Elektronik II

BJT fark yükselteci, CMRR ve aktif yüklü fark yükselteci

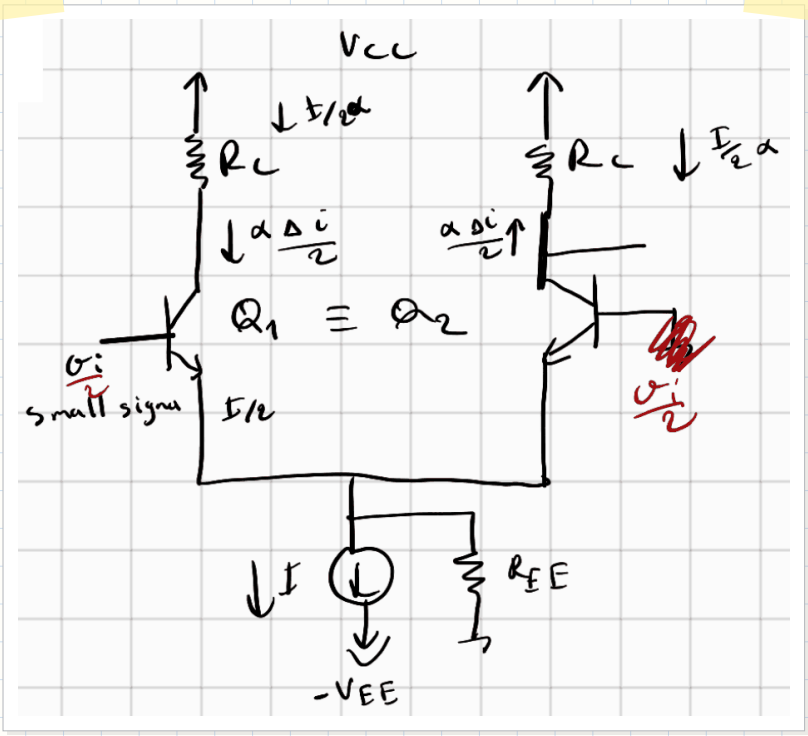
Orijinal not: Ders7.pdf

UYARI Bu belge, el yazısı ders notlarından Claude (Anthropic) yardımıyla dijitale aktarılmıştır. Yardımcı kaynak olarak hazırlanmıştır; hata veya eksik içerebilir. Lütfen orijinal notları ve ders kaynaklarını esas alın.

NOTICE *This document was transcribed from handwritten lecture notes with the help of Claude (Anthropic). It is meant as a supplementary resource and may contain errors or omissions. Always check against the original notes and official course material.*

orj. s. 1

? In ac



orijinal çizim, s. 1

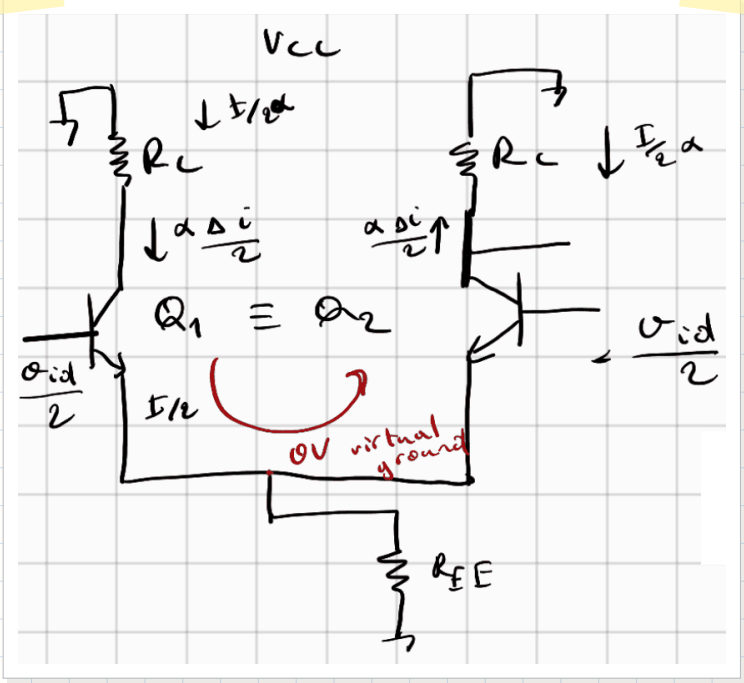
$$v_1 = V_{CC} - \frac{\alpha R_C I}{2} - \frac{\alpha \Delta i_1}{2}$$

