

$$I_D = \frac{\beta}{2} (V_{GS} - V_T)^2$$

$$V_{GS} = V_G - V_S = V_D = V_{DD} - I_D R_D$$

$$I_D = \frac{\beta}{2} (V_{DD} - I_D R_D - V_T)^2$$

$$I_D = \frac{\beta}{2} (V_{DD} - V_T)^2 - 2 I_D R_D \beta (V_{DD} - V_T) + I_D^2 \beta R_D^2$$

$$I_D^2 R_D^2 - 2 I_D R_D \beta (V_{DD} - V_T) + (V_{DD} - V_T)^2 = \frac{2 I_D \beta}{\beta}$$

$$I_D^2 R_D^2 - 2 I_D (R_D \beta + \frac{1}{\beta}) + (V_{DD} - V_T)^2 = 0$$

$$I_{D \frac{1}{2}} = \frac{2 (R_D \beta + \frac{1}{\beta}) \pm \sqrt{4 (R_D \beta + \frac{1}{\beta})^2 - 4 R_D^2 \beta (V_{DD} - V_T)^2}}{2 R_D^2} = \frac{8166,67 \pm 242000}{2 R_D^2}$$

$$V_{GS} = V_{DD} - R_D I_D$$

$$I_D = \frac{\beta}{2} (V_{DD} - R_D I_D - V_T)^2 \quad (9 - 2000 I_D)^2 = 4166,67 I_D$$

$$2000^2 I_D^2 - 36000 I_D + 81 = 4166,67 I_D$$

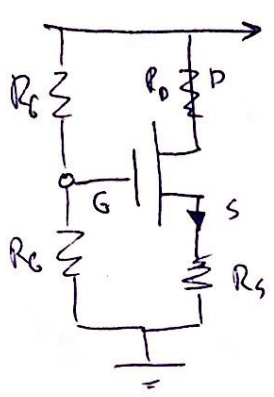
$$2000^2 I_D^2 - 40166,67 I_D + 81 = 0 \quad \Delta = 17814,63$$

$$I_{D \frac{1}{2}} = \frac{40166,67 \pm \sqrt{A^2 - 4 \cdot 81 \cdot 2000^2}}{2 \cdot 2000^2}$$

$$I_{D1} = \frac{57981,3}{2 \cdot 2000^2} = 7,25 \mu A \quad \left. \begin{array}{l} V_{GS} = -2,5V < V_T \\ V_{GS} = 6,42V > V_T \end{array} \right\}$$

$$I_{D2} = 2,79 \mu A$$

$V_{GS} < V_T$   
 $0 < V_T$  (T)



$$V_G = \frac{V_{DD}}{2} = 5V$$

$$I_D = \frac{\beta}{2} (V_{GS} - V_T)^2$$

$$V_{GS} = V_G - V_S$$

$$V_S = I_D R_S$$

$t_i = a_i$   
 $a_i = b_i$   
 $b_i = t_i$

$$I_D = \frac{\beta}{2} \left( \frac{V_{DD}}{2} - V_T - R_S \cdot I_D \right)^2$$

$$6000^2 I_D^2 - 48000 I_D + 16 = 2000 I_D$$

$$6000^2 I_D^2 - 50000 I_D + 16 = 0$$

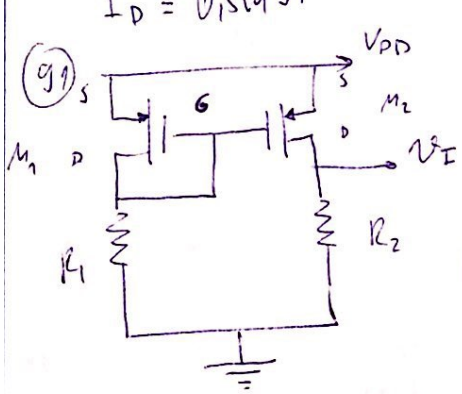
$$2000 I_D = (4 - 6000 I_D)^2$$

$$I_{D1} = \frac{50000 \pm \sqrt{50000^2 - 64 \cdot 6000^2}}{2 \cdot 6000^2}$$

$I_{D1} = 0.887 \text{ mA}$   $V_{GS} = 5.334 \text{ V} = V_S$   $V_{GS} < V_T$  ~~4~~

