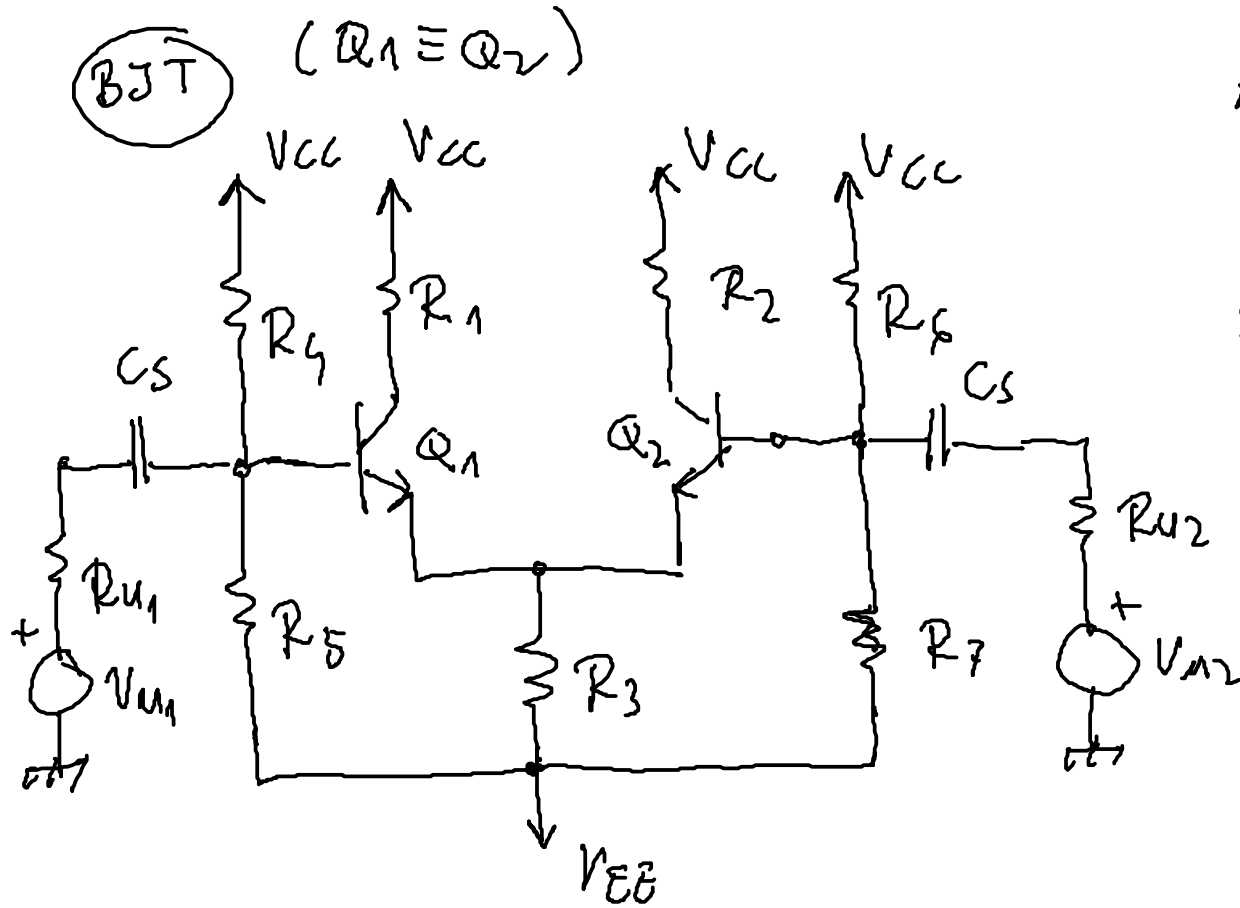


\* DIFERENCIJALNI POJAČAVAČ \*

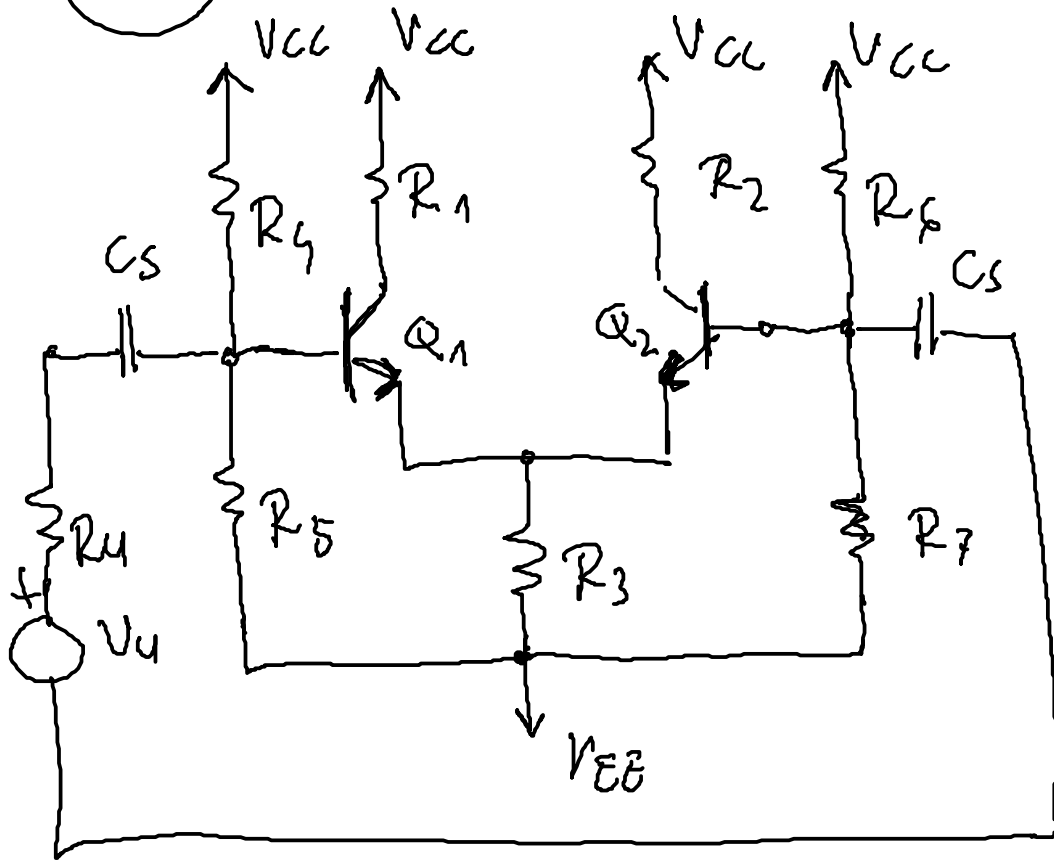


$$A_d = \frac{V_{iz}}{V_{U1} - V_{U2}} \quad \text{— DIFERENCIJALNO POJAČANJE}$$

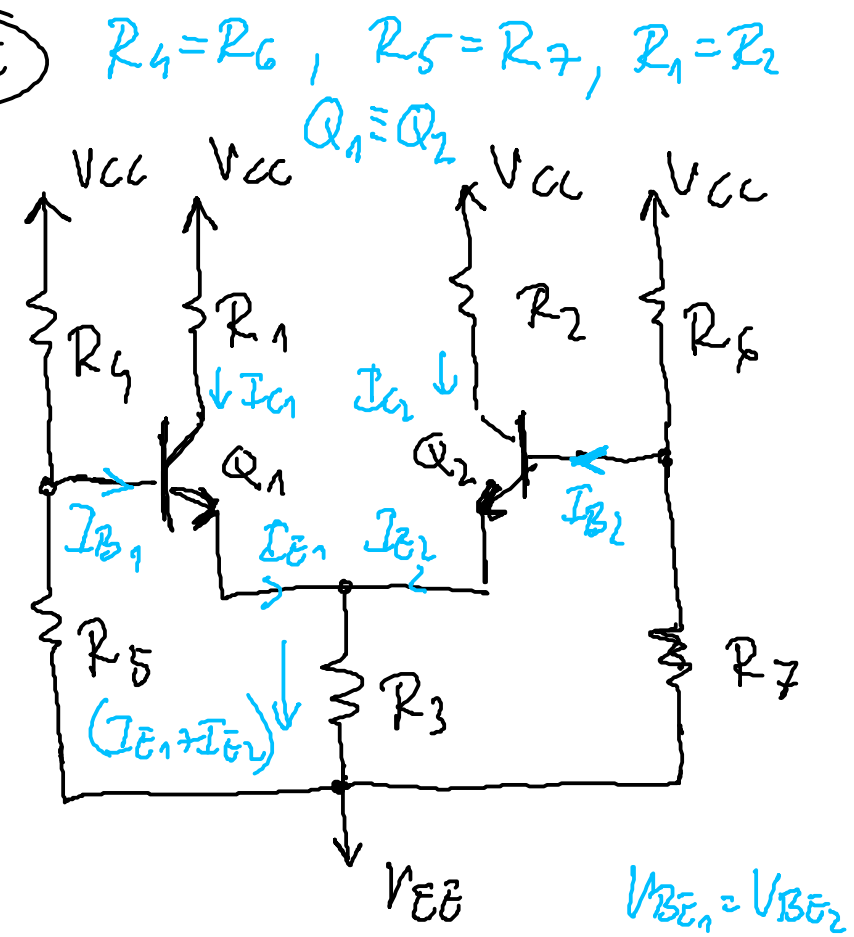
$$A_c = \frac{V_{iz}}{(V_{U1} + V_{U2})/2} \quad \text{— POJAČANJE SREDNJE VREDNOSTI}$$

