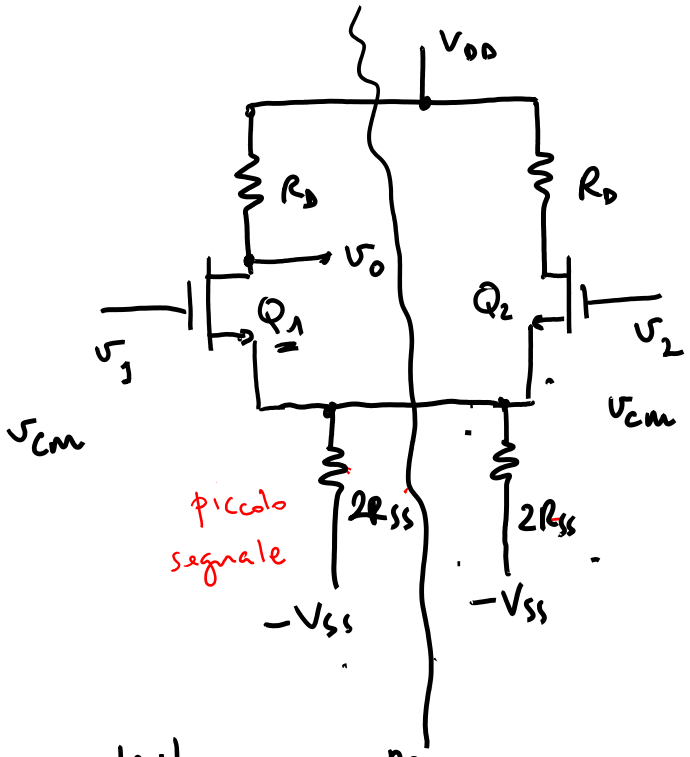


$$CMRR = \frac{|A_d|}{|A_{cm}|} \cong \frac{g_m R_D}{2(R_D/2R_{SS})} \cong g_m R_{SS}$$

$V_{GS} = -V_S$

GUADAGNO DIFFERENZIALE

$$A_d = \frac{g_m}{2} \cdot R_D \leftarrow$$

$$A_d = \frac{v_o}{v_2 - v_1} \qquad v_{id}$$

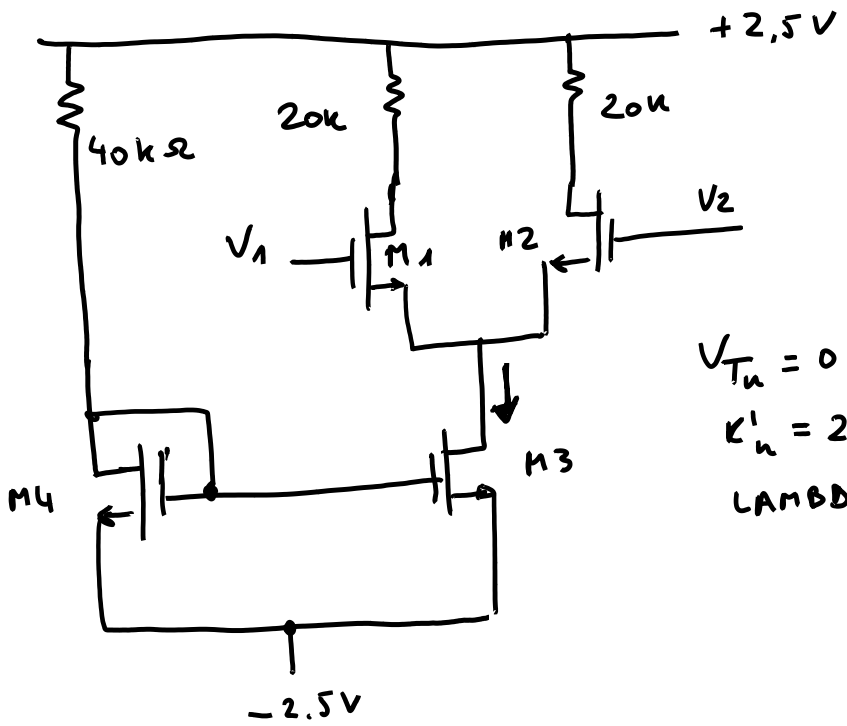
differenziale puro $\Rightarrow$ R_{SS} scompare

