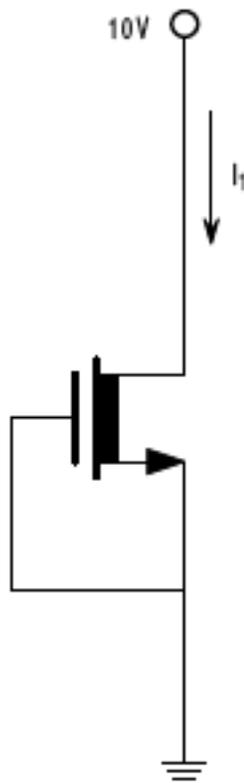
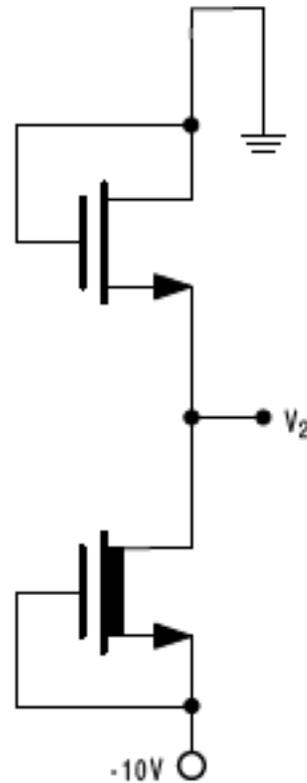


PROBLEMA 1: POLARIZACIÓN DE MOSETS

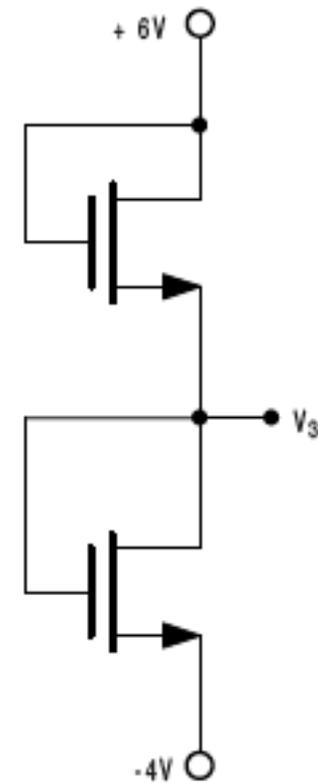
Calcular las corrientes y voltajes señaladas en los circuitos de la figura si para todos los dispositivos $|V_{th}| = 1V$ y $K = 0,5mA/V^2$, considerando que en saturación se cumple $I_D = K (V_{GS} - V_t)^2$



a)

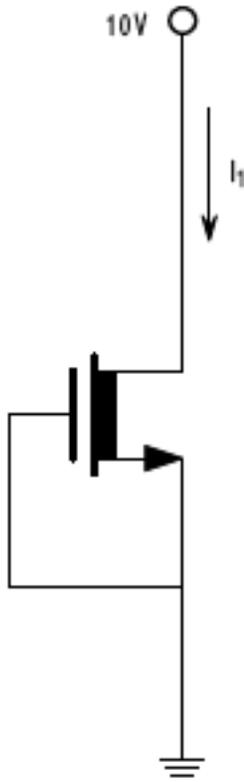


b)



c)

a)



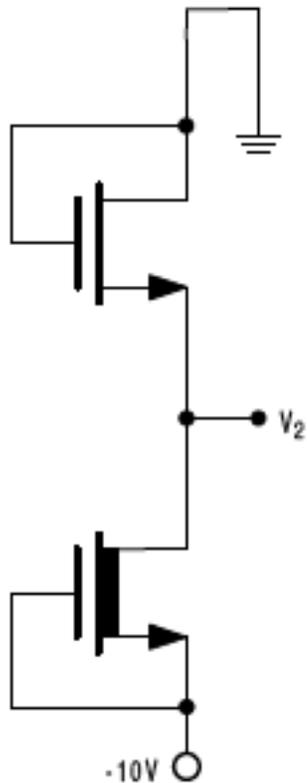
$$I_D = \frac{0,5 \text{ mA}}{V^2} (V_{GS} - V_T)^2$$

$$V_{GS} = 0$$

$$V_T = -1$$

$$I_D = \frac{0,5 \text{ mA}}{V^2} (0 - (-1) \text{ V})^2 = 0,5 \text{ mA}$$

b) Del circuito externo:



$$\sqrt{V_{DS1}} + \sqrt{V_{DS2}} = 10$$

$$\sqrt{V_{GS2}} = \{$$

En el MOSFET de vaciamiento Q2:

$$I_D = 0,5 (0 - (-1))^2 = 0,5 \text{ mA}$$

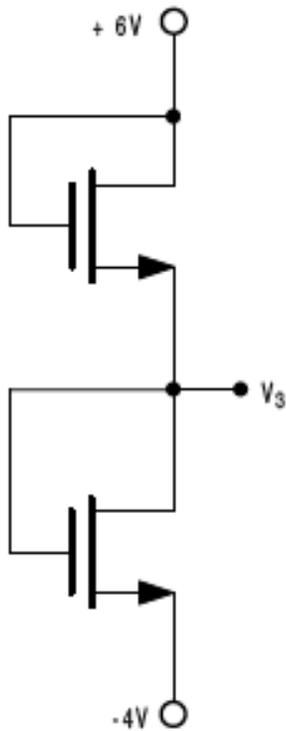
En el MOSFET de enriquecimiento Q1 la corriente es la misma, por lo tanto:

$$0,5 (\sqrt{V_{GS1}} - 1)^2 = 0,5 \text{ mA}$$

$$\sqrt{V_{GS1}} - 1 = \pm 1 \quad \sqrt{V_{GS1}} = 2$$

$$V_2 = V_{S1} = -2V$$

c) Del circuito externo



$$V_{G1} = V_{D1} = 6V \quad V_{S2} = -4V$$

$$V_{S1} = V_{D2} = V_3 \quad V_{G2} = V_{D2} = 1$$

$$I_{D1} = I_{D2}$$

$$0,5 (V_{GS1} - 1)^2 = 0,5 (V_{GS2} - 1)^2$$

$$V_{GS1} = V_{GS2}$$

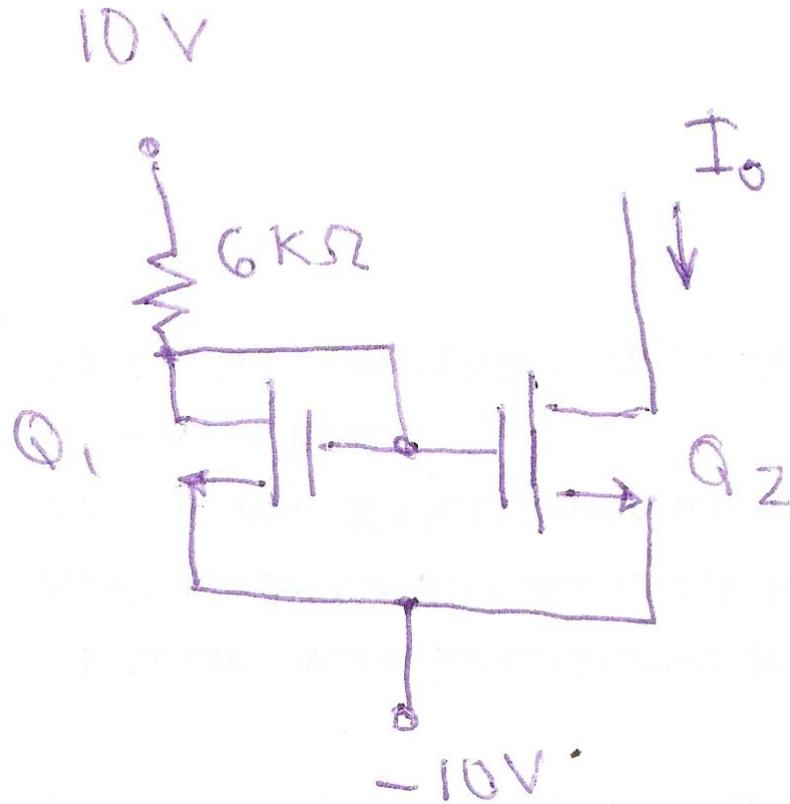
$$V_{G1} - V_{S1} = V_{G2} - V_{S2}$$

$$6V - V_{S1} = V_{G2} - (-4)$$

$$6V - 4V = 2V = V_{G2} + V_{S1} =$$

$$V_3 + V_3 = 2V_3 = 2 \quad V_3 = 1$$

PROBLEMA 3 ESPEJO DE CORRIENTE CON MOSFETS. CÁLCULO DE I_0



Parámetros: $K = 3\text{mA/V}^2$ $V_t = 1\text{V}$
Calcule I_0

$$10\text{V} = I_0 \times 6\text{k} + V_{GS_1} - 10$$

$$20\text{V} = 6 I_0 + V_{GS_1}$$

$$V_{GS_1} = 20\text{V} - 6 I_0$$

$$I_0 = K (V_{GS} - V_t)^2$$

$$I_0 = 3(20 - 6I_0 - 1)^2 = 3(19 - 6I_0)^2$$

Resolviendo:

$$I_D = 3(361 - 228I_D + 36I_D^2)$$

$$0 = 1083 - 685I_D + 108I_D^2$$

$$I_D = \frac{685 \pm \sqrt{469225 - 467856}}{216}$$

$$I_D = \frac{685 \pm 37}{216} \begin{matrix} \nearrow 3,34 \\ \searrow 3 \end{matrix}$$

$$V_{GS_1} = 20V - 6 \times 3,34 = 0$$

$$V_{GS_1} = 20V - 6 \cdot 3 = 2V$$

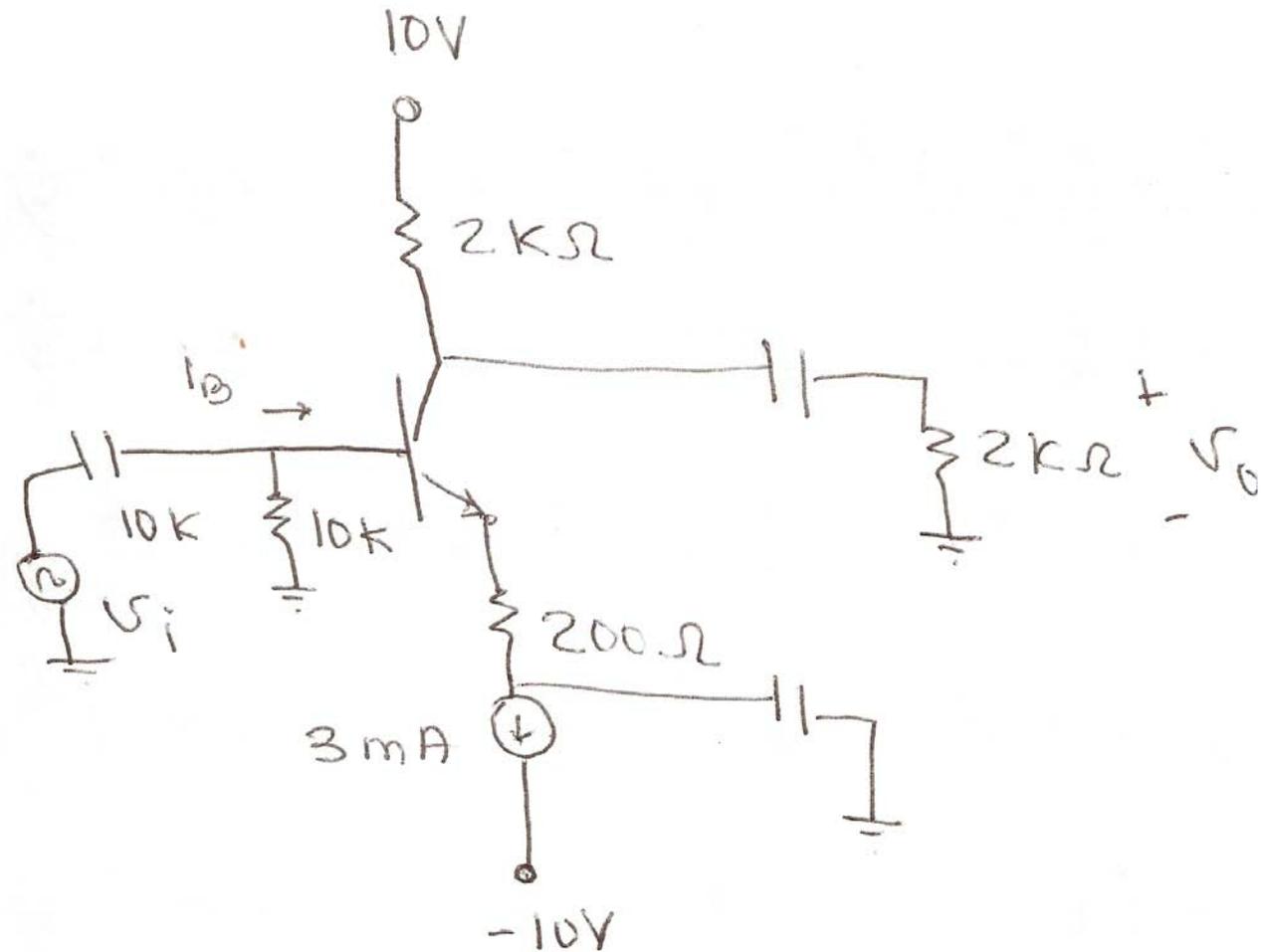
$$\boxed{I_D = 3 \text{ mA}}$$

PROBLEMA 4: AMPLIFICADOR EMISOR COMÚN CON RESISTENCIA DE EMISOR, POLARIZADO CON FUENTE DE CORRIENTE

Para el circuito mostrado calcular el punto de operación, la ganancia de voltaje, la ganancia de corriente, la resistencia de entrada y la resistencia de salida.