$$\rho = \left| \frac{A_d}{A_c} \right| \quad \text{— FAKTOR POSTISKIVANJA SREDNJE VREDNOSTI (CMRR)}$$

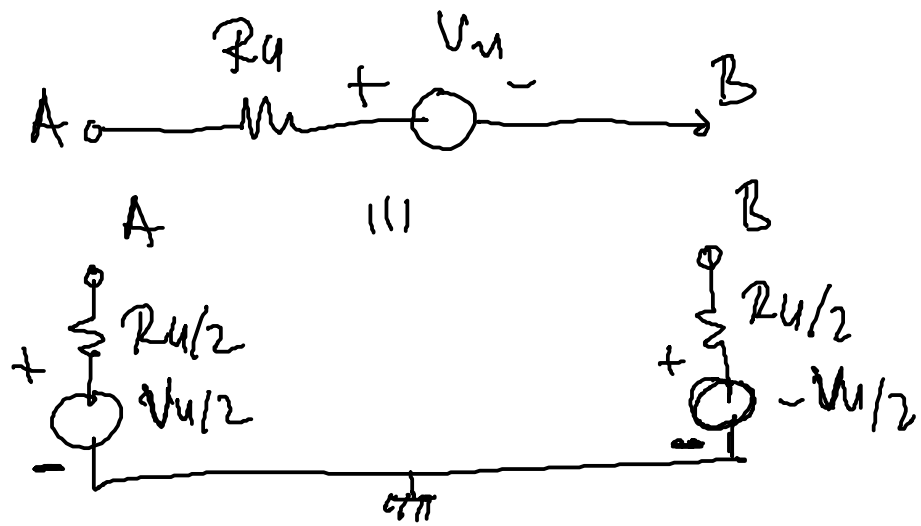
BJT



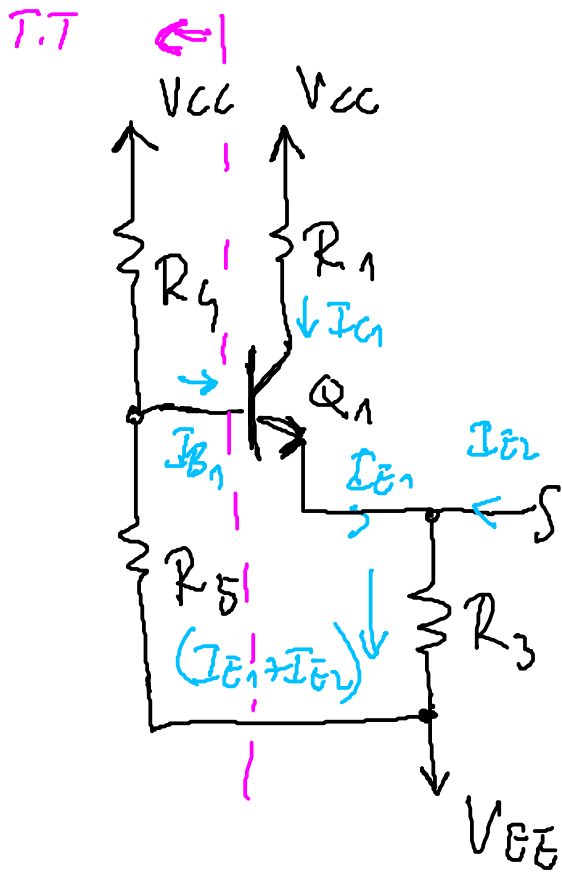
DC



$I_{B1} = I_{B2}, I_{C1} = I_{C2}, I_{E1} = I_{E2}, \beta_1 = \beta_2$



$V_{AB} = V_{U/2} - (-V_{U/2}) = V_U$   
 $R_{AB} = R_{U/2} + R_{U/2} = R_U$



$$V_{TEV} = \frac{R_5}{R_4 + R_5} \cdot V_{CC} + \frac{R_4}{R_4 + R_5} \cdot V_{EE}$$

$$R_{TEV} = R_4 \parallel R_5$$

$$2 I_{E1} = 2(1 + \beta_1)$$

$$V_{TEV} = I_{B1} \cdot R_{TEV} + V_{BE1} + (I_{E1} + I_{E2}) \cdot R_3 + V_{EE}$$

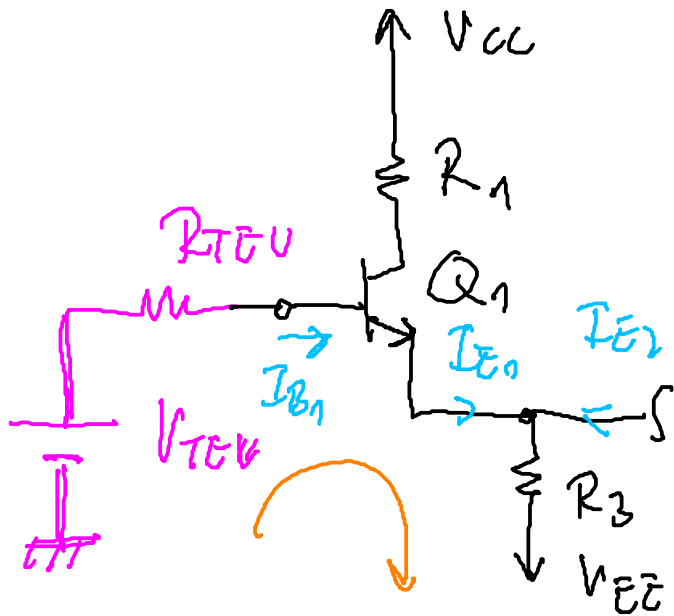
$$I_{E1} = I_{E2} = (1 + \beta_1) I_{B1}$$

$$I_{B1} = \frac{V_{TEV} - V_{BE1} - V_{EE}}{R_{TEV} + 2(1 + \beta_1) \cdot R_3}$$