GUADAGNO DI MODO COMUNE

$\rightarrow$ R_D , $2R_{SS}$

$$A_{cm} = \frac{-g_m R_D}{1 + g_m \cdot 2R_{SS}} = \frac{-g_m R_D}{1 + 2 g_m R_{SS}}$$

$$\cong -\frac{R_D}{2R_{SS}}$$



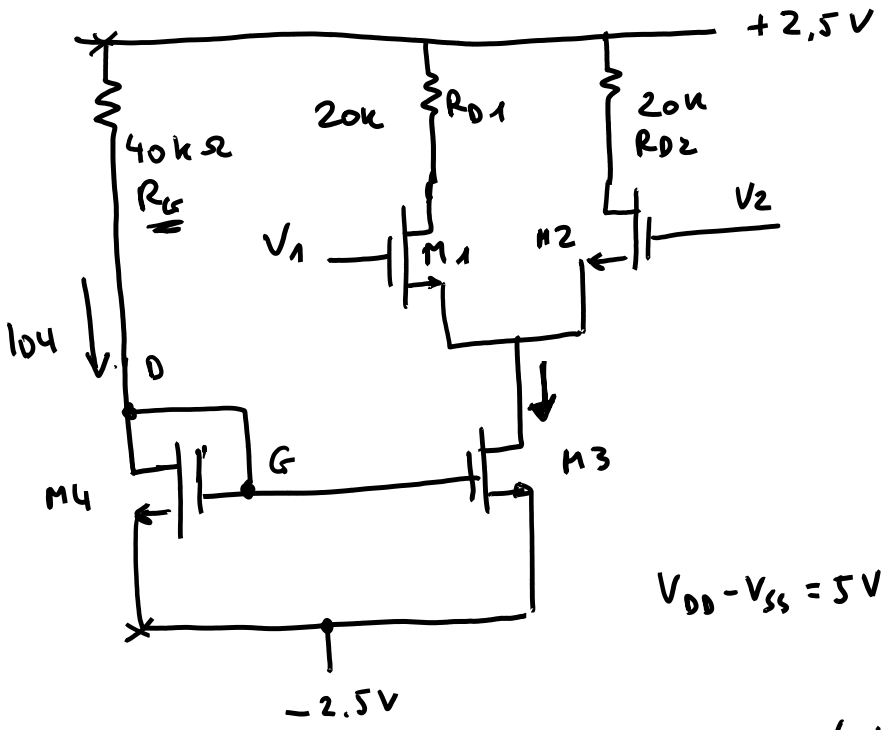
M1, M2, $\frac{W}{L} = \frac{20}{0.8}$

M3, M4 $\frac{W}{L} = \frac{5.6}{0.8}$

$V_{Tn} = 0.7\,V$

$K'_n = 200\,\mu A/V^2$

LAMBDA $= \lambda = 0.1\ V^{-1}$



V_{DS4} = V_{GS4}

$I_{D4} \Rightarrow V_{DD} - V_{SS} = I_{D4} \cdot R_G + V_{GS4}$

R_G = 40kΩ

$$I_{D4} = \frac{k_{n4}}{2}\left(V_{GS4} - V_T\right)^2$$

$$k_{n4} = k'_{n4} \cdot \left(\frac{W}{L}\right)_4 = 200\,\mu A/V^2 \cdot \frac{5.6}{0.8}$$

$$V_{DD} - V_{SS} = 5V = I_D \cdot 40k + V_{GS4}$$

I_D ↑ mA

$$5V = 0.5 \cdot \left(k'_n \cdot \frac{W}{L} \cdot \left(V_{GS} - V_T\right)^2\right) 40k + V_{GS}$$

$$5V = 0.5\left(200 \cdot 10^{-3} \cdot 7 \left(V_{GS} - V_T\right)^2 \cdot 40k\right) + V_{GS}$$