$$v_2 = V_{CC} - \frac{\alpha R_C I}{2} + \frac{\alpha \Delta i}{2}$$

$$\boxed{v_D = v_2 - v_1 = \alpha \Delta i R_C}$$

$$\Delta i = g_m v_i$$

[1] Claude notu: muhtemelen $\mp \alpha \Delta i R_C/2$ olmalı (R_C çarpanı eksik; aşağıdaki $v_D = \alpha \Delta i R_C$ ile uyumlu).



orijinal çizim, s. 1

$$\Delta i = g_m v_{id}$$

$$\left.\begin{aligned} v_2 &= \frac{g_m v_{id}}{2} R_C \\ v_1 &= -\frac{g_m v_{id}}{2} R_C \end{aligned}\right\} \quad v_d = g_m v_{id} R_C = v_2 - v_1$$

$$A_d = g_m R_C = \frac{v_d}{v_{id}}$$

$A_d \rightarrow$ differential

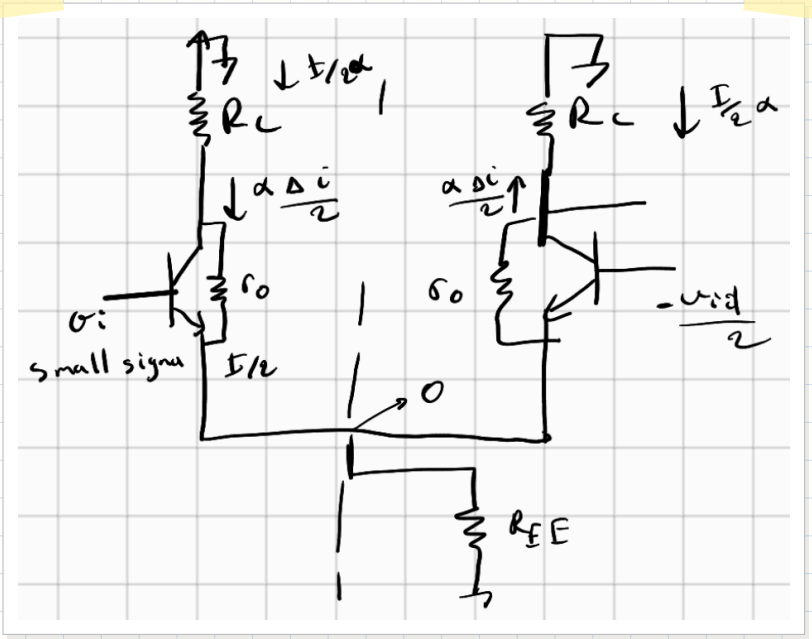
$$g_m = \frac{I_C}{V_T}$$

orj. s. 2

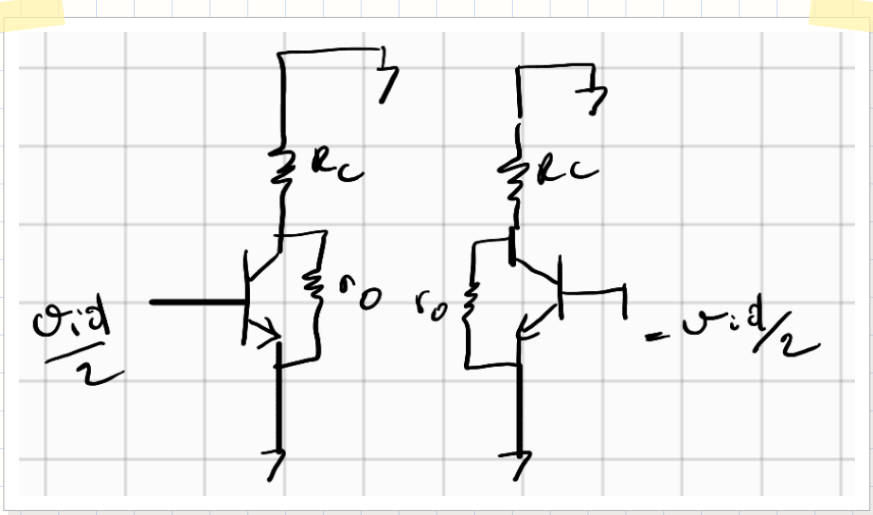
$$A_d = \frac{I_c}{V_T} R_C = \frac{I_C R_C}{V_T}$$

soğukta kazanç artar

Effect of r_o?