$$r_{\pi 1} = \frac{V_T}{I_{B1}}$$

$$g_{m1} = \frac{I_{C1}}{V_T} = \frac{\beta_1 I_{B1}}{V_T}$$

$$r_{\pi 2} = r_{\pi 1}; \quad g_{m2} = g_{m1}$$

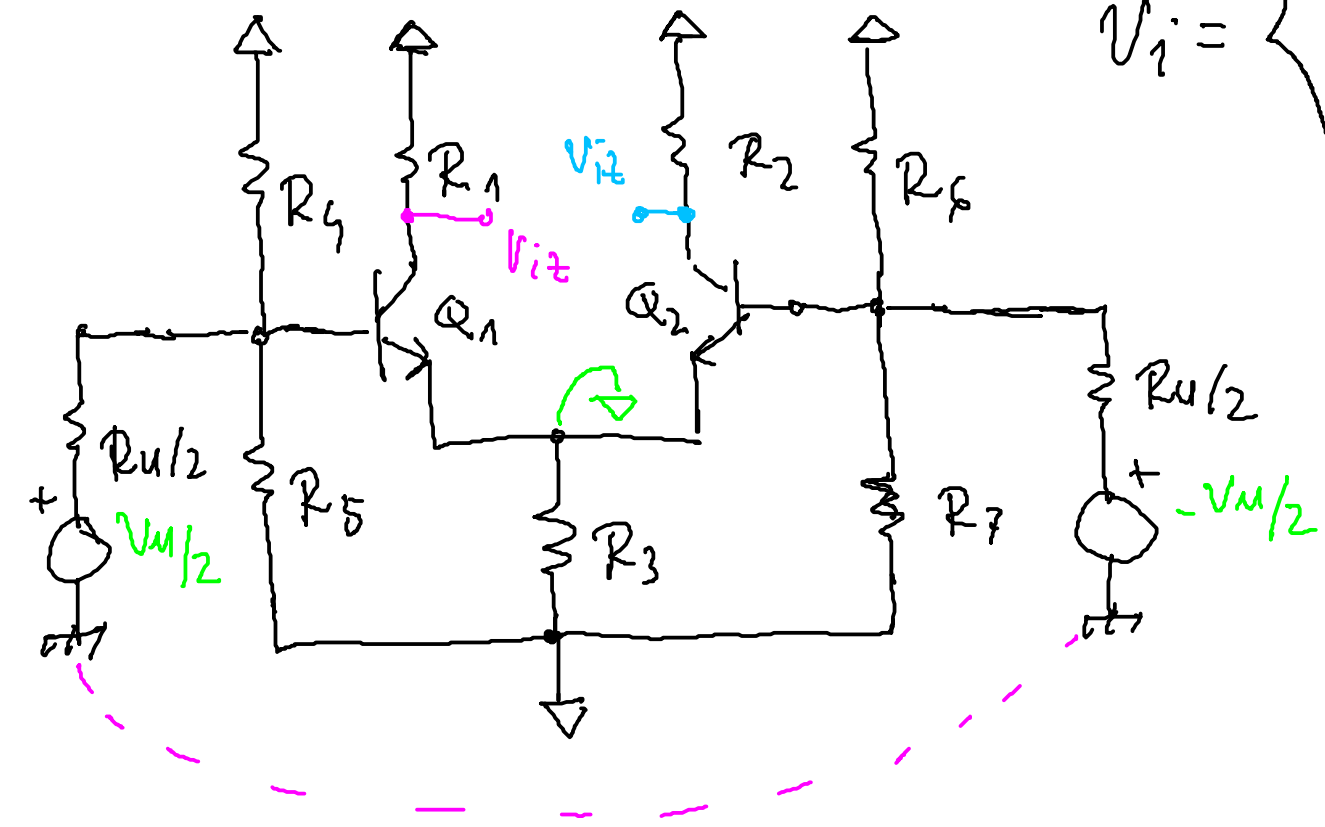


$A_d$  ZA DIFERENCIJALNO POJAČANJE PRETPOSTAVLJAMO:  $V_{u1} = \frac{V_u}{2} = -V_{u2}$

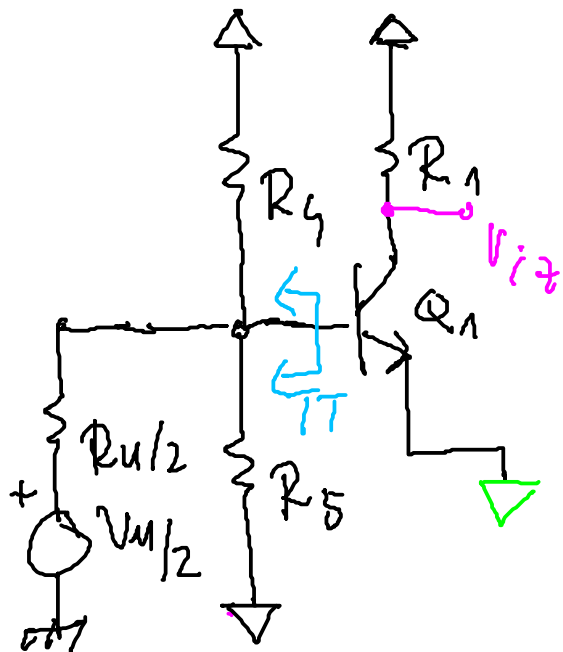
$$A_d \triangleq \frac{V_{i2}}{V_{u1} - V_{u2}} = \frac{V_{i2}}{\frac{V_u}{2} - (-\frac{V_u}{2})} = \frac{V_{i2}}{V_u}$$

$R_{u1} = R_{u2} = R_u/2$

$V_i = \begin{cases} V_{i2} \Rightarrow A_d > 0 & \textcircled{1} \\ V_{i2} \Rightarrow A_d < 0 & \textcircled{2} \end{cases}$

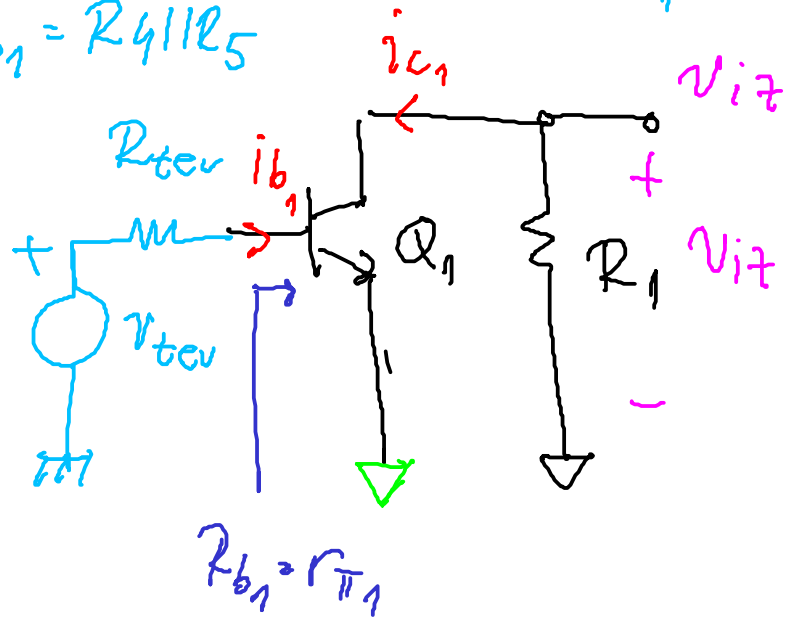


2



$$R_{tev} = (R_{u/2}) \parallel R_4 \parallel R_5, \quad V_{tev} = \frac{R_{B1}}{R_{B1} + R_{u/2}} \cdot \frac{v_u}{2}$$