$$\beta = 100$$

$$V_{be} = 0,7V$$



Punto de operación, sabiendo que $I_E = 3\text{mA}$

$$I_E \approx I_C$$

$$V_B = I_B \times 10\text{K} = -0,3\text{V}$$

$$I_B = \frac{I_C}{\beta} = 0,03\text{mA}$$

$$V_B - V_E = 0,7\text{V}$$

$$V_E = V_B - 0,7\text{V} = -0,3\text{V} - 0,7\text{V} = -1\text{V}$$

$$V_C = 10\text{V} - 2\text{K}I_C = 10\text{V} - 6\text{V} = 4\text{V}$$

$$V_{CE} = V_C - V_E = 4\text{V} - (-1\text{V}) = 5\text{V}$$

$$I_C = 3\text{mA}$$

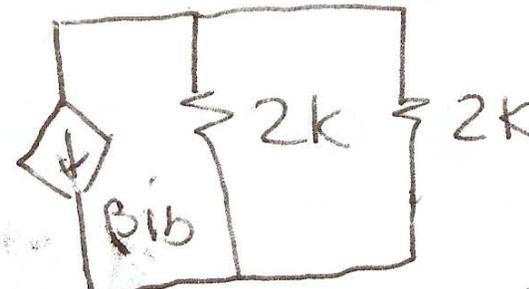
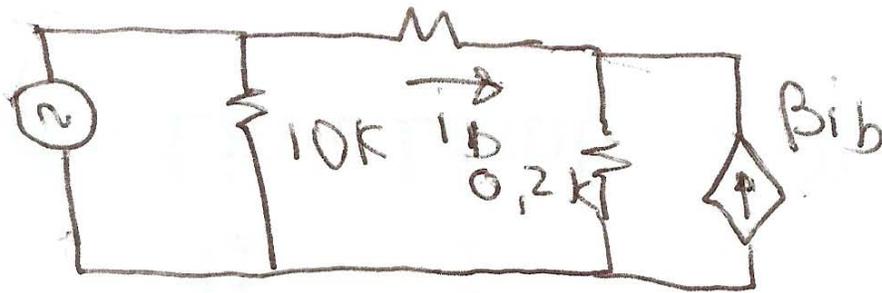
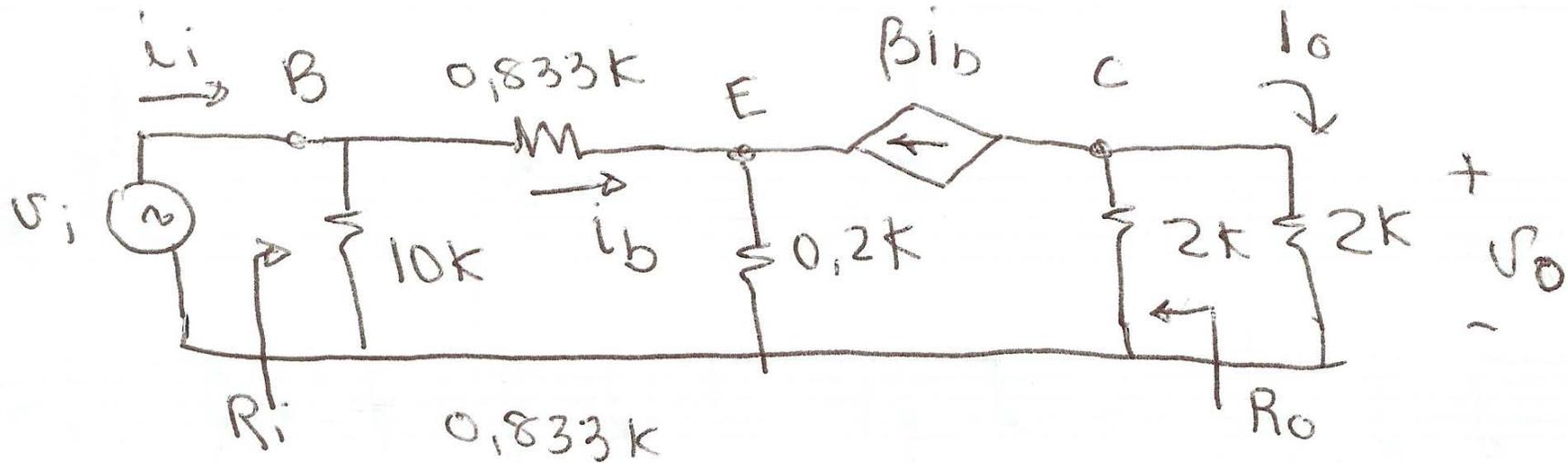
$$I_B = 0,03\text{mA}$$

$$V_{CE} = 5\text{V}$$

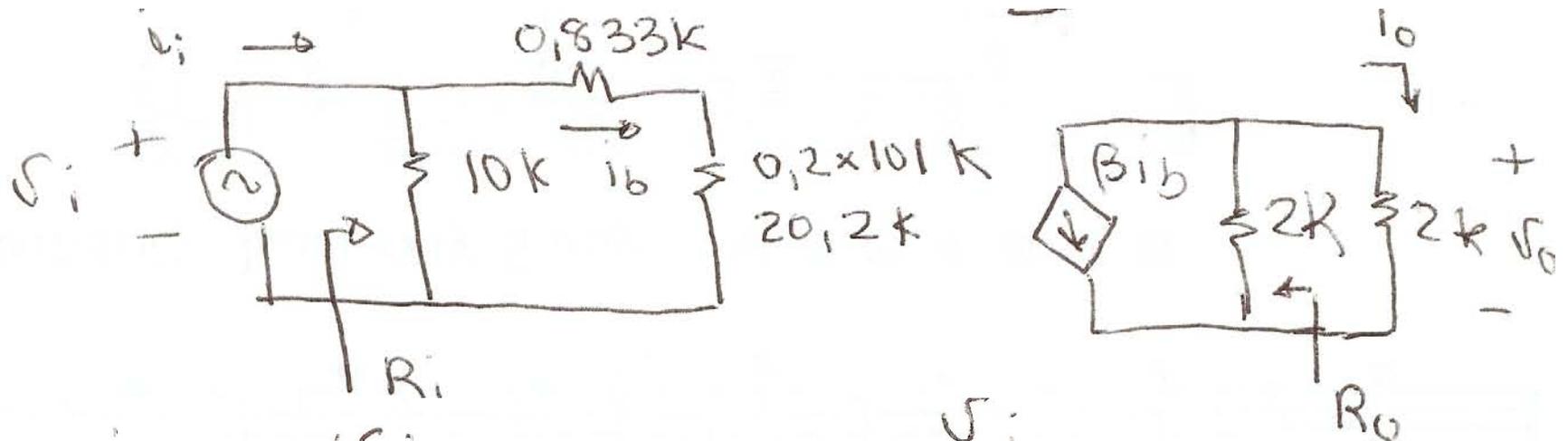
Análisis AC

$$g_m = \frac{3 \text{ mA}}{0,025 \text{ V}} = 120 \frac{\text{mA}}{\text{V}}$$

$$r_{\pi} = \frac{\beta}{g_m} = 0,833 \text{ k}\Omega$$



Ganancia de voltaje



$$i_b = \frac{v_i}{20,2 \text{ k} + 0,833 \text{ k}} = \frac{v_i}{21 \text{ k}}$$