orijinal çizim, s. 2

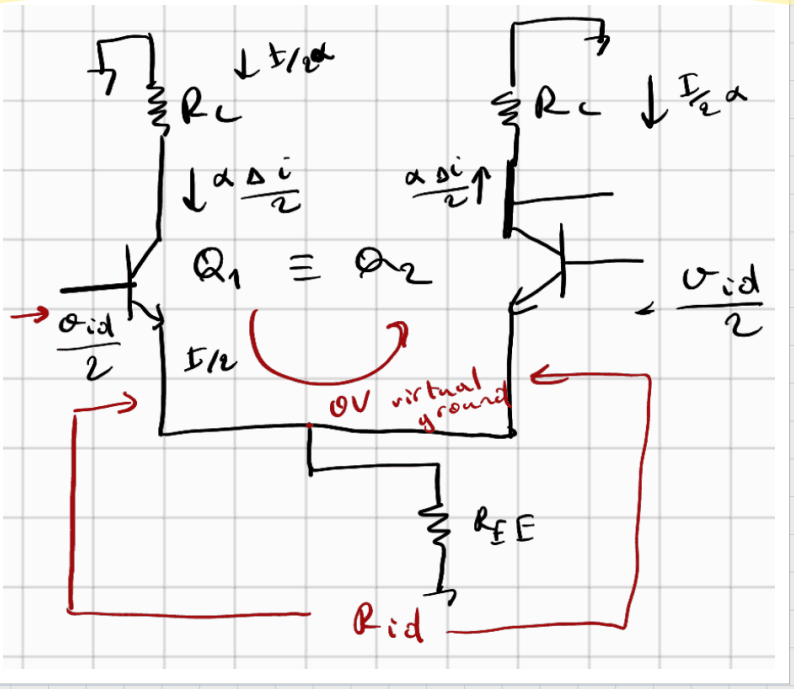


orijinal çizim, s. 2

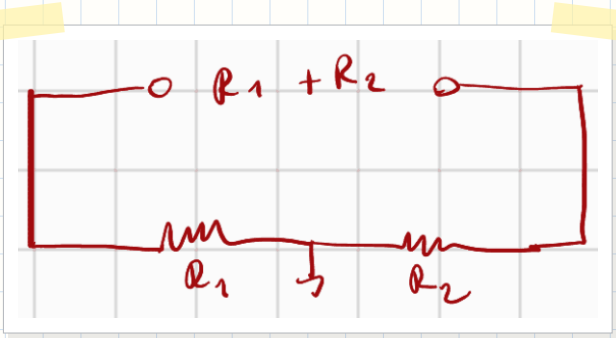
$$v_1 = -\frac{v_{id}}{2} g_m (r_o \parallel R_C) \qquad v_2 = \frac{v_{id}}{2} g_m (r_o \parallel R_C)$$

$$v_d = g_m (R_C \parallel r_o) v_{id} \Rightarrow A_d = \frac{v_d}{v_{id}} = g_m (R_C \parallel r_o) \simeq g_m R_C$$