$I_{D2} = 0.15 \text{ mA}$   $V_{GS} = 3 \text{ V}$   $V_{GS} = 2 \text{ V} > V_T$   
 $V_D = 7 \text{ V}$   $V_{GD} < V_T?$   
 $V_D = V_{DD} - I_D R_D$   $V_{GD} = -2 \text{ V} < V_T$

$V_G = 5 \text{ V}$   $V_D = 7 \text{ V}$   $V_S = 3 \text{ V}$   
 $I_D = 0.15 \text{ mA}$



in  $M_1$  u  $M_2$  cy 3ac  
 $I_{D1} = \frac{\beta_1}{2} (V_{SG1} - |V_{TP}|)^2$   $12 - V_{SG1} - 10(V_{SG1} - 1)^2 = 0$

$$V_{DD} - V_{SG1} - I_{D1} R_1 = 0$$

$$V_{SG1} = V_{DD} - I_{D1} R_1$$

$$I_{D1} \cdot \frac{2}{\beta} = (V_{DD} - |V_{TP}| - I_{D1} R_1)^2$$

$$V_{DD} - V_{SG1} - R_1 \frac{\beta_1}{2} (V_{SG1} - |V_{TP}|)^2$$

$$12 - V_{SG1} - 10 V_{SG1}^2 + 20 V_{SG1} - 10 = 0$$

$$10 V_{SG1}^2 - 19 V_{SG1} - 2 = 0$$

$I_{D1} = 1 \text{ mA}$   $V_{G1} = 10 \text{ V}$

$$V_{SG1} = V_{SG2}$$

$$I_{D2} = \frac{\beta_2}{2} (V_{SG2} - |V_{TP}|)^2$$

$$I_{D1} = \frac{\beta_1}{2} (V_{SG1} - |V_{TP}|)^2$$

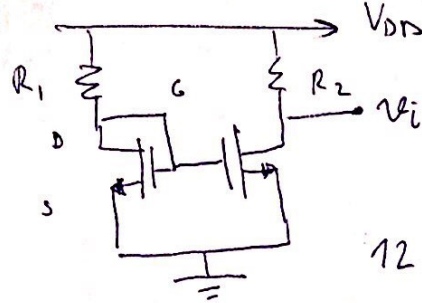
$$I_{D2} = 2 I_{D1} = 2 \text{ mA}$$

$V_{SG1} = -0.1 \text{ V} < |V_{TP}|$   
 $V_{SG1} = 2 \text{ V} > |V_{TP}|$

$V_{D2} = 3 \text{ V}$   
 $V_{D1} = 10 \text{ V}$

$V_{SG1} = 2 \text{ V} > |V_{TP}|$   $V_{DG2} = -2 \text{ V} < |V_{TP}|$   
 $V_{DG1} = 0 < |V_{TP}|$   $V_{SG2} = 2 \text{ V} > |V_{TP}|$

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$$I_{D1} = \frac{\beta_1}{2} (V_{GS1} - |V_{TN}|)^2$$

$$V_{DD} - I_{D1} R_1 - V_{GS1} = 0$$

$$12 - \frac{R_1 \cdot \beta_1}{2} (V_{GS1} - 1)^2 - V_{GS1} = 0$$

$$20 V_{GS1}^2 - 49 V_{GS1} + 8 = 0 \quad V_{GS1}'' = 0.122V < V_{TN}$$

$$V_{GS1} = 1.183V > V_{TN}$$

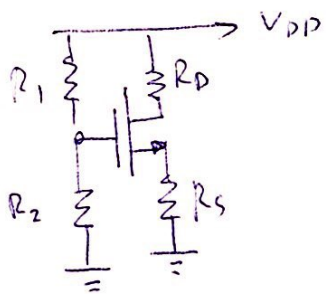
$$V_{GS1} = V_{GS2}$$

$$I_{D2} = 2 I_{D1} = 2 \text{ mA}$$

$$I_{D1} = \frac{V_{DD} - V_{D1}}{R_1} = 1 \text{ mA}$$

$$V_i = V_{DD} - R_2 I_{D2} = 12 - 8 = 4V$$

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$$V_G = \frac{R_2}{R_1 + R_2} V_{DD} = 4V \quad I_D = \frac{\beta}{2} (V_{GS} - V_{TN})^2$$