$$R_{B1} = R_4 \parallel R_5$$

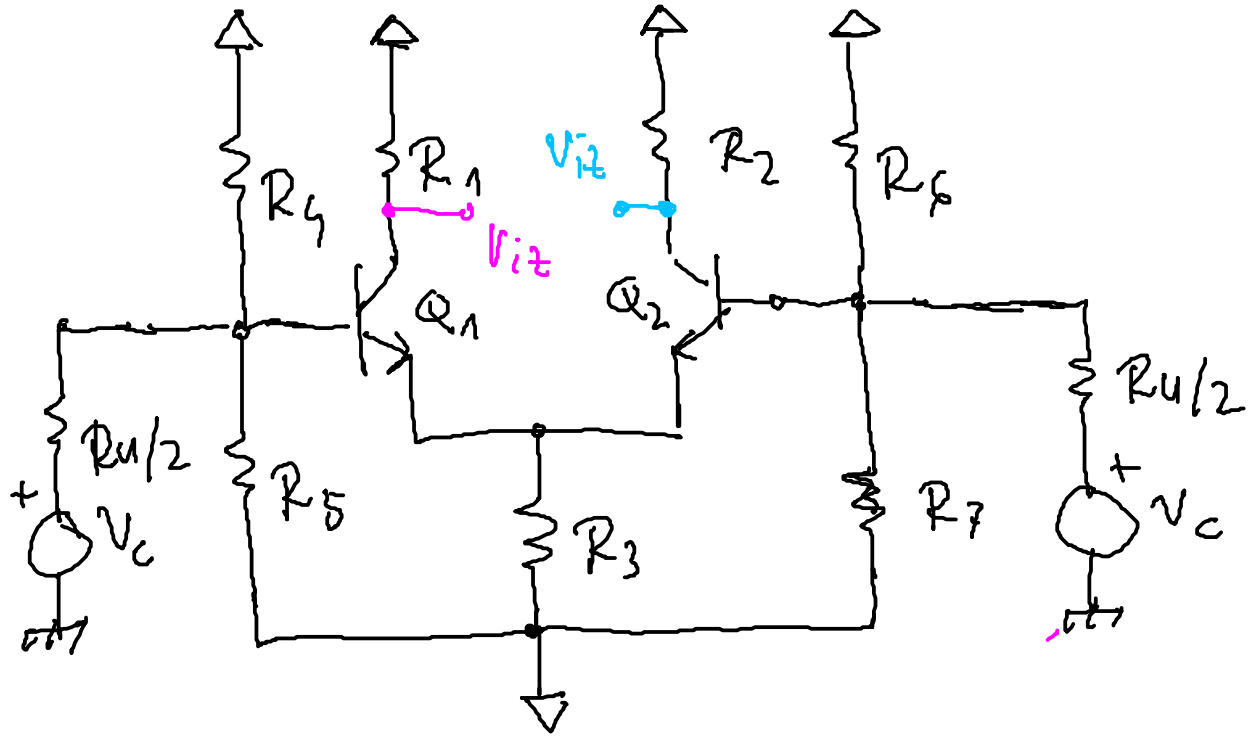


$$R_{b1} = r_{\pi 1}$$

$$A_d = \frac{\dot{v}_{i7}}{v_u} = \frac{v_{i7}}{i_{c1}} \cdot \frac{i_{c1}}{i_{b1}} \cdot \frac{i_{b1}}{v_{tev}} \cdot \frac{v_{tev}}{v_u} = -R_{c1} \cdot \beta_1 \cdot \frac{1}{R_{tev} + R_{\pi 1}} \cdot \frac{1}{2} \cdot \frac{R_{B1}}{R_{B1} + R_{u/2}}$$

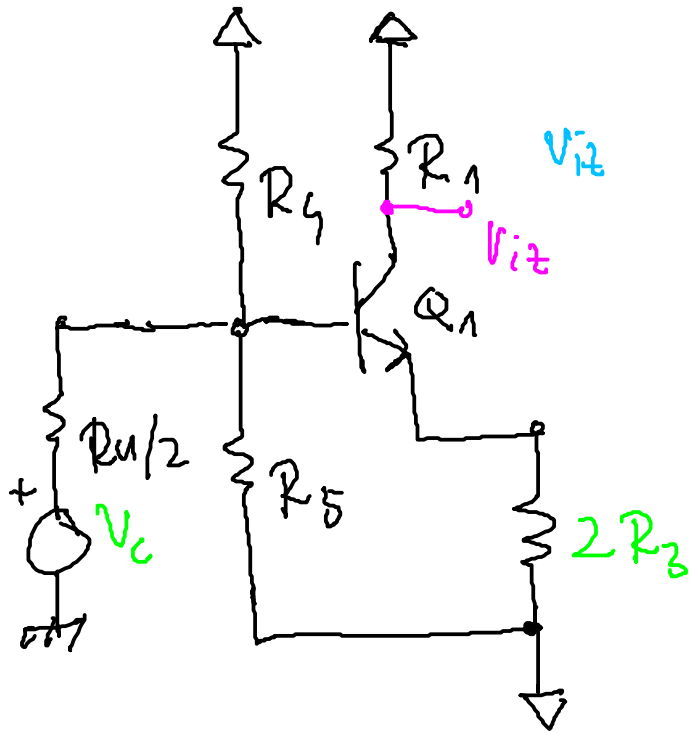
$A_c$  ZA POJAČAČIJE SRÉDNIJE VREDNOSTI PRETPOSTAVIJAMO:  $V_{m1} = V_{m2} = V_c$

$$A_c \triangleq \frac{V_{i2}}{(V_{m1} + V_{m2})/2} = \frac{V_{i2}}{(V_c + V_c)/2} = \frac{V_{i2}}{V_c}$$

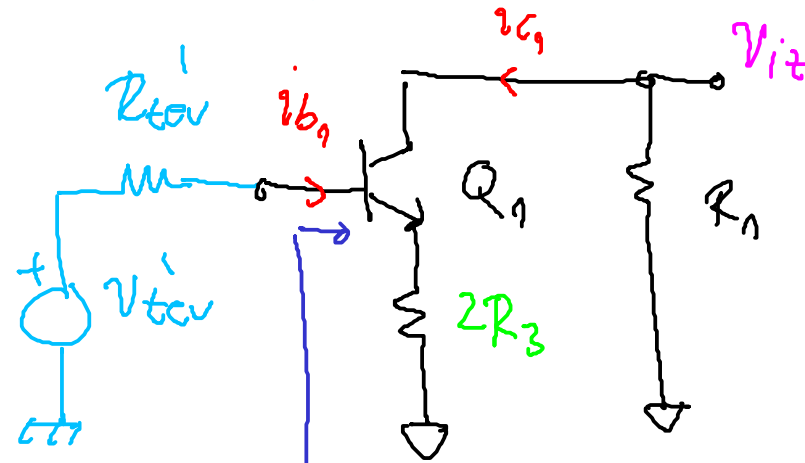


$$R_{tev}' = R_{tev} = (R_u/2) \parallel R_4 \parallel R_5$$

$$V_{tev}' = \frac{R_{B1}}{R_{B1} + (R_u/2)} \cdot V_c \quad ; \quad R_{B1} = R_4 \parallel R_5$$



≡



$$R_{b1}' = r_{\pi_1} + (1 + \beta_1) \cdot (2R_3)$$

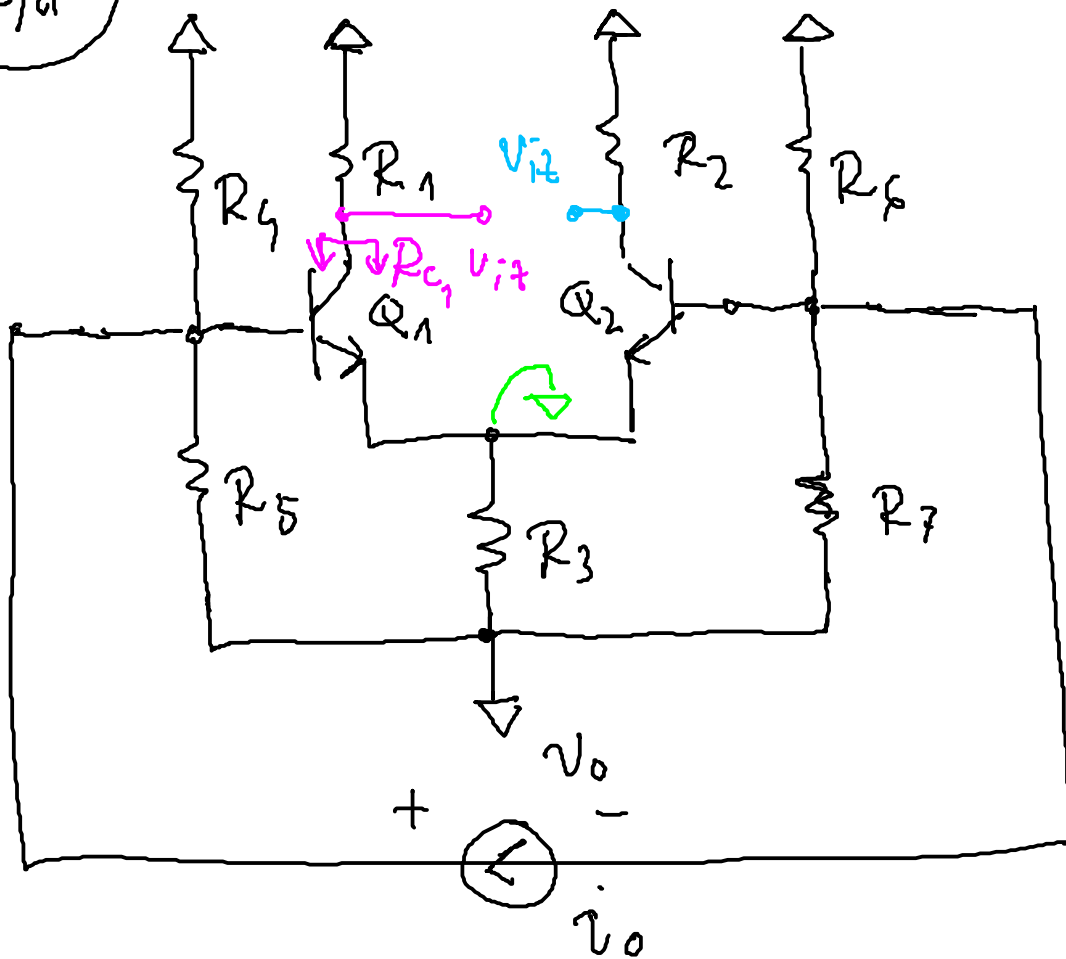
$$A_c = \frac{V_{it}}{V_c} = \frac{V_{it}}{i_{c1}} \cdot \frac{i_{c1}}{i_{b1}} \cdot \frac{i_{b1}}{V_{tev}'} \cdot \frac{V_{tev}'}{V_c} = -R_n \cdot \beta_1 \cdot \frac{1}{R_{tev}' + R_{b1}'} \cdot \frac{R_{B1}}{R_{B1} + R_u/2}$$