$$v_o = -\beta i_b (R_L \parallel R_C) = -100 \times 1 \text{ k} \times \frac{v_i}{21 \text{ k}}$$

$$A_v = \frac{v_o}{v_i} = -\frac{100}{21} = -4,76$$

Ganancia de corriente, resistencia de entrada y de salida

$$R_o = 2\text{K}\Omega$$

$$R_i = 10\text{K}\Omega \parallel 21\text{K}\Omega = 6,77\text{K}\Omega$$

$$i_i = \frac{v_i}{R_i} \quad v_o = 2\text{K} i_o \quad A_i = \frac{i_o}{i_i}$$

$$A_i = \frac{v_o}{2\text{K}} \cdot \frac{R_i}{v_i} = A_v \frac{6,77\text{K}}{2\text{K}} = -16,11$$

PROBLEMA 5: ESPEJO DE CORRIENTE CON BJTs

Para el circuito mostrado calcule R para que la corriente i_o sea de $0,5\text{mA}$, con $V_o = 2\text{V}$. Considere $\beta = 100$ y $V_{BE} = 0,7\text{V}$

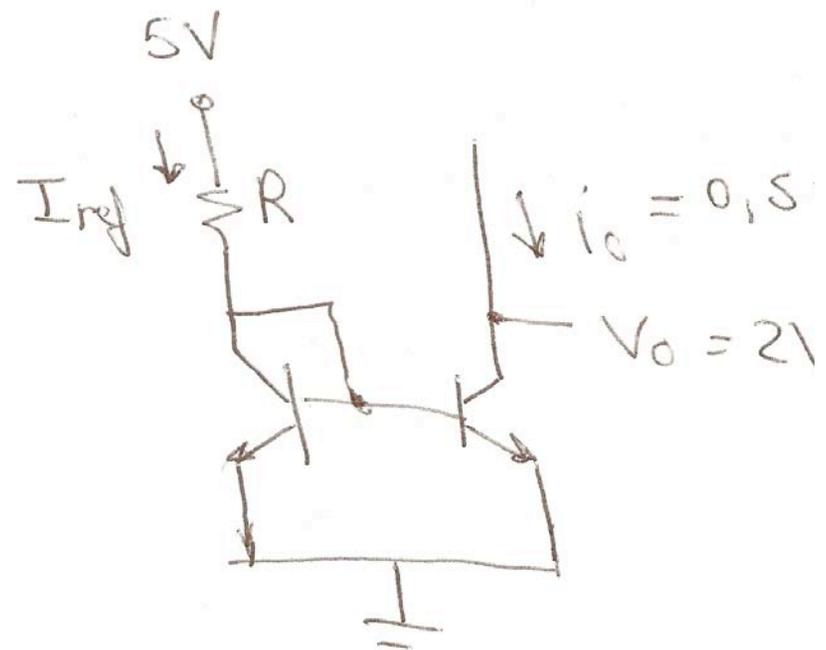
$$5\text{V} = I_{\text{ref}} R + V_{BE} \quad I_{\text{ref}} = I_o$$

$$V_{CEQ} = 5\text{V} - R I_{\text{ref}}$$

$$V_{CEQ} = V_{BE}$$

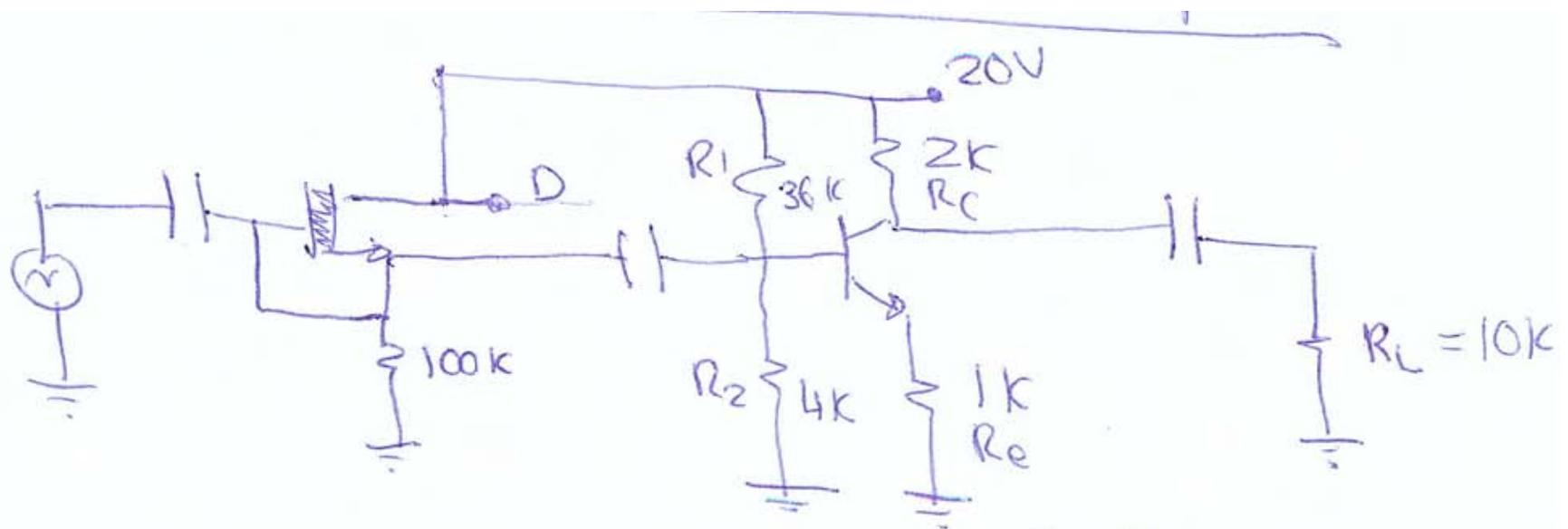
$$I_{\text{ref}} = \frac{5\text{V} - 0,7\text{V}}{R} = 0,5\text{mA}$$

$$R = \frac{5 - 0,7}{0,5} = 8,6\text{ k}\Omega$$



PROBLEMA 6: AMPLIFICADOR COMBINADO CON MOSFET Y BJT

En el siguiente circuito determinar el punto de operación de ambos transistores



$$K = 0,1 \text{ mA}$$
$$\lambda = 0$$
$$V_t = -1 \text{ V}$$

$$\beta = 100$$
$$V_{BE} = 0,7 \text{ V}$$

Punto de operación del MOSFET de vaciamiento

$$V_{GS} = 0$$

$$i_d = k (v_{gs} - V_t)^2$$

$$I_d = 0,1 (0 - (-1))^2 = 0,1 \text{ mA}$$

$$V_{DS} = 20 \text{ V} - 100 i_d = 20 - 100 \times 0,1 = 20 - 10 = 10 \text{ V}$$