$$V_{GS} = V_G - I_D R_3$$

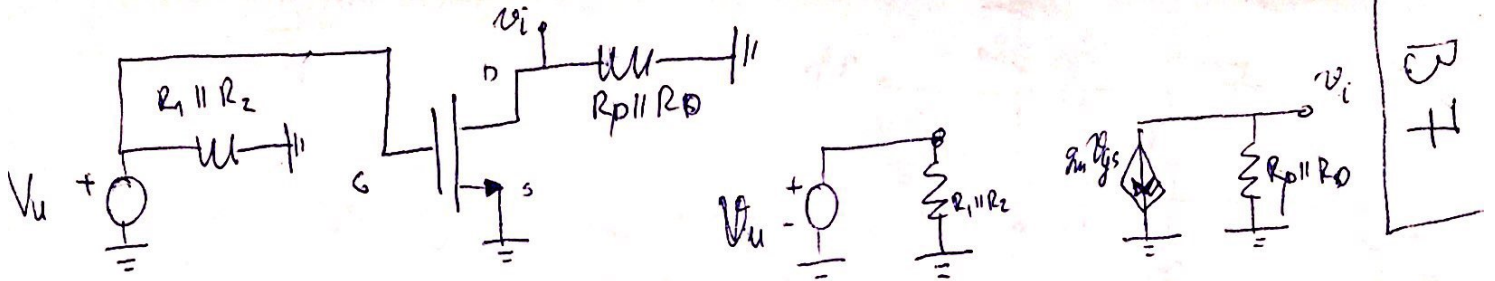
$$\frac{2}{\beta} I_D = \left( \frac{R_2}{R_1 + R_2} V_{DD} - I_D R_3 - V_{TN} \right)^2 \quad 4000 I_D = \frac{(3 - 1000 I_D)^2}{8000}$$

$$1000^2 I_D^2 - 10000 I_D + 9 = 0 \quad I_{D1/2} = \frac{10000 \pm \sqrt{10000^2 - 4 \cdot 9 \cdot 1000^2}}{2 \cdot 1000^2}$$

$$I_{D1} = 9 \text{ mA} \quad V_s =$$

$$I_{D2} = 1 \text{ mA} \quad V_s = 1V \quad V_D = V_{DD} - I_D R_4 = 12 - 4 = 8V$$

$$V_{GS} = 3V > V_{TN}$$

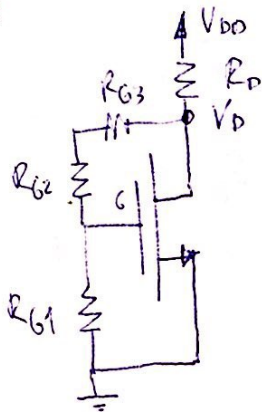


~~$V_{gs}$~~   $g_m = \sqrt{2\beta I_D} = 1 \text{ mS}$   $R_{VL} = R_1 || R_2$   
 $R_{ZL} = R_D$

$v_i = -g_m v_{gs} \cdot R_D || R_s$   $v_{gs} = \frac{v_u}{R_{VL} || R_{ZL}}$

$a = -g_m R_D || R_s = \underline{\underline{-2}}$

(g<sub>u</sub>) DC:



$V_D = V_{DD} - I_D R_D$   $V_{DS} = V_{DD} - (I_Q + I_D) R_D$

$V_{GS} = V_{DS} \cdot \frac{R_{G1}}{R_{G1} + R_{G2} + R_{G3}}$

$I_Q = \frac{V_{DS}}{R_{G1} + R_{G2} + R_{G3}}$

$I_D = \frac{\beta}{2} (V_{GS} - V_T)^2$

$V_{DS} = V_{DD} - \left( \frac{V_{DS}}{R_1 + R_2 + R_3} + \frac{\beta}{2} \left( V_{DS} \cdot \frac{R_{G1}}{R_{G1} + R_{G2} + R_{G3}} - V_T \right)^2 \right) R_D$

