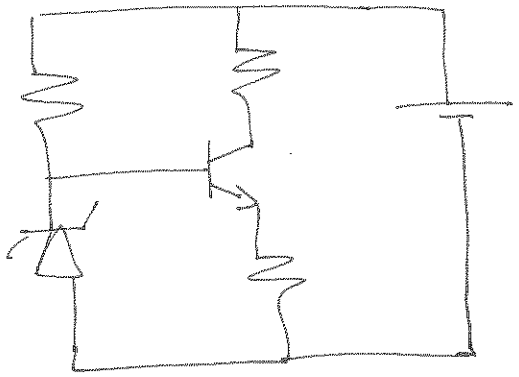
Solución:

a) Circuito DC



Zener en ruptura

Malla B-E

$$V_z = V_{BE} + I_E R_3 \Rightarrow I_E = \frac{V_z - V_{BE}}{R_3}$$

Si activa $\Rightarrow I_E = \frac{6'3 - 0'7}{2K} = 2'8\,mA$

$$I_B = \frac{2'8\,mA}{201} = 13'93\,\mu A \qquad I_C = 2'786\,mA$$

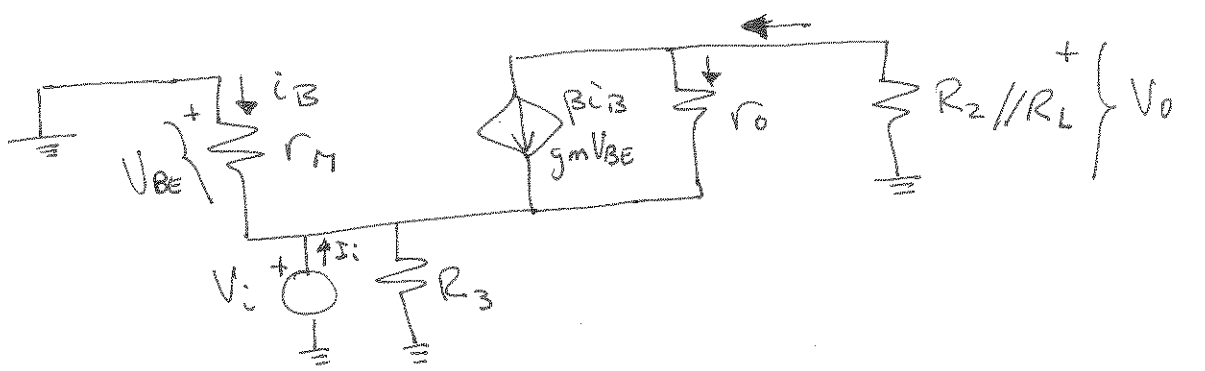
Malla C-E

$$V_{CE} = 15 - I_C R_2 - I_E R_3 = 2'43V > 0'2V \checkmark$$

Comprobamos $I_Z > 0$

$$I_Z = I_{R_1} - I_B = \frac{15 - 6'3}{R_1} - 13'93\mu A = 7'236\,mA \checkmark$$

b)



c) con efecto Early:

$g_m = 108\ mA/V$

$R_2 // R_L = 2K\Omega$

$r_o = 8'97K\Omega$

$r_\pi = 1'85K\Omega$

$V_i = -V_{be}$

$$-\frac{V_o}{R_2 // R_L} = g_m V_{be} + \frac{V_o - V_i}{r_o} \Rightarrow$$

$$\left(g_m + \frac{1}{r_o}\right) V_i = \left(\frac{1}{R_2 // R_L} + \frac{1}{r_o}\right) V_o$$