orj. s. 3

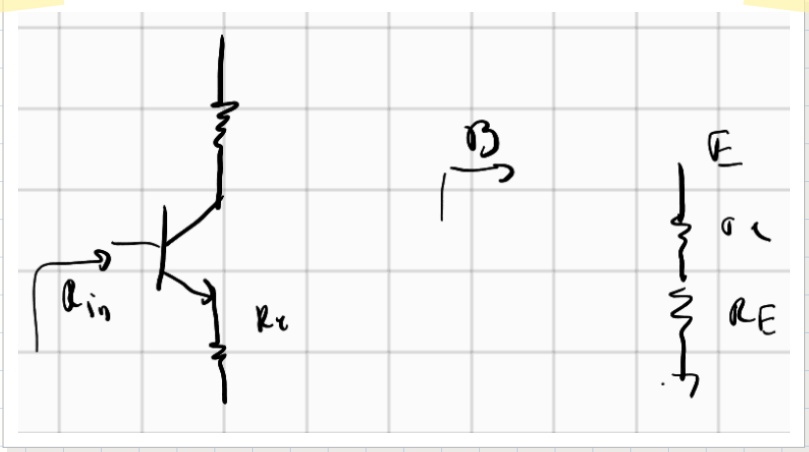


orijinal çizim, s. 3



orijinal çizim, s. 3

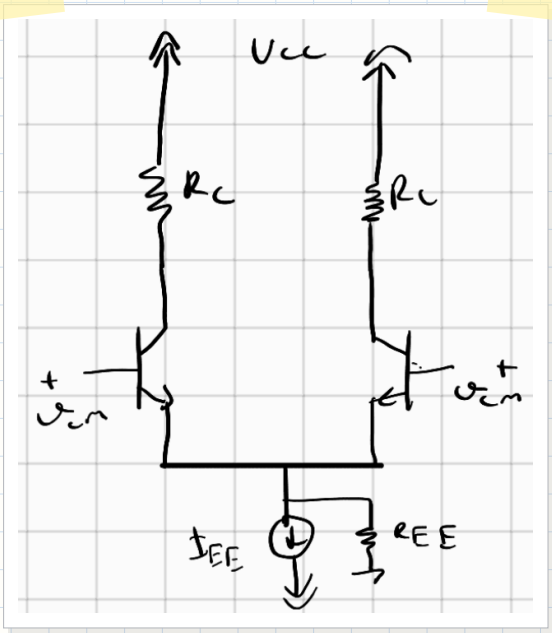
$$R_{id} = 2(\beta + 1)(r_e + R_E)$$



orijinal çizim, s. 3

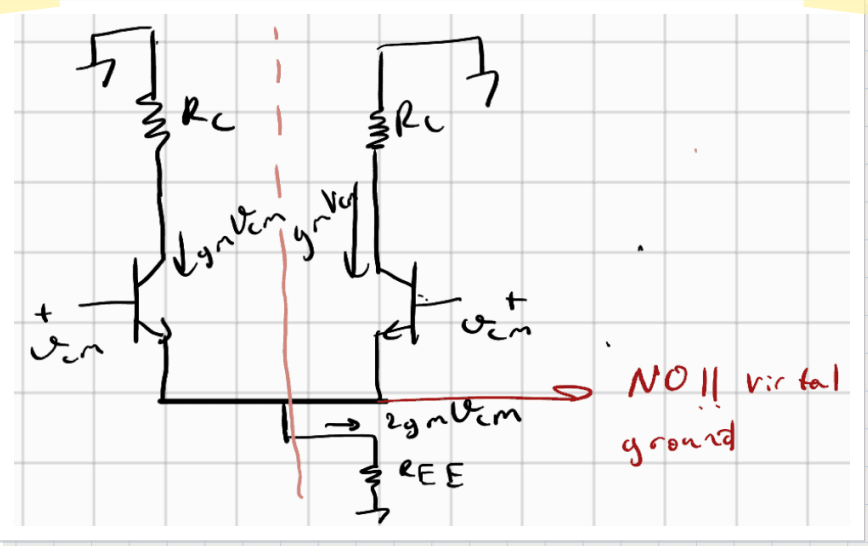
orj. s. 4

CMRR and Common mode operation

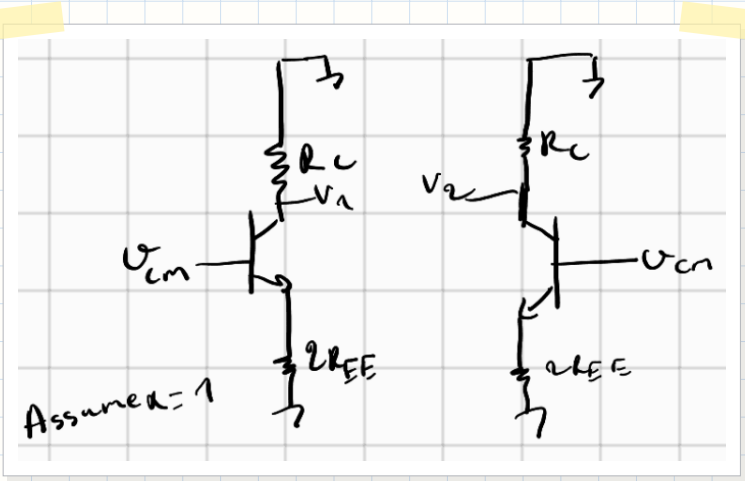


orijinal çizim, s. 4

Ac mode



orijinal çizim, s. 4



orijinal çizim, s. 4

$$A_{cm,single} = \frac{v_1}{v_{cm}} \simeq \frac{-R_C}{2R_{EE} + r_e} = \frac{-R_C}{2R_{EE}}$$