V_T = 0.7

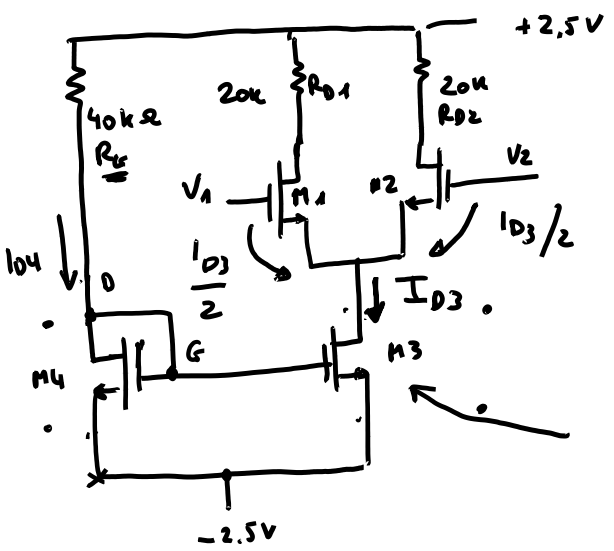
$$0 = 28 \cdot V_{GS}^2 - 38.2\, V_{GS} + 8.72$$

$V_{GS_4} = 1.074\,V$ unica soluzione accettabile

$V_{GS4} - V_{Tn} = 0.374\,V$

$$I_{D4} = \frac{K'_n}{2} \cdot \frac{W}{L} \cdot (0.374)^2 = 98\,\mu A = I_{D4}$$

$100\,\mu A/V^2$; 7



Trascuriamo λ : $I_{D4} = I_{D3} = 98\,\mu A$

$I_{D1} = I_{D2} = 49\,\mu A$

V_{GSQ}, V_{DSQ} M1 - M2

$I_{D1} = I_{D2} = 49\,\mu A$ $\qquad V_{OV_{1,2}} = \sqrt{\frac{2 I_D}{k_n}} = \sqrt{\frac{98 \cdot 10^{-6}}{200 \cdot 10^{-6} \cdot \frac{20}{0.8}}} = 0.14\ V$

$V_{GS} = \underbrace{0.14}_{V_{OV}} + V_T = \underline{\underline{0.84\ V}} = -V_S$

il source a riposo si trova a $-0.84\ V$

$V_{DS1,2} = V_{DD} - 20\,k\Omega \cdot I_D = V_D = 2.5 - 20 \cdot 49 \cdot 10^{-3}$

($20\,k\Omega$ ↑ R_D)

$V_{DS} = V_D - V_S = 2.5 - 20 \cdot 49 \cdot 10^{-3} + \underbrace{0.84\ V}_{-V_S} = 2.36\ V > V_{GS} - V_T = V_{OV} = 0.14\ V$

SATURAZIONE DI M1 - M2. OK

PUNTO A RIPOSO M1, M2

$$g_{m,1,2} = \sqrt{2 K'_n \frac{W}{L} I_D} = \underline{0.7\ mS}$$

$$|A_d| = \frac{g_m R_D}{2} = 0,7 \cdot 20/2 = 7\ V/V$$

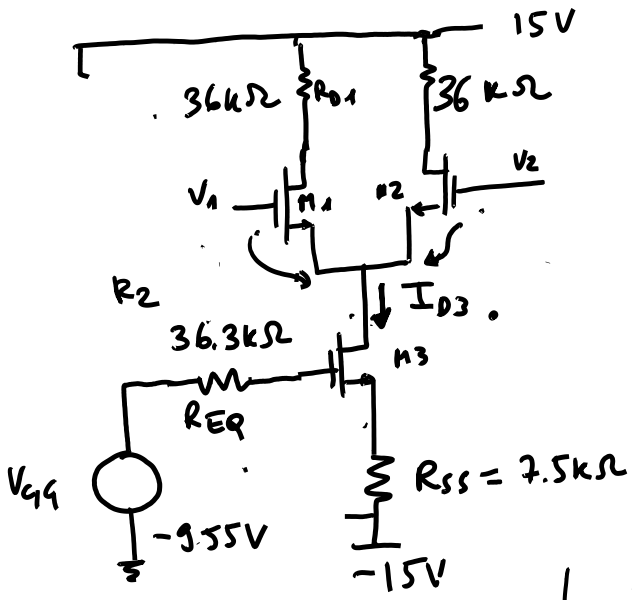
$$|A_{cm}| = \frac{g_m R_D}{1 + 2 g_m R_{ss}}$$

↑ è la resistenza del transistor M3

$\boxed{r_{o3}}$ $\quad r_{o3} = \frac{1}{\lambda I_{D3}}$ ← senza effetto di modulaz canale $= 102\ k\Omega$