$$S = \left| \frac{A_d}{A_c} \right| = \frac{R_n \cdot \beta_1 \cdot \frac{1}{R_{tev}' + R_{\pi_1}} \cdot \frac{1}{2} \cdot \frac{R_{B1}}{R_{B1} + R_u/2}}{R_n \cdot \beta_1 \cdot \frac{1}{R_{tev}' + R_{b1}'} \cdot \frac{R_{B1}}{R_{B1} + R_u/2}} = \frac{1}{2} \cdot \frac{R_{tev}' + R_{b1}'}{R_{tev}' + r_{\pi_1}}$$

$$\rho = \frac{1}{2} \cdot \frac{R_{tev} + r_{\pi 1} + (1 + \beta_1) \cdot 2R_3}{R_{tev} + r_{\pi 1}} = \frac{1}{2} + \frac{(1 + \beta_1) \cdot R_3}{R_{tev} + r_{\pi 1}}$$

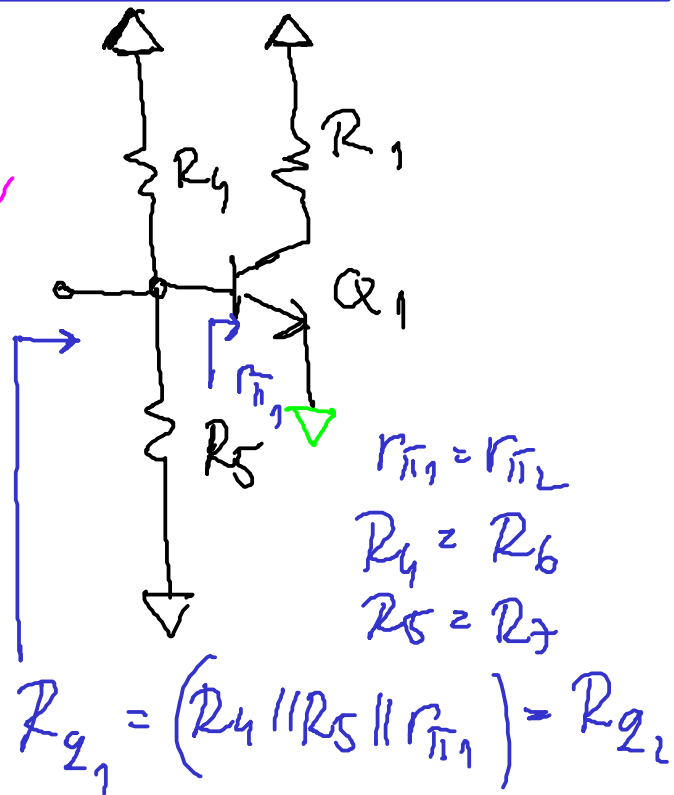
$R_{ul,d}$

ДИФЕРЕНЦИАЛЬНАЯ УЛАЗНАЯ СОПРОТИВЛЕНИЕ



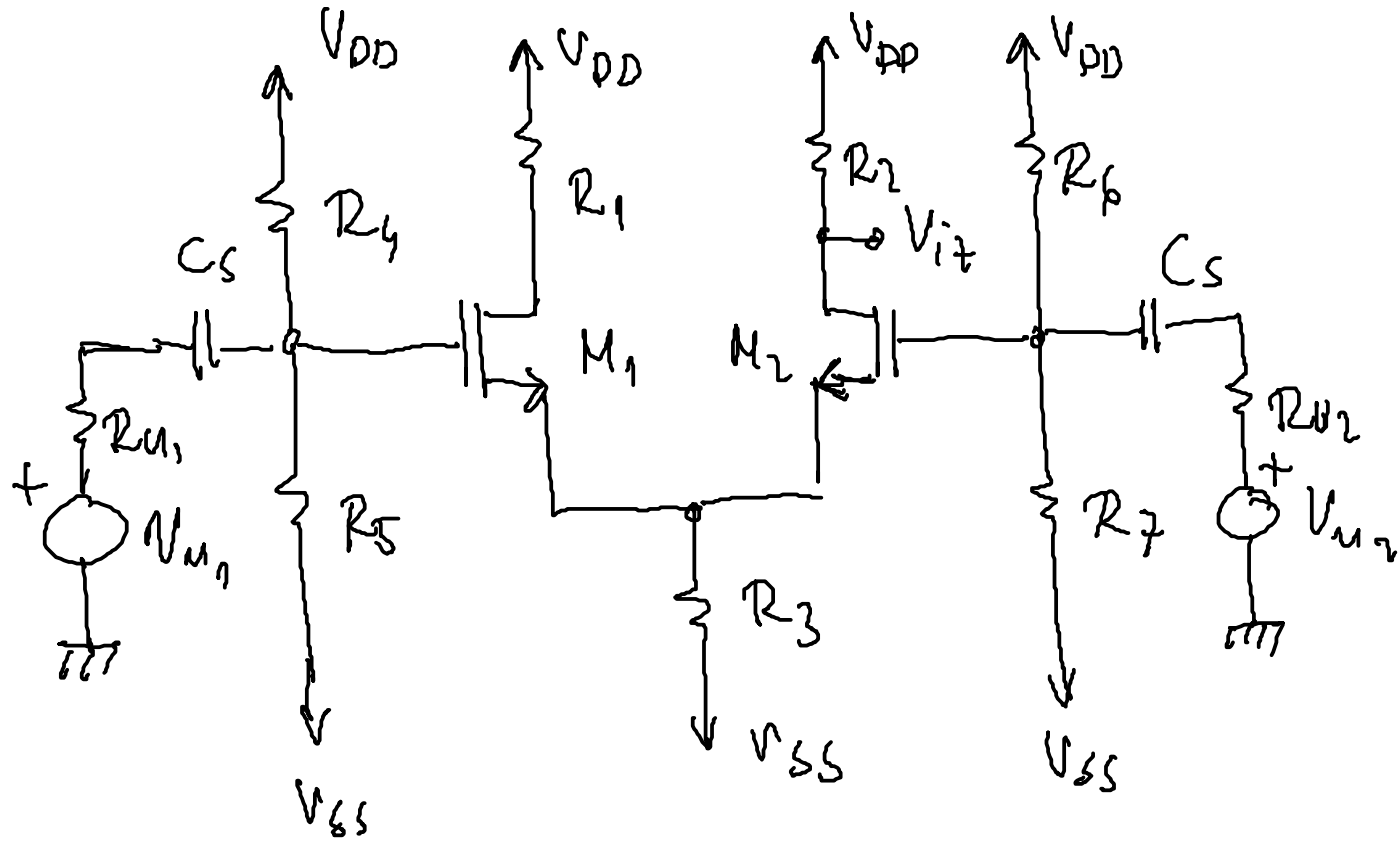
$$R_{ul,d} = \frac{V_0}{I_0} = 2R_{q1} = 2R_{q2}$$

$R_{c1} \rightarrow \infty \Omega$   
 $V_A \rightarrow \infty V$   
 $R_{i7} = R_{c1} \parallel R_1$   
 $R_{i7} = R_1$