$$V_{GS} = 0$$

$$I_D = 0,1 \text{ mA}$$

$$V_{DS} = 10 \text{ V}$$

Punto de operación del BJT

Bipolar

$$R_B = 4k \parallel 36k = 3,6k$$

$$V_{BB} = \frac{4}{40} \times 20 = 2V$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B + R_e(\beta+1)} = \frac{2 - 0,7}{3,6 + 10} = 0,01243 \text{ mA}$$

$$I_C = \beta I_B = 1,24 \text{ mA}$$

$$I_E = (\beta+1) I_B = 1,25 \text{ mA}$$

$$V_{CE} = 20 - 2I_C - 1I_E = 20 - 2,48 - 1,25 = 16,26V$$

$$I_B = 0,01243 \text{ mA}$$

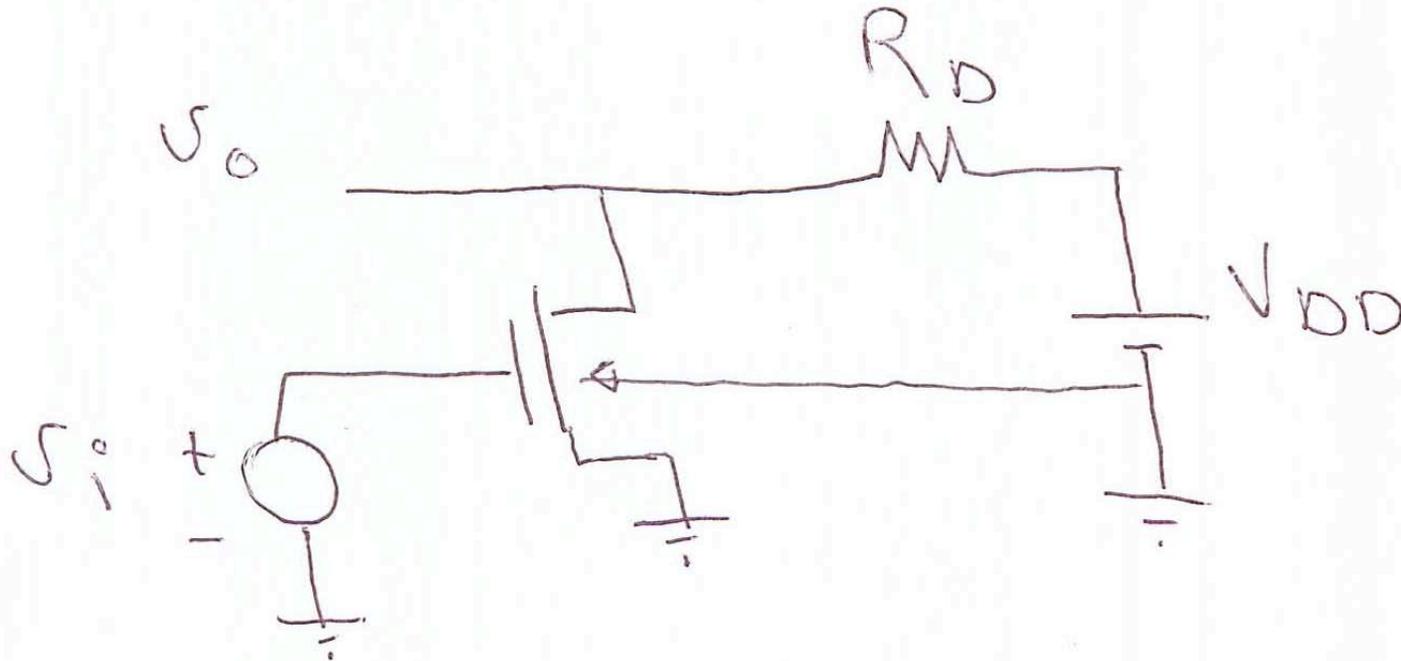
$$I_C = 1,24 \text{ mA}$$

$$I_E = 1,25 \text{ mA}$$

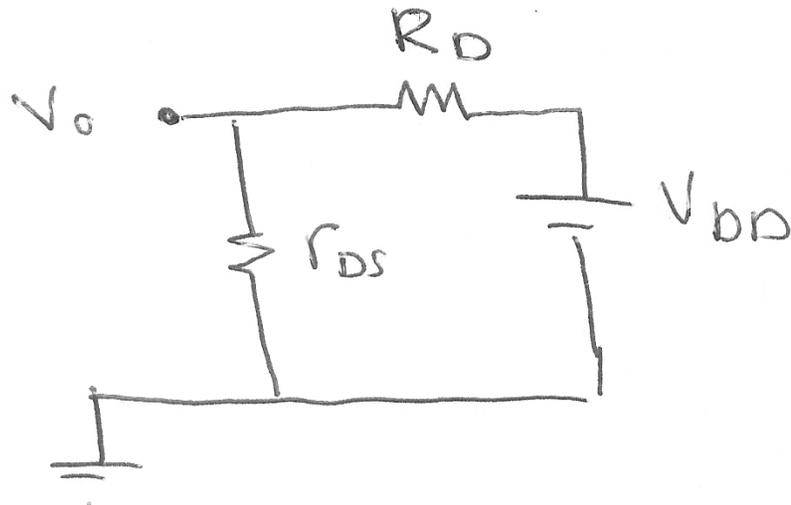
$$V_{CE} = 16,26 \text{ V}$$

PROBLEMA 7: EL MOSFET COMO RESISTENCIA

Para el circuito mostrado se han hecho mediciones experimentales sobre el circuito y se ha comprobado que el MOSFET no está en saturación. Si $v_i > V_t$ demuestre que $v_o = V_{DD} r_{DS}/(r_{DS}+R_D)$