$|A_{cm}| = 1,014$

$$CMRR = 20 \log \frac{7}{1.014} = \underline{16.8\ dB}$$



M1, M2, M3 $k_n = 400\,\mu A/V^2$, $V_{Tn} = 1V$

$\lambda = 0.02\,V^{-1}$

. punto a riposo, . calcolare A_d, A_{cm}, CMRR

$$V_{GG} = V_{SS} \cdot \frac{R_2}{R_1 + R_2} = -15 \cdot \frac{100}{100+57} = -9.55\,V$$

$$R_{EQ} = 100k\Omega \,//\, 57k\Omega = 36,3\,k\Omega$$

$$V_{GS3} = V_{G3} - I_{D3} \cdot R_{SS} - V_{SS} =$$

$$V_{G3} = -9.55\,V$$

$$V_{GS3} = -9.55 - \frac{k_n}{2}\left(V_{GS3} - V_T\right)^2 \cdot 7.5 + 15V$$

$$I_{D3} = \frac{k_n}{2}\left(V_{OV}\right)^2 = 0.2\left(1.42\right)^2 = 0.403\,mA$$

$$I_{D1} = I_{D2} = 0.2\,mA$$

$$0 = 1.5V_{GS3}^2 - 2V_{GS3} - 3.95$$

$$V_{GS3} = 2.42V \qquad V_{OV3} = 1.42V$$

V_{GS1} , V_{GS2} $\quad$ 0.2mA $\quad$ $V_{GS1} = \underbrace{1}_{V_T} + \sqrt{\frac{2I_D}{k_n}} = 1 + \sqrt{\frac{2 \cdot 0.2}{0.4}}$

λ trascurato

$= 2V = V_{GS1,2}$

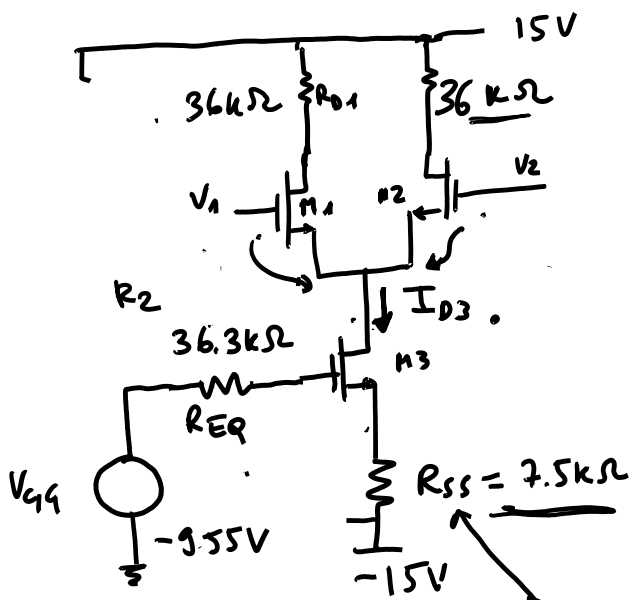
$V_{DS3} = +V_{S1} - V_{S3} = -V_{GS1} - 7.5\, I_{D3} - (-15V) =$ $\quad$ M3 SATURO

($V_{S1} = V_{D3}$, $I_{D3} = 0.4$)

$= -2V - 7.5 \cdot 0.4 + 15V = 9.97V > V_{OV3}$

$V_{DS1} = V_{DS2} = V_{D1} - V_{S1} = 15V - 36 \cdot I_{D1} - (-V_{GS1}) = 15 - 36 \cdot 0.2 + 2 = 9.75V$

$9.75V > V_{OV1} = 2 - 1 = 1V$



$$r_{o3} = \frac{1}{\lambda I_D} = \frac{1}{\frac{0.02 \cdot 0.4}{\lambda}} \cong 120\,k\Omega$$

transistor con resistenza di source

R_{SS} → carico attivo ≡ resistenza di uscita source comune con R_S

$$R_{out3} = r_{o3}(1 + g_m R_{SS}) \cong 650\,k\Omega$$

$$g_{m_{1,2}} = \frac{2 I_{D1,2}}{V_{ov1}} = 0.4\,mS$$

$$|A_d| \cong \frac{g_m R_D}{2} = 7.22\ V/V$$

$$|A_{cm}| \cong \frac{R_D}{2R_{OUT3}} = \frac{36}{1302} \cong 0.027$$

$$CMRR = 20 \log \frac{7.22}{0.027} \sim 48.33\ dB$$