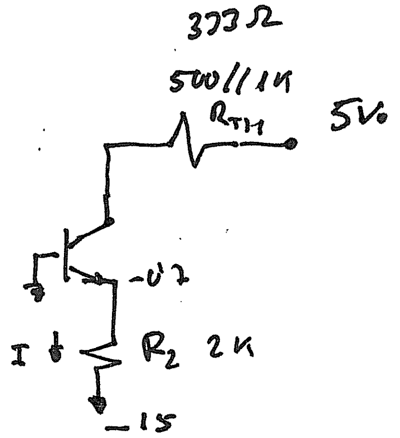


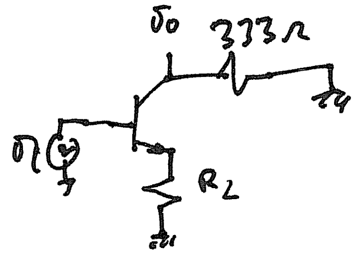
$$I_{R2} = \frac{-0'7+15}{2K} = 7'15\,mA.$$

$$V_C = 5 - 7'15 \cdot 10^{-3} \cdot 333 = 2'62\,V.$$

$$V_E = -0'7$$

$$V_C - V_E = 2'62 - (-0'7) = \underline{\underline{3'32\,V.}}$$

CIRCUITO EQUIVALENTE EN ALTERNA:



CIRCUITO INCREMENTAL EQUIVALENTE:

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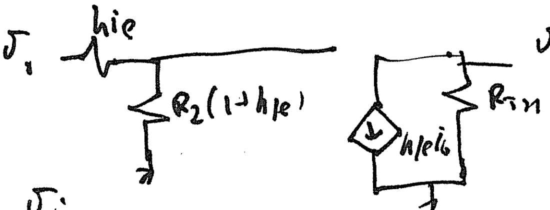


$$v_o = -R_{TH} h_{fe} i_b = \frac{-R_{TH} \cdot h_{fe} \cdot}{h_{ie} + R_2(1+h_{fe})} v_i$$

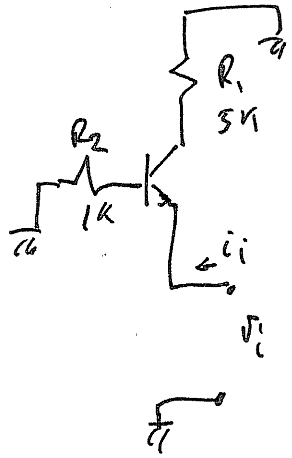
$$\frac{v_o}{v_i} = -\frac{R_{TH} h_{fe}}{h_{ie} + R_2(1+h_{fe})} \simeq -\frac{R_{TH}}{R_2} =$$

$$h_{ie} = \frac{V_T}{I_{CQ}} \cdot \beta_F$$

$$h_{ie} = \frac{25\,mV}{7'15\,mA} \cdot 200$$

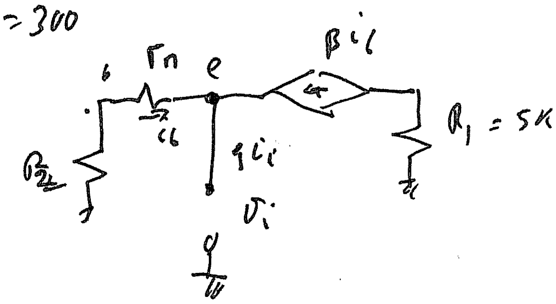
$$h_{ie} = 700\,\Omega$$

Ej. 14.



$I_{CQ} = 1mA \quad r_o = \infty$

$\beta_F = 300$



$$+v_i\left(\frac{1}{r_\pi+R_2}\right) - \beta i_b = i_i =$$

$$i_b = -\frac{v_i}{r_\pi+R_2}$$

$$+v_i \cdot \frac{1}{r_\pi+R_2} + \frac{\beta}{r_\pi+R_2} v_i - i_i = 0$$

$$+v_i\left[\frac{1}{r_\pi+R_2} + \frac{1}{\frac{r_\pi+R_2}{\beta}}\right] = i_i$$

$$r_\pi = \frac{V_T}{I_{CQ}}\beta =$$

$$\frac{v_i}{i_i} = \frac{1}{\frac{1}{r_\pi+R_2} + \frac{1}{\frac{r_\pi+R_2}{\beta}}} = (r_\pi+R_2) \,||\, \frac{r_\pi+R_2}{\beta} \simeq$$

$$\frac{26mV \cdot 300}{1mA} = 7'8k$$

$$\frac{r_\pi+R_2}{\beta} = \frac{7'8K + 1K}{300} = 29'33\,\Omega$$