$$\frac{v_2}{v_{cm}} = \frac{-R_C}{2R_{EE} + r_e} \simeq \frac{-R_C}{2R_{EE}}$$

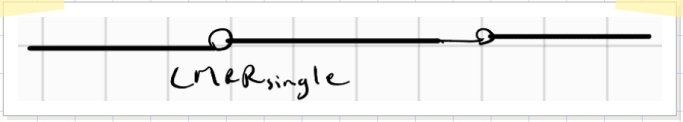
$$A_{cm,diff} = \frac{v_1 - v_2}{v_{cm}} = 0$$

orj. s. 5

CMRR diff

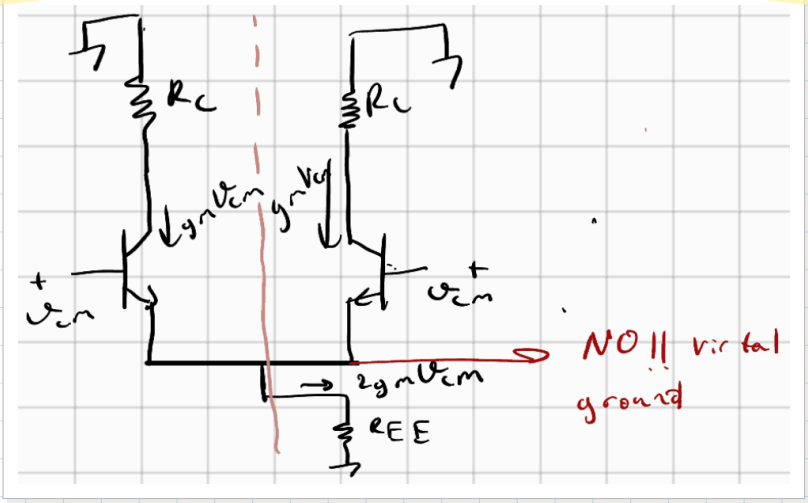
$$CMRR = \frac{A_{diff}}{A_{cm\,diff}}$$

$$CMRR = \frac{g_m R_C}{0} = \infty$$



orijinal çizim, s. 5

$$\left|\frac{A_{d\,single}}{A_{cm\,single}}\right| = \left|\frac{\frac{1}{2} g_m R_C}{\frac{R_C}{2R_{EE}}}\right| = g_m R_{EE}$$