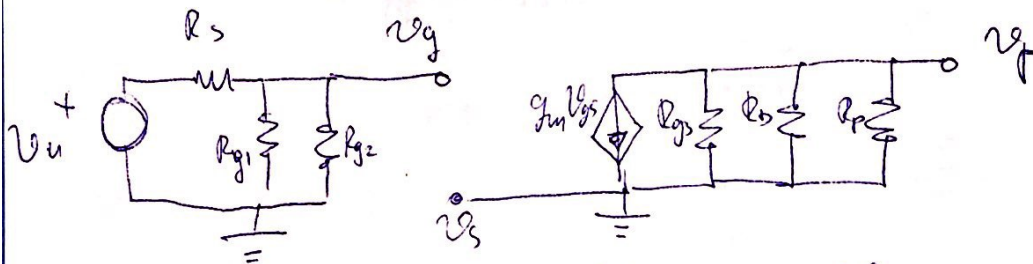
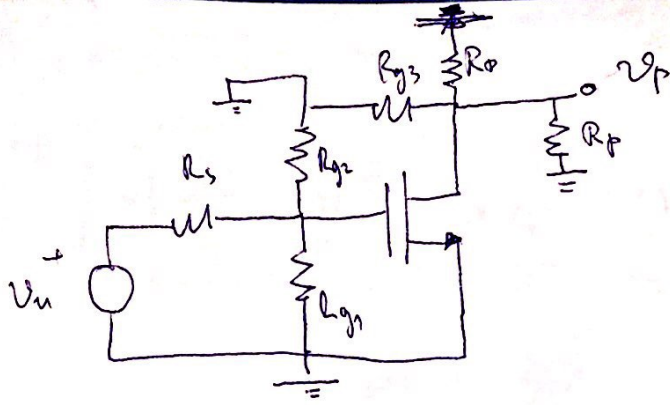
$V_{DS} = 10 - \left( \frac{V_{DS}}{5 \cdot 10^6} + 2.5 \cdot 10^{-4} (0.4 V_{DS} - 1)^2 \right) \cdot 2 \cdot 10^4$

$V_{DS}' = 5V \Rightarrow V_{GS} = 2V > V_T$

$I_D = \frac{\beta}{2} (V_{GS} - V_T)^2 = 250 \mu A$

$V_{DS}'' = -1.25V \Rightarrow V_{GS} = -0.5V < V_T$

$g_m = \sqrt{2 I_D \cdot \beta} = 0.5 \text{ mS}$

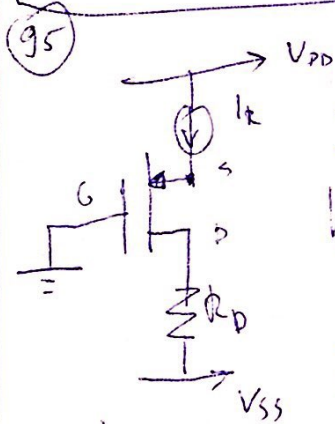


$$V_{gs} = V_{in} \cdot \frac{R_{g1} \parallel R_{g2}}{R_s + R_{g1} \parallel R_{g2}}$$

$$V_o = -g_m V_{gs} \cdot R_D \parallel R_L \parallel R_{g3}$$

$$a = -g_m \frac{R_{g1} \parallel R_{g2}}{R_s + R_{g1} \parallel R_{g2}} \cdot R_D \parallel R_L \parallel R_{g3}$$