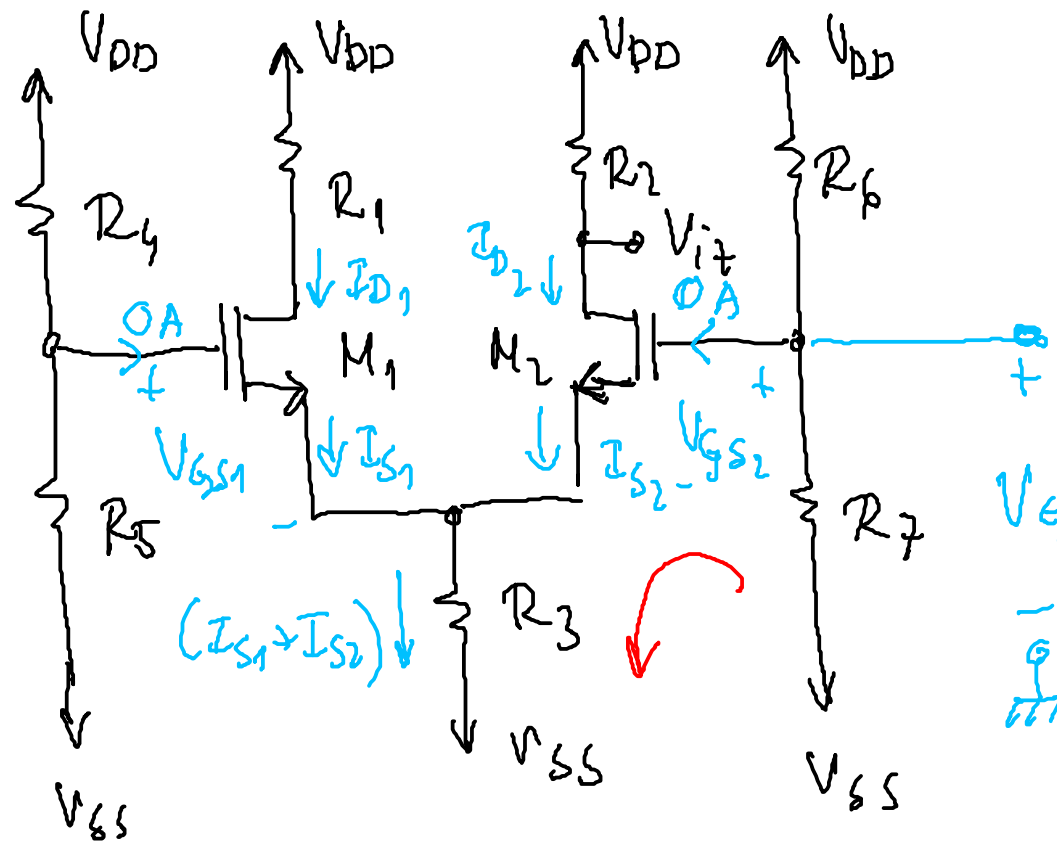




MOS



DC



$$V_{th1} = V_{th2}$$

$$A_1 = A_2$$

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

$$I_D = I_S$$

$$V_{G2} = \frac{R_7}{R_7 + R_6} \cdot V_{DD} + \frac{R_6}{R_6 + R_7} \cdot V_{SS}$$

$$V_{G2} = V_{GS2} + (I_{S1} + I_{S2}) \cdot R_3 + V_{SS} = V_{GS2} + 2 I_{D2} R_3 + V_{SS}$$

$$V_{G2} - V_{th2} = \underbrace{V_{GS2} - V_{th2}}_{V_{ov2}} + 2 A_2 \cdot R_3 (V_{GS2} - V_{th2})^2 + V_{SS}$$

$$V_{G2} - V_{th2} = V_{ov2} + 2 A_2 R_3 V_{ov2}^2 + V_{SS}$$

$$V_{ov2}^2 \cdot (2A_2 \cdot R_3) + V_{ov2} - (V_{G2} - V_{TH2} - V_{SS}) = 0$$

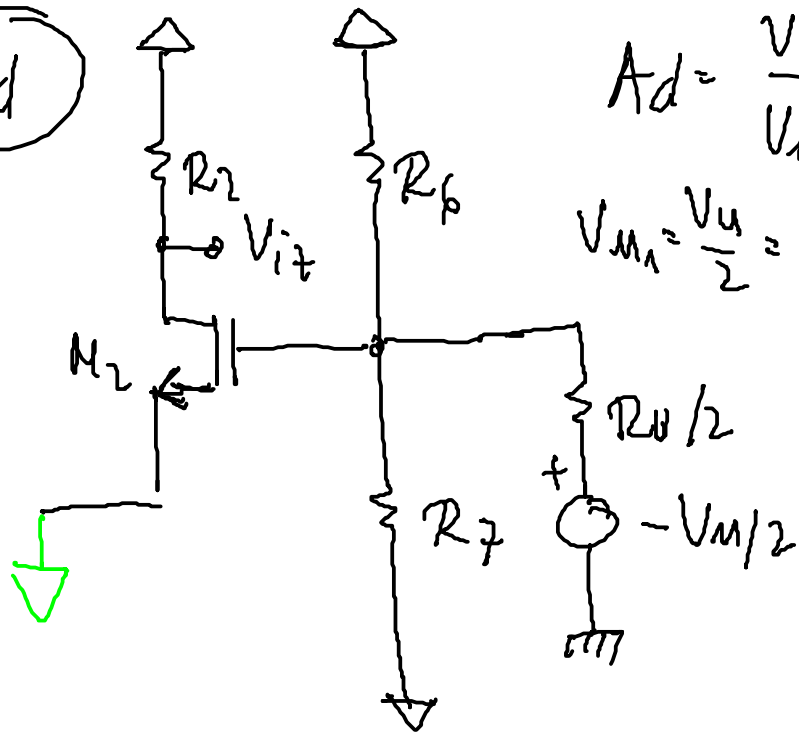
$$V_{ov2} = \frac{-1 + \sqrt{1 + 4(2 \cdot A_2 \cdot R_3) \cdot (V_{G2} - V_{TH2} - V_{SS})}}{2 \cdot (2 \cdot A_2 \cdot R_3)}$$

↓

$$I_{D2} = A_2 \cdot V_{ov2}^2 \Rightarrow g_{m2} = 2A_2 \cdot V_{ov2}; \quad r_{o2} \approx \frac{1}{\lambda I_{D2}}, \quad g_{m2} = g_{m1}, \quad r_{o2} = r_{o1}$$

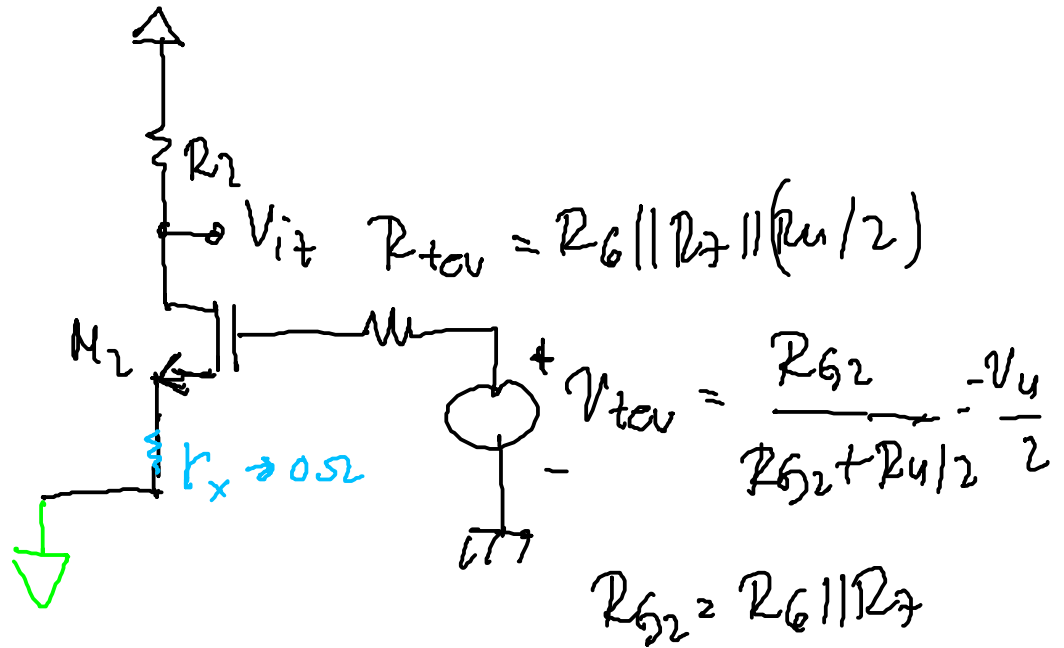
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$A_d$