Está en triodo. Es equivalente a una resistencia

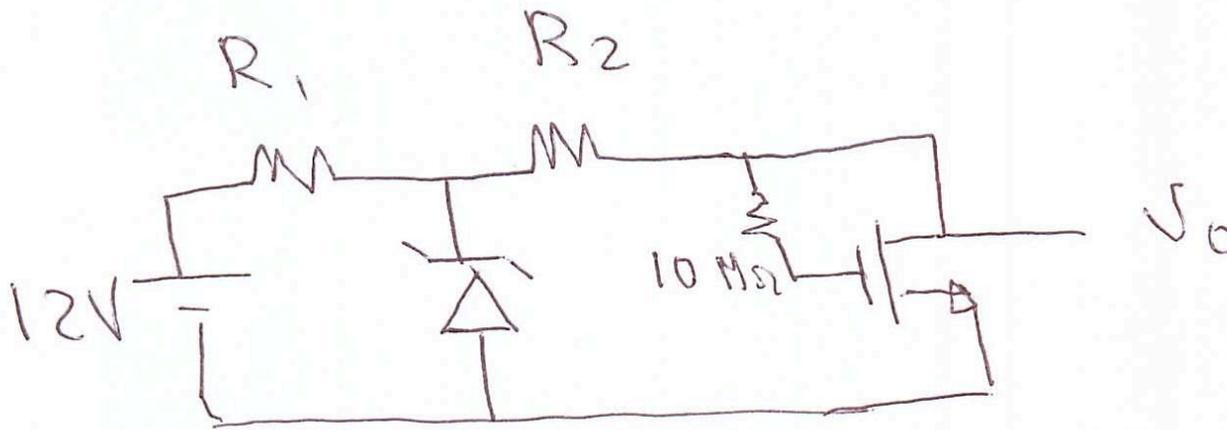


Por divisor de tensión

$$V_o = \frac{r_{DS}}{r_{DS} + R_D} V_{DD}$$

PROBLEMA 8: MOSFET Y ZENER

a) Dado el circuito mostrado en la figura, calcule los valores de R_1 y R_2 para que $I_D = 0,5\text{mA}$ y la corriente del zener esté 75% por encima de la corriente de prueba del zener, I_{ZT} . El zener es el 1N4374A



$$k_n'W/L = 1 \text{ mA/V}^2$$

$$V_t = 1\text{V}$$

$$\lambda = 0$$

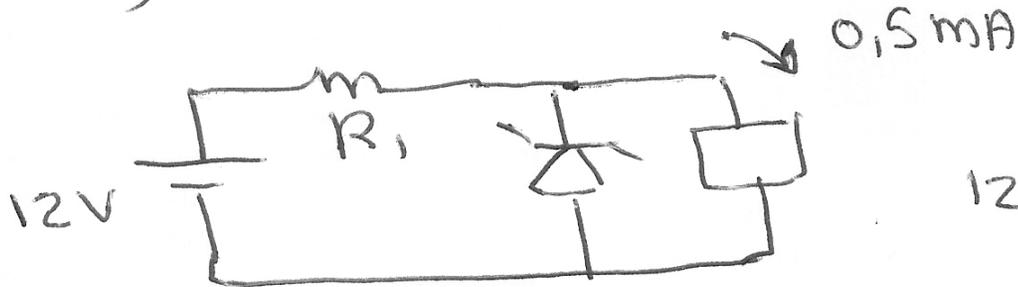
b) Seleccione valores comerciales para las resistencias R_1 y R_2 y calcule los nuevos valores de la corriente I_D y del voltaje en el zener.

Características de los dispositivos

$$\text{Zener 1N4734} \quad \left\{ \begin{array}{l} V_Z = 5.6 \text{ V} \quad I_{ZT} = 45 \text{ mA} \\ R_Z = 5 \Omega \end{array} \right.$$

$$\text{MOSFET} \quad \left\{ \begin{array}{l} k' \frac{W}{L} = 1 \frac{\text{mA}}{\text{V}^2} \quad K = \frac{1}{2} \frac{1 \text{ mA}}{\text{V}^2} = 0.5 \frac{\text{mA}}{\text{V}^2} \\ V_T = 1 \text{ V} \quad \lambda = 0 \end{array} \right.$$