$$R_{in} = R_s + R_{g1} \parallel R_{g2} \quad R_{out} = R_{g3} \parallel R_D$$



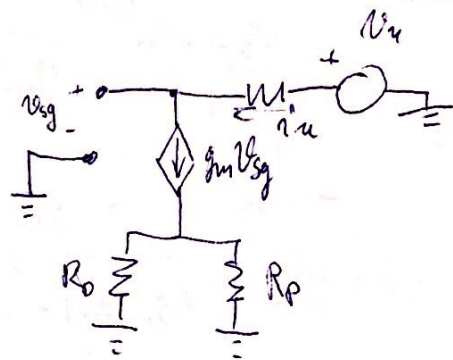
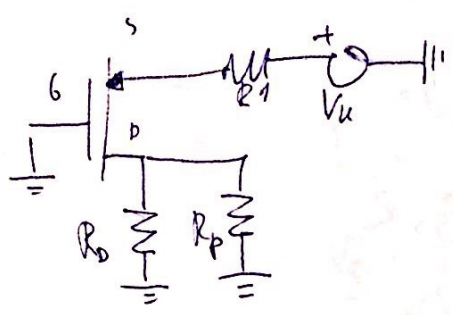
$$I_D = I_R = 2 \text{ mA} \quad V_S = 3 \text{ V}$$

$$V_D = I_D R_D + V_{SS} = -6 \text{ V}$$

$$I_D = \frac{\beta}{2} (V_{SG} - |V_{TH}|)^2$$

$$\frac{V_D - V_{SS}}{R_D} = I_D \quad \sqrt{\frac{2I_D}{\beta}} + |V_{TH}| = V_{SG} = V_S$$

$$g_m = \sqrt{2BI_D}$$



$$i_p = \frac{R_D}{R_D + R_S} i_u = \frac{R_D}{R_D + R_S} g_m v_{sg} i_u$$

$$a_1 = \frac{i_p}{i_u} = \frac{R_D}{R_D + R_S}$$

$$i_t = \frac{v_t - v_{sg}}{R_1} \quad v_{sg} = -R_1 i_t \quad i_t = g_m v_{sg} = g_m (v_t - R_1 i_t)$$

$$\frac{v_{sg}}{R_1} = -g_m v_{sg} \quad v_t = \left( \frac{1}{g_m} + R_1 \right) i_t$$

$$R_{VL} = \frac{1}{g_m} + R_1$$

$R_{iZL} = R_D$

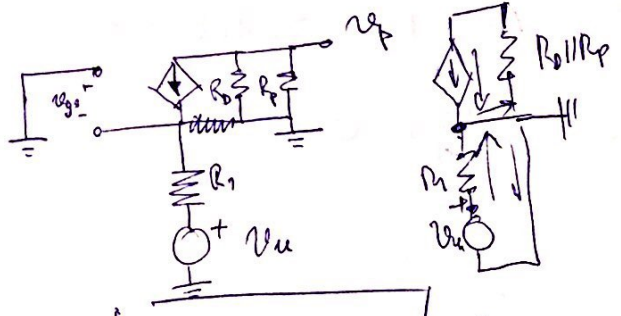
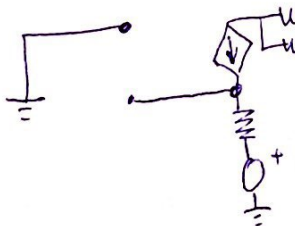
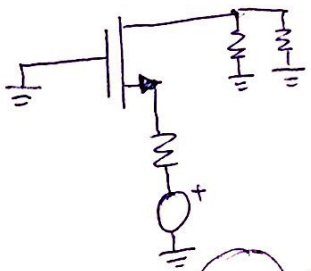
(96)

$$I_D = I_0 \quad V_D = V_{DD} - R_D I_0 = 10 - 5 = 5V = V_D$$

$$V_{gs} = \sqrt{\frac{2I_D}{\beta}} + V_{TN} = 1 + 1 = 2V$$

$$V_g = 0 \quad V_s = -2V$$

$$g_m = \sqrt{2BI_D}$$



$$v_p = -g_m v_{gs} R_D || R_P$$

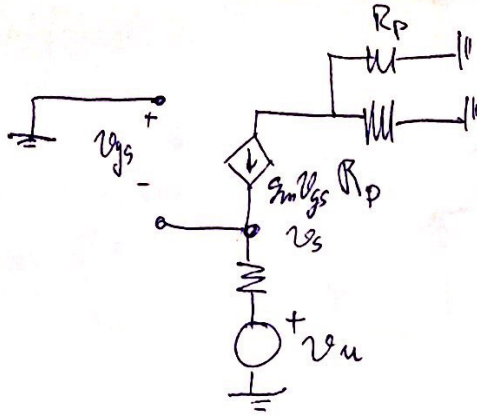
$$v_p = g_m \cdot \frac{R_D || R_P}{g_m R_1} \cdot v_u$$