$$A_d = \frac{V_{i7}}{V_{u1} - V_{u2}}$$

$$V_{m1} = \frac{V_u}{2} = -V_{m2}$$



$$R_{tov} = R_6 \parallel R_7 \parallel (R_u/2)$$

$$V_{tov} = \frac{R_{G2}}{R_{G2} + R_u/2} \cdot \frac{-V_u}{2}$$

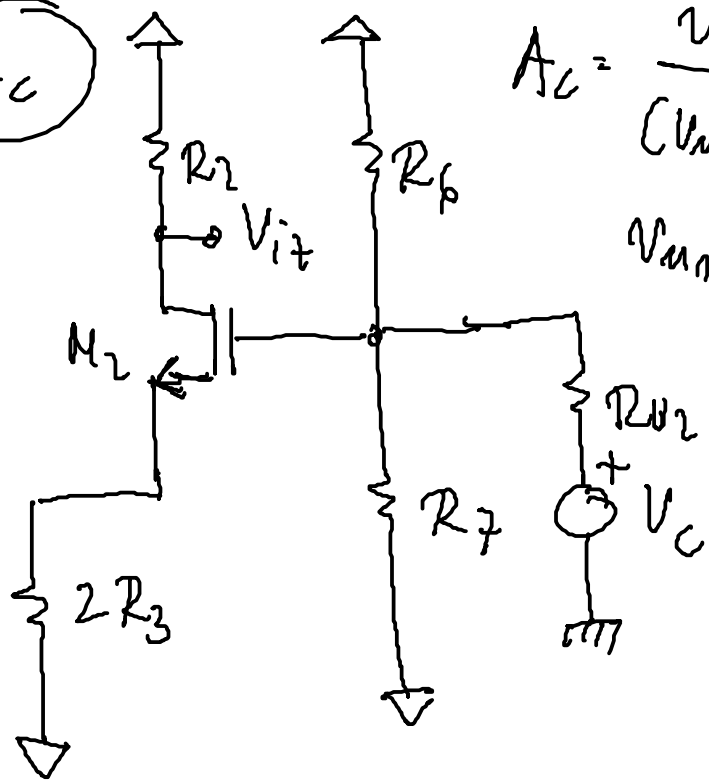
$$R_{G2} = R_6 \parallel R_7$$

$\parallel g_{m2} \cdot r_{o2}$

$$A_d = \frac{V_{i7}}{V_u} = \frac{V_{i7}}{V_{tov}} \cdot \frac{V_{tov}}{V_u} = \frac{-\mu_2 R_2}{R_2 + r_{o2} + (1 + \mu_2) r_x} \cdot \frac{R_{G2}}{R_{G2} + R_u/2} = \frac{1}{2}$$

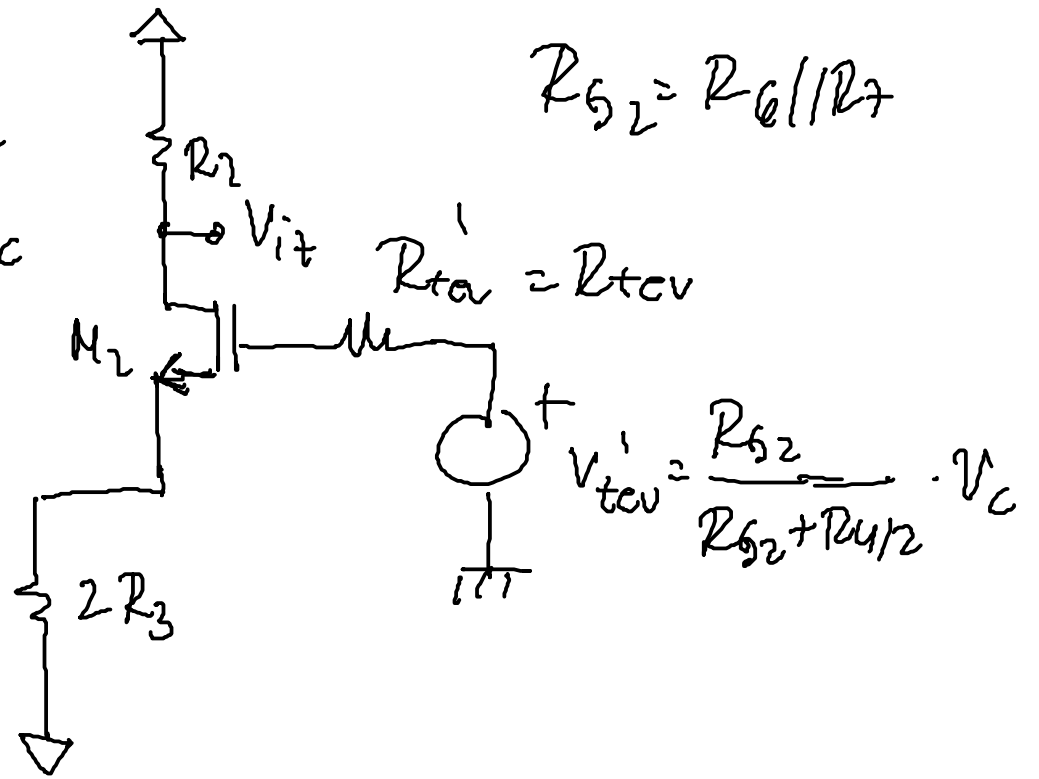
$$A_d = \frac{1}{2} \frac{R_{G2}}{R_{G2} + R_u/2} \cdot g_{m2} (R_2 \parallel r_{o2}) = \frac{1}{2} \frac{R_{G2}}{R_{G2} + R_u/2} \cdot \frac{\mu_2 R_2}{R_2 + r_{o2}}$$