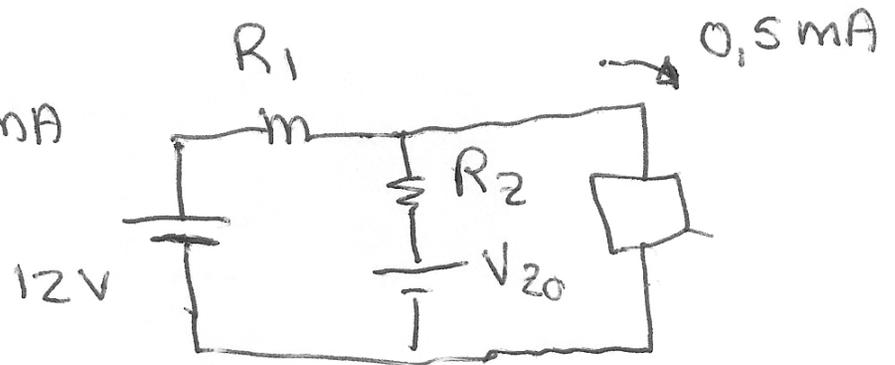
a) Cálculo de R_1



$$V_Z = V_{Z0} + I_{ZT} R_Z$$

$$R_1 = \frac{12V - 5,375V}{78,75 + 0,5} = 78,6 \Omega$$

Valores comerciales : 75Ω
 82Ω

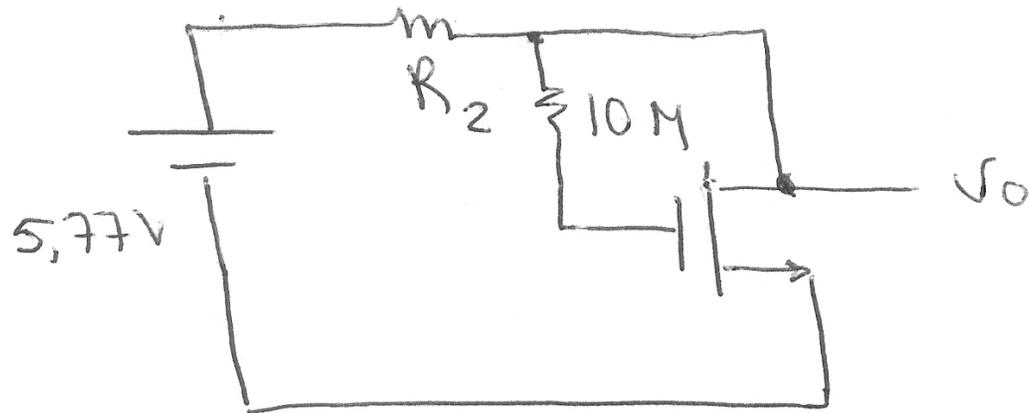


$$V_{Z0} = 5,6V - 45mA \times 0,005K = 5,375V$$

$$I_{Z1} = 1,75 \times 45mA = 78,75mA$$

$$V_{Z1} = 5,375V + 78,75mA \times 0,005K = 5,77V$$

Cálculo de R_2



$V_G = V_D$ $V_{GS} = 0$ Saturación

$$I_D = \frac{0,5 \text{ mA}}{V^2} (V_{GS} - V_t)^2$$

Pero $I_D = 0,5 \text{ mA}$

$$0,5 \text{ mA} = \frac{0,5 \text{ mA}}{V^2} (V_{GS} - V_t)^2$$

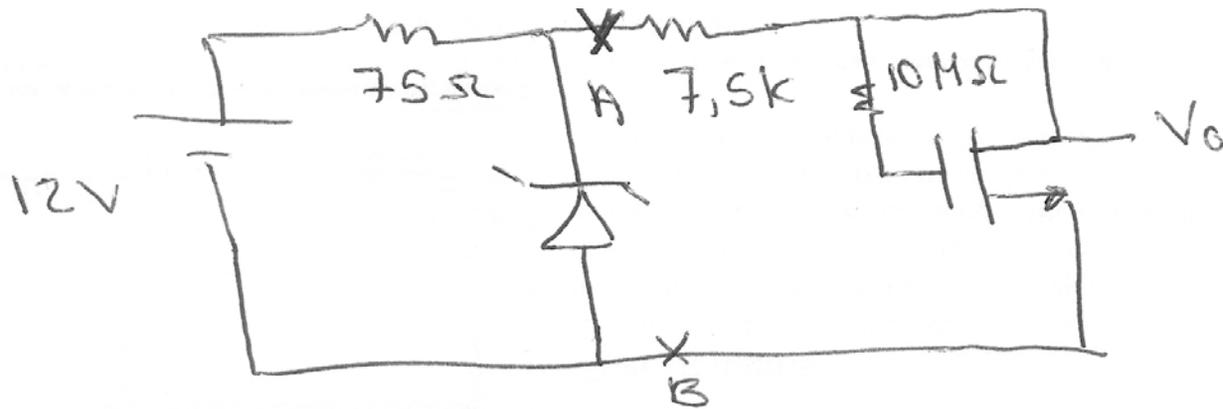
$$\pm 1 = (V_{GS} - V_t)$$

$$V_{GS} = 2V = V_G = V_D$$

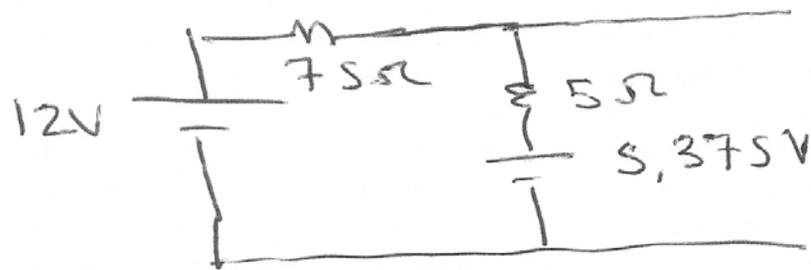
$$R_2 = \frac{V_Z - 2V}{0,5mA} = 7,54 k\Omega$$

Valores comerciales 7,5k
8,2k

b) Análisis del circuito con las resistencias de 75Ω y $7,5K\Omega$



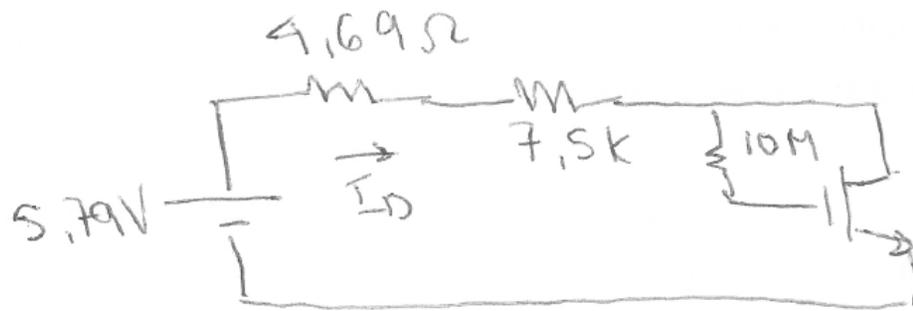
Aplicando el modelo del zener y calculando el Thevenin entre A y B .



$$I = \frac{(12 - 5,375)V}{(75 + 5)\Omega} = 82,81 \text{ mA}$$

$$V_{th} = 82,81 \text{ mA} \times 0,005 \text{ K} + 5,375 \text{ V} = 5,79 \text{ V}$$

$$R_{th} = 75 \Omega \parallel 5 \Omega = 4,69 \Omega$$



$$5,79 = 7,50469 I_D + V_{DS}$$

$$V_D = V_G = V_{GS} = V_{DS}$$

$$V_{GS} = 5,79 - 7,5 I_D$$

$$I_D = 0,5 (5,79 - 7,5 I_D - 1)^2$$

$$2 I_D = (4,79 - 7,5 I_D)^2$$

$$2I_D = (4,79 - 7,5I_D)^2$$

$$2I_D = 22,94 - 71,85I_D + 56,25 = 0$$

$$56,25I_D^2 - 73,85I_D + 22,94 = 0$$

$$I_D = \frac{73,85 \pm \sqrt{5.453,82 - 5.161,5}}{2 \times 56,25} =$$

$$\frac{73,85 \pm \sqrt{292,32}}{2 \times 56,25} = \frac{73,85 \pm 17,1}{112,5}$$

$$I_{D1} = 0,81 \text{ mA}$$

$$I_{D2} = 0,5 \text{ mA}$$

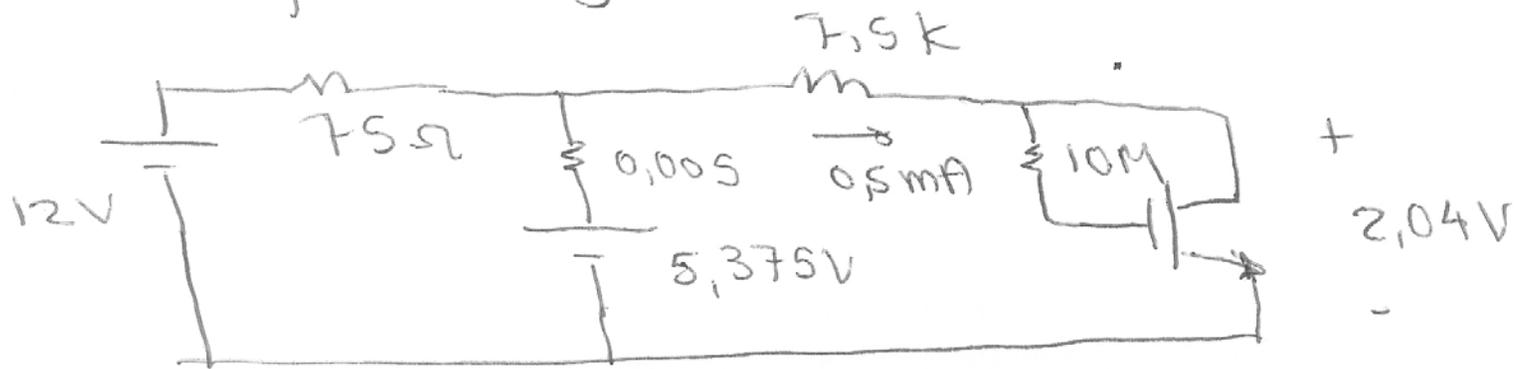
$$V_{GS1} = 5,79 - 7,5 \times 0,81 = -0,27 \text{ V}$$