$$a = \frac{R_D || R_P}{R_1}$$

$$g_m v_{gs} + \frac{v_u}{R_1} = 0 \quad v_{gs} = -\frac{v_u}{g_m R_1}$$

$$g_m v_{gs} = -\frac{v_u}{R_1}$$

$$v_{gs} = -\frac{v_u}{g_m R_1}$$



$$\frac{v_s - v_u}{R_1} = g_m v_{gs}$$

$$-v_{gs} - v_u = g_m v_{gs} R_1$$

$$v_{gs} (1 + g_m R_1) = -v_u$$

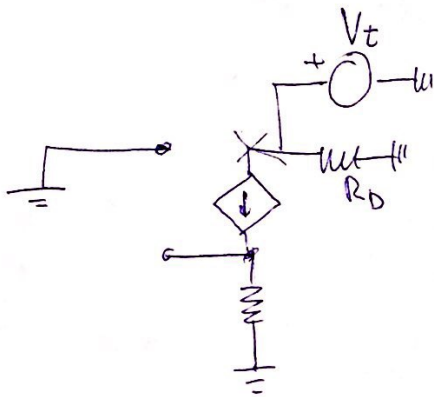
$$v_{gs} = -\frac{v_u}{1 + g_m R_1}$$

$$V_p = -g_m v_{gs} R_p \parallel R_D$$

$$V_p = \frac{g_m R_p \parallel R_D}{1 + g_m R_1} v_u$$

$$g_m v_{gs} = -\frac{g_m v_u}{1 + g_m R_1}$$

$$i_t = \frac{g_m v_u}{1 + g_m R_1} \left[ R_{in} = \frac{1}{g_m} + R_1 \right]$$



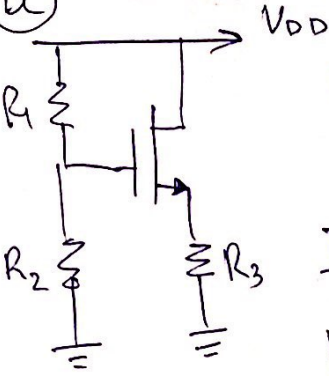
$$R_{iZL} = R_D$$

$$g_m v_{gs} \cdot R_1 = -v_{gs}$$

$$v_{gs} (1 + g_m R_1) = 0$$

$$v_{gs} = 0$$

97 (DC)



$$V_G = \frac{R_2}{R_1 + R_2} V_{DD}$$

$$I_D = \frac{\beta}{2} (V_{GS} - V_{TN})^2$$

$$V_S = \frac{V_{DD}}{2}$$

$$V_S = I_D R_3 = \frac{\beta R_3}{2} \left( \frac{R_2}{R_1 + R_2} V_{DD} - V_S - V_{TN} \right)^2$$

$$V_S = 5 \left( \frac{R_2}{R_1 + R_2} V_{DD} - V_S - 1 \right)^2 = \frac{V_{DD}}{2}$$

$$V_S = 5 \left( \left( \frac{R_2}{R_1 + R_2} V_{DD} - 1 \right)^2 - 2 \left( \frac{R_2}{R_1 + R_2} V_{DD} - 1 \right) V_S + V_S^2 \right)$$

$$\frac{V_{DD}}{2} = 5 \left( \frac{R_2}{R_1 + R_2} V_{DD} - 1 \right)^2 - 10 \left( \frac{R_2}{R_1 + R_2} V_{DD} - 1 \right) \frac{V_{DD}}{2} + 5 \frac{V_{DD}^2}{4}$$

$$2.5 = 5 \left( \frac{R_2}{R_1 + R_2} \cdot 5 - 1 \right)^2 - 5 \left( \frac{R_2}{R_1 + R_2} \cdot 5 - 1 \right) + \frac{125}{4}$$