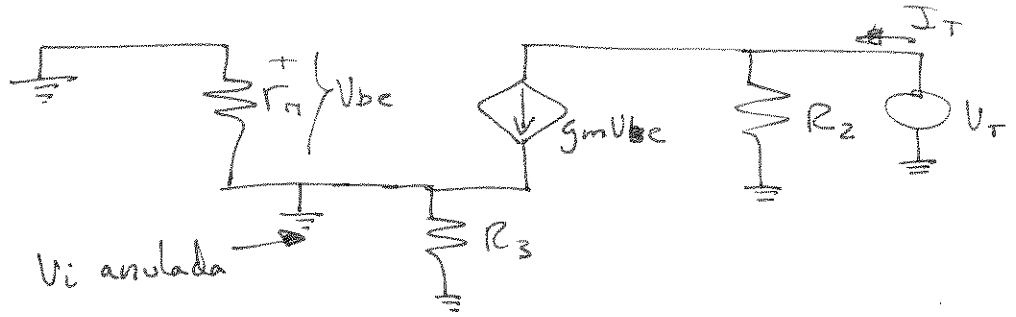
Amplificador No inversor Base común

$$\Rightarrow \Delta v = \frac{V_o}{V_i} = \frac{g_m + \frac{1}{r_o}}{\frac{1}{R_2 // R_L} + \frac{1}{r_o}} = 176'8$$

sin efecto Early $(r_o \longrightarrow \infty) \Rightarrow \Delta v = g_m (R_2 // R_L) = 216$

d) $$R_{IN} = \frac{V_i}{I_i} = \frac{V_i}{\frac{V_i}{r_\pi} + \frac{V_i}{R_3} + g_m V_i} = \frac{1}{\frac{1}{r_\pi} + \frac{1}{R_3} + g_m} = 9'17\Omega$$

circuito para Rout



$V_{be} = 0 \Rightarrow g_m V_{be} = 0 \Rightarrow R_{OUT} = \frac{V_T}{I_T} = R_2 = 2'5K\Omega$

e) (1) Límite activa-saturación: $\begin{cases} U_{CE} = 0'2\,V \\ i_C = \beta i_B \end{cases}$ $\quad i_E = (\beta+1)\, i_B$

Malla C-E

$$15V = \beta i_B\, 2'5K + 0'2V + (\beta+1)\, i_B\, 2K$$

$$\hookrightarrow i_B = \frac{15 - 0'2}{2'5K\,\beta + (\beta+1)\,2K} = 16'4\,\mu A \Rightarrow I_C = 3'28\,mA$$

Malla B-E

$$V_Z = V_{BE} + (\beta+1)\, i_B\, 2K = 7'29\,V$$

Comprobamos I_Z

$$I_Z = I_{R_1} - I_B = \frac{15 - 7'29}{1'2K} - 16'4\mu A = 6'4\,mA$$

(2) estaremos en saturación

C-E: $15V = i_C\, 2'5K + 0'2 + i_E\, 2K$

B-E: $V_Z = 0'7V + i_E\, 2K$

OTRA: $15V = (4mA + i_B)\, 1'2K + V_Z$

KCL: $i_E = i_C + i_B$

$$15V = (i_E - i_B)\, 2'5K + 0'2 + i_E\, 2K = 4'5K\, i_E + 0'2 - i_B\, 2'5K$$

$$15V = (4mA + i_B)\, 1'2K + 0'7 + i_E\, 2K = 2K\, i_E + 0'7 + (4mA + i_B)\, 1'2K$$

$$\Rightarrow \begin{cases} 14'8 = 4'5K\, i_E - i_B\, 2'5K & (\times 1'2) \\ 9'5 = 2K\, i_E + i_B\, 1'2K & (\times 2'5) \end{cases}$$

$$41'51 = 10'4K\, i_E \rightarrow i_E = 3'99\,mA$$

$$\Rightarrow i_B = 1'26\,mA \qquad i_C = 2'73\,mA \qquad i_C < \beta i_B \checkmark$$

$$V_Z = 8'68\,V$$

// Diodo zener ON $\Rightarrow = \frac{1}{T}\, 0'7V \Rightarrow$ el transistor está en el límite corte-activa $\Rightarrow I_E = I_C = I_B = 0$