No válido

$$V_{GS2} = 5,79 - 7,5 \times 0,5 = 2,04 \text{ V}$$

Válido

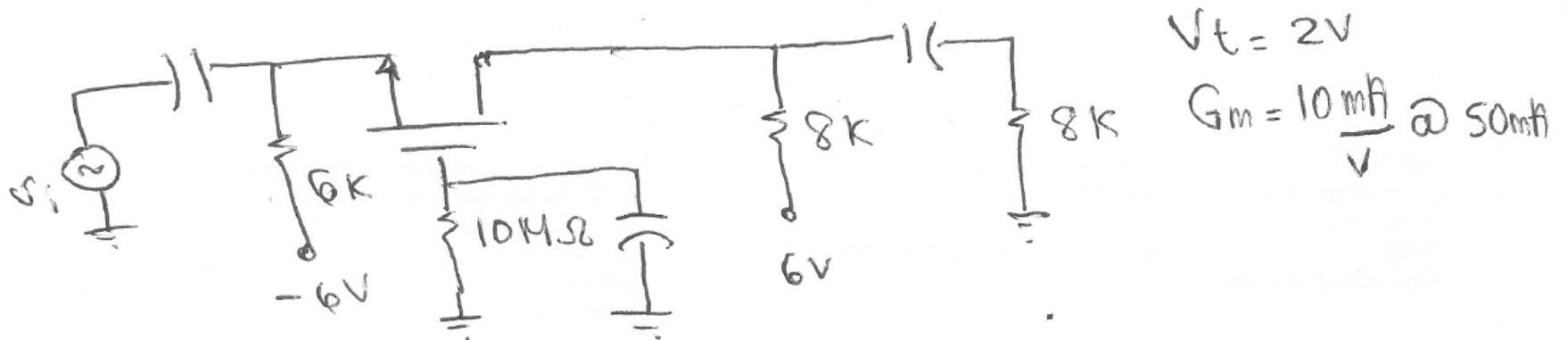
Voltaje en el zener



$$V_Z = 0,5 \text{ mA} \times 7,5 \text{ k} + 2,04 \text{ V} = 5,79 \text{ V}$$

PROBLEMA 9: GATE COMÚN

Dado el circuito mostrado en la figura, calcule la ganancia de voltaje, la resistencia de entrada y la resistencia de salida sin considerar la carga.



Polarización: $I_D = 0,5 \text{ mA}$ $V_{GS} = 3V$ $V_{DS} = 5V$ $g_m = 1\text{mA/V}$

Análisis AC:



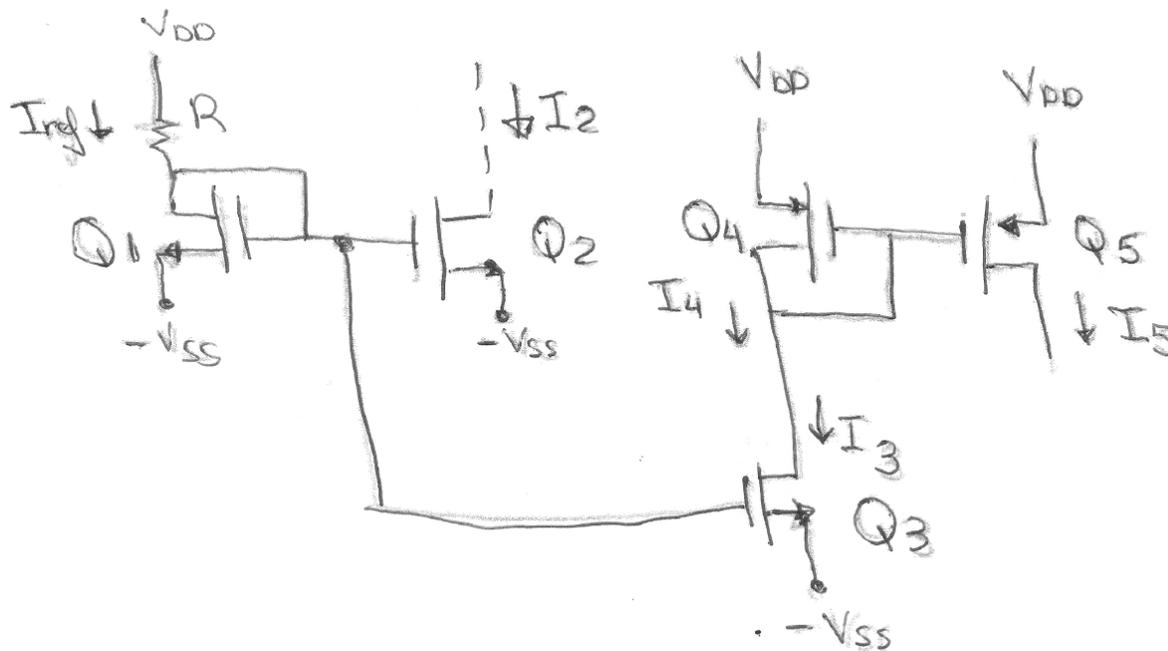
$$A_v = 4 \quad R_i = 0,86k\Omega \quad R_o = 8k\Omega$$

PROBLEMA 10: FUENTES DE CORRIENTE

Calcule R para que $I_5 = 1 \text{ mA}$

$K_1 = K_2 = K_3 = K_4 = K_5 = 1 \text{ mA/V}^2$ $V_{t1} = V_{t2} = V_{t3} = V_{t4} = V_{t5} = 1 \text{ V}$

$V_{DD} = 5 \text{ V}$ $V_{SS} = -5 \text{ V}$



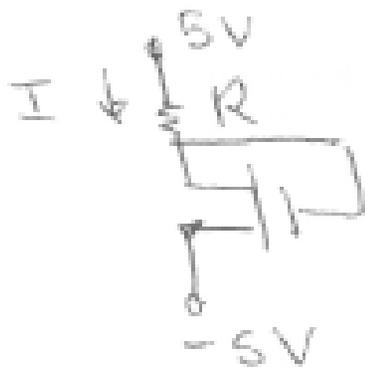
$$R = 8 \text{ k}\Omega$$

$$V_{GS1} = V_{GS2} \Rightarrow I_2 = I_{Ref}$$

$$V_{GS3} = V_{GS1} \Rightarrow I_3 = I_2$$

$$I_4 = I_3 = I_2 = I_{Ref}$$

$$V_{GS4} = V_{GS5} \Rightarrow I_5 = I_4 = I_{Ref}$$



$$k = \frac{1 \text{ mA}}{V^2}$$

$$V_t = 1 \text{ V}$$

$$V_{GS} = V_{DS}$$

$$5 \text{ V} = V_{DS} + 5 I_D - 5$$

$$10 = R I_D + V_{GS}$$

$$I_D = k (V_{GS} - V_t)^2$$

$$1 \text{ mA} = \frac{1 \text{ mA}}{V^2} (V_{GS} - 1)^2$$

$$V_{GS} - V_t = 1 \text{ V}$$

$$V_{GS} = 2 \text{ V}$$

$$R = \frac{10 - V_{GS}}{1 \text{ mA}} = \frac{10 - 2}{1} = 8 \text{ k}\Omega$$