$$5(25x^2 - 10x + 1) - 5x + 5 - 2.5 + \frac{125}{4} = 0$$

$$125x^2 - 50x + 5 - 5x + 5 - 2.5 + \frac{125}{4} = 0$$

$$125x^2 - 55x + 38.75 = 0$$

$$V_S = V_G - V_{GS}$$

$$V_{GS} = \sqrt{\frac{2I_D}{\beta}} + V_T = \sqrt{\frac{2V_S}{\beta \cdot R_3}} + V_T = \sqrt{\frac{V_{DD}}{\beta R_3}} + V_T = 1.71V$$

$$V_S = \frac{V_{DD}}{2} \quad V_G = \frac{V_{DD}}{2} + V_{GS} = 4.21V \quad I_D = \frac{V_G}{R_3}$$

$$\frac{R_2}{R_1 + R_2} = \frac{V_G}{V_{DD}}$$

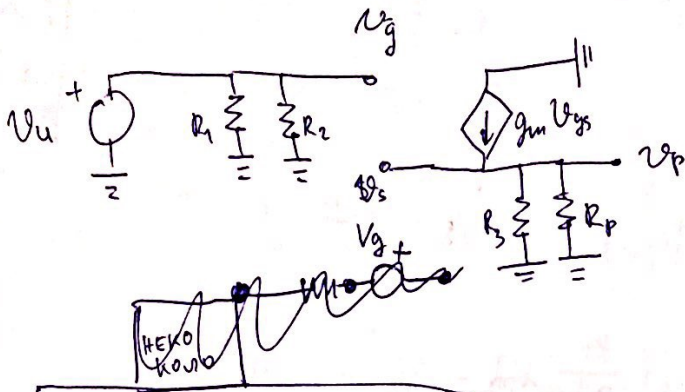
$$\frac{V_{DD}}{V_G} = \frac{R_1}{R_2} + 1$$

$$R_2 = \left( \frac{V_{DD}}{R_1 V_G} - \frac{1}{R_1} \right)^{-1}$$

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$$V_g = V_u$$

$$V_p = V_s = g_m V_{gs} R_3 \parallel R_p$$

$$V_s = g_m R_3 \parallel R_p (V_g - V_s)$$

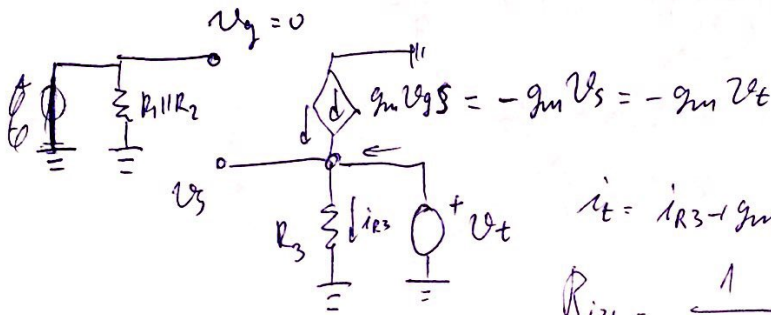
$$V_s (1 + g_m R_3 \parallel R_p) = g_m R_3 \parallel R_p V_g$$

$$V_s = \frac{g_m R_3 \parallel R_p}{1 + g_m R_3 \parallel R_p} V_p = V_o$$

$$A = \frac{g_m R_3 \parallel R_p}{1 + g_m R_3 \parallel R_p}$$

$$R_{UL} = R_1 \parallel R_2$$

$$R_{iZL} =$$



$$i_t = i_{R_3} - g_m V_t = \frac{V_t}{R_3} + g_m V_t = V_t \left( \frac{1}{R_3} + g_m \right)$$

$$R_{iZL} = \frac{1}{\frac{1}{R_3} + g_m} = \frac{R_3}{1 + R_3 g_m}$$

$$R_3 \parallel \frac{1}{g_m} = \frac{R_3 \cdot \frac{1}{g_m}}{R_3 + \frac{1}{g_m}} = \frac{\frac{R_3}{g_m}}{\frac{R_3 g_m + 1}{g_m}} = \frac{R_3}{1 + R_3 g_m}$$