$A_c$



$$A_c = \frac{V_{i7}}{(V_{u1} + V_{u2})/2}$$

$$V_{u1} = V_{u2} = V_c$$



$$R_{G2} = R_6 || R_7$$

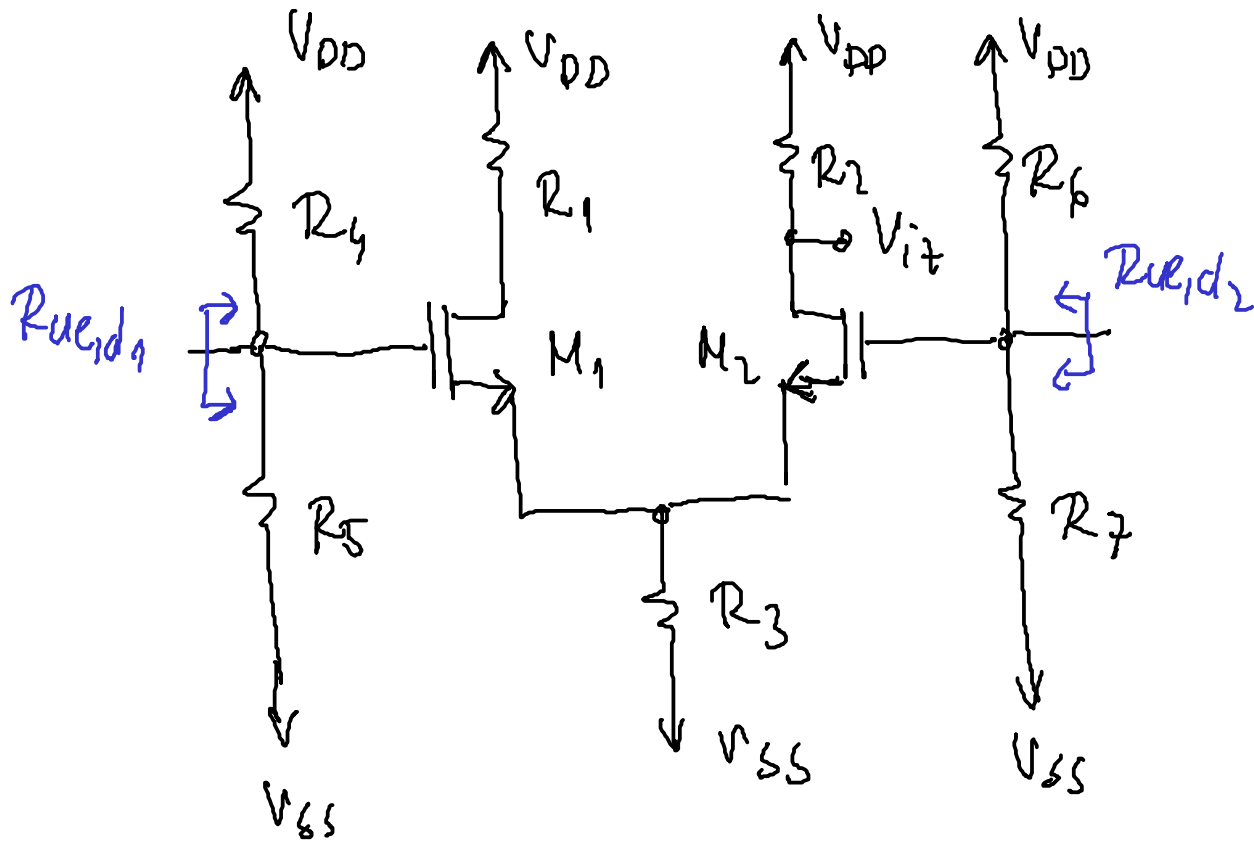
$$R_{tov}^1 = R_{tov}$$

$$V_{tov}^1 = \frac{R_{G2}}{R_{G2} + R_{u1}/2} \cdot V_c$$

$$A_c = \frac{V_{i7}}{V_c} = \frac{V_{i7}}{V_{tov}^1} \cdot \frac{V_{tov}^1}{V_c} = \frac{-\mu_2 \cdot R_2}{R_2 + r_{o2} + (1 + \mu_2) \cdot 2R_3} \cdot \frac{R_{G2}}{R_{G2} + R_{u1}/2}$$

$$\rho = \left| \frac{A_d}{A_c} \right| = \frac{\frac{1}{2} \frac{R_{G2}}{R_{G2} + R_{u1}/2} \cdot \frac{\mu_2 R_2}{R_2 + r_{o2}}}{\frac{\mu_2 R_2}{R_2 + r_{o2} + (1 + \mu_2) \cdot 2R_3} \cdot \frac{R_{G2}}{R_{G2} + R_{u1}/2}} = \frac{1}{2} \left( 1 + \frac{(1 + \mu_2) \cdot 2R_3}{R_2 + r_{o2}} \right)$$

$$f = \frac{1}{2} + \frac{(1+\mu_2) \cdot R_3}{R_2 + V_{o2}}$$



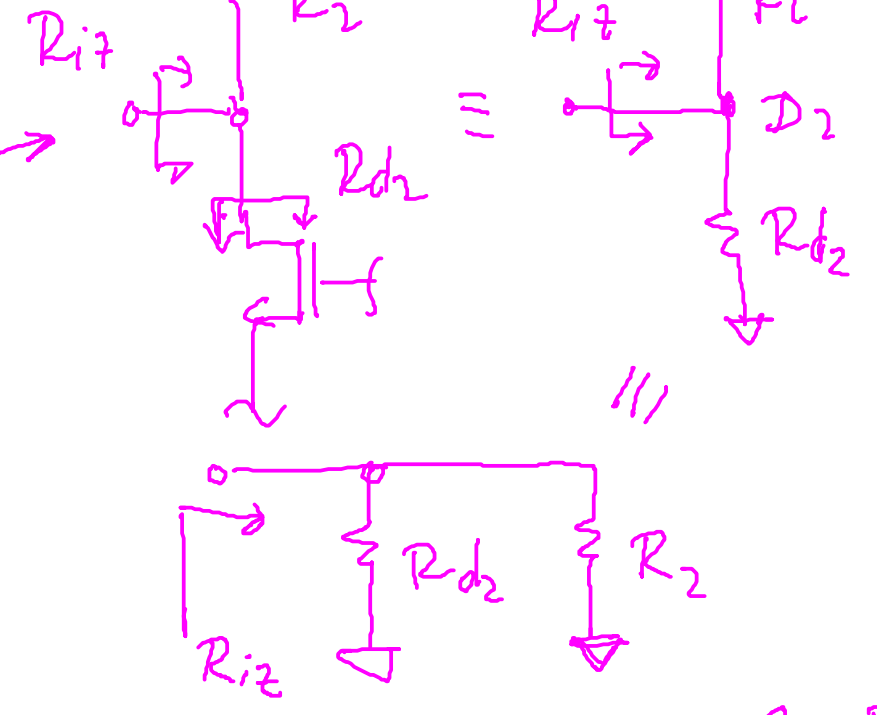
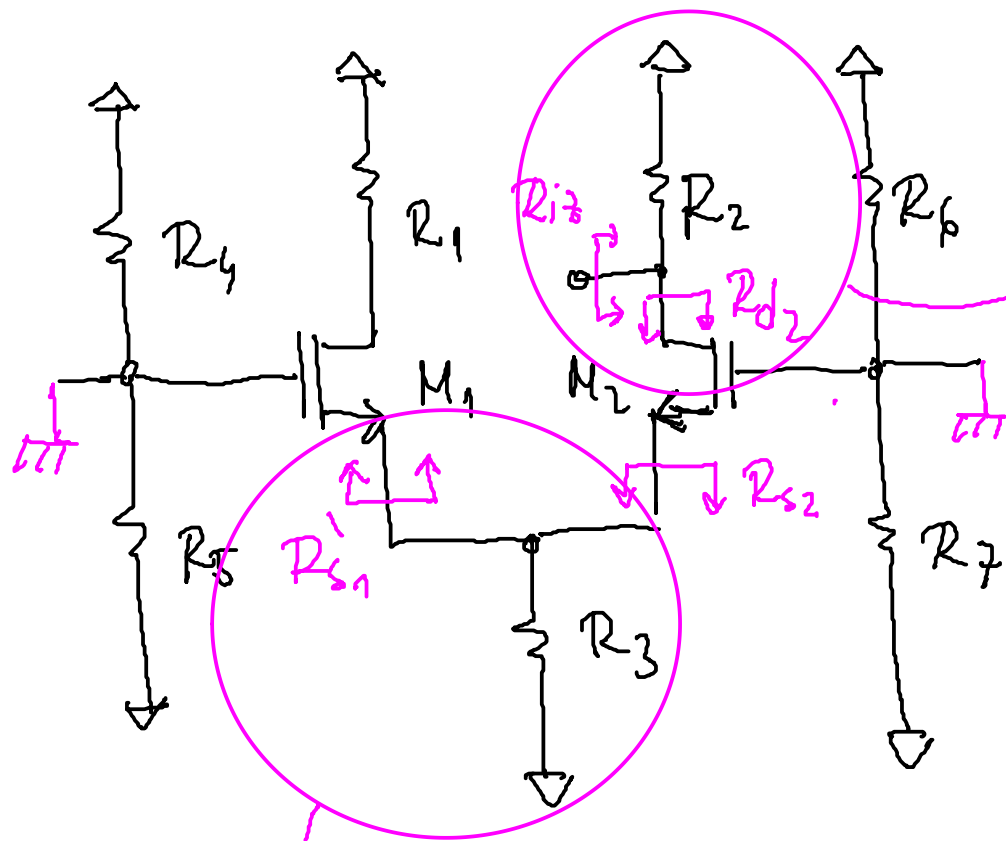
$$\begin{aligned} R_{ue,d} &= R_{ue,d_1} + R_{ue,d_2} \\ &= 2(R_4 || R_5) \\ &= 2(R_6 || R_7) \end{aligned}$$

$$R_{ue,d_1} = R_4 || R_5$$

$$R_{ue,d_2} = R_6 || R_7$$

$$R_4 = R_5$$

$$R_6 = R_7$$



$$R_{i7} = R_2 \parallel R_{d2} ; R_{d2} = r_{o2} + (1 + \mu_2) R_{s2} ; R_{s2} = R_3 \parallel R'_{s1} ; R'_{s1} = \frac{r_{o1} + R_1}{1 + \mu_1}$$