orijinal çizim, s. 5

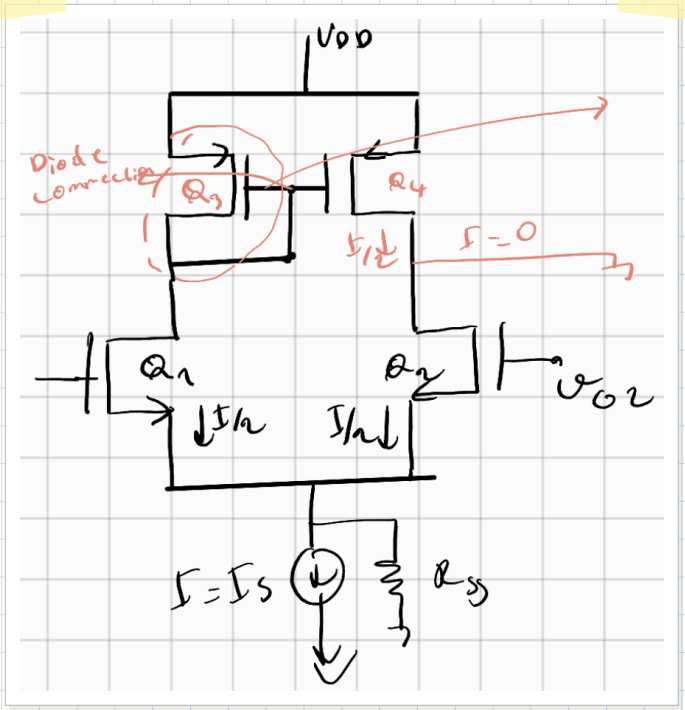
$$R_{icm} = ?$$

$$(\beta + 1)\left(R_{EE} + \frac{r_e}{2}\right)$$

$$= (\beta + 1)(R_{EE})$$

orj. s. 6

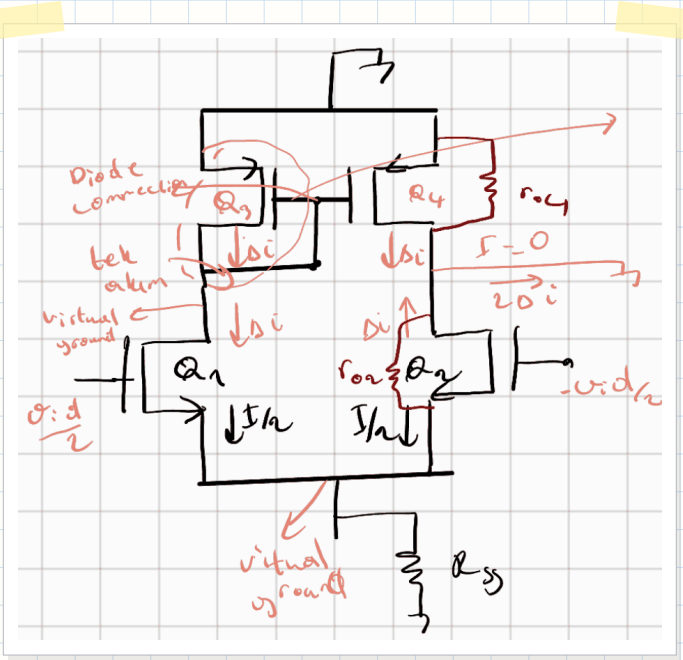
Active-Loaded CMOS differential Amplifier



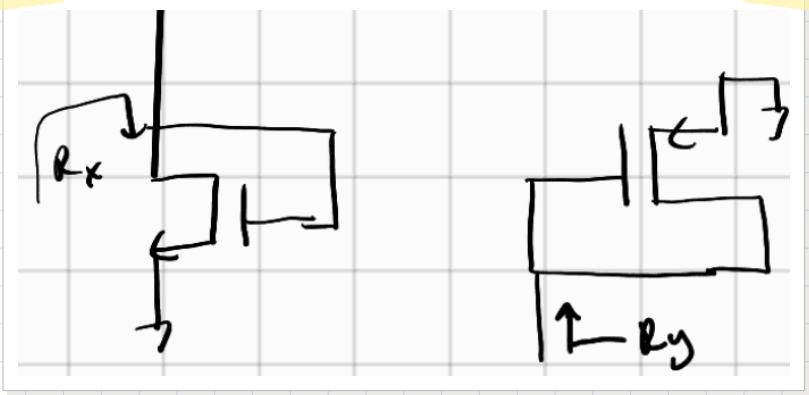
orijinal çizim, s. 6



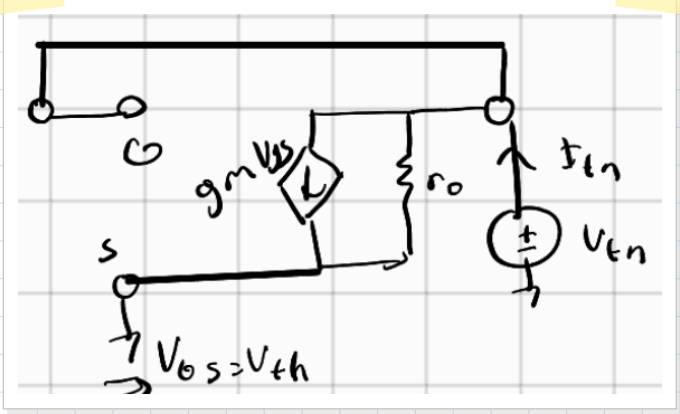
orijinal çizim, s. 6



orijinal çizim, s. 6



orijinal çizim, s. 6



orijinal çizim, s. 6

$$I_{th} = g_m v_{gs} + \frac{v_{gs}}{r_o}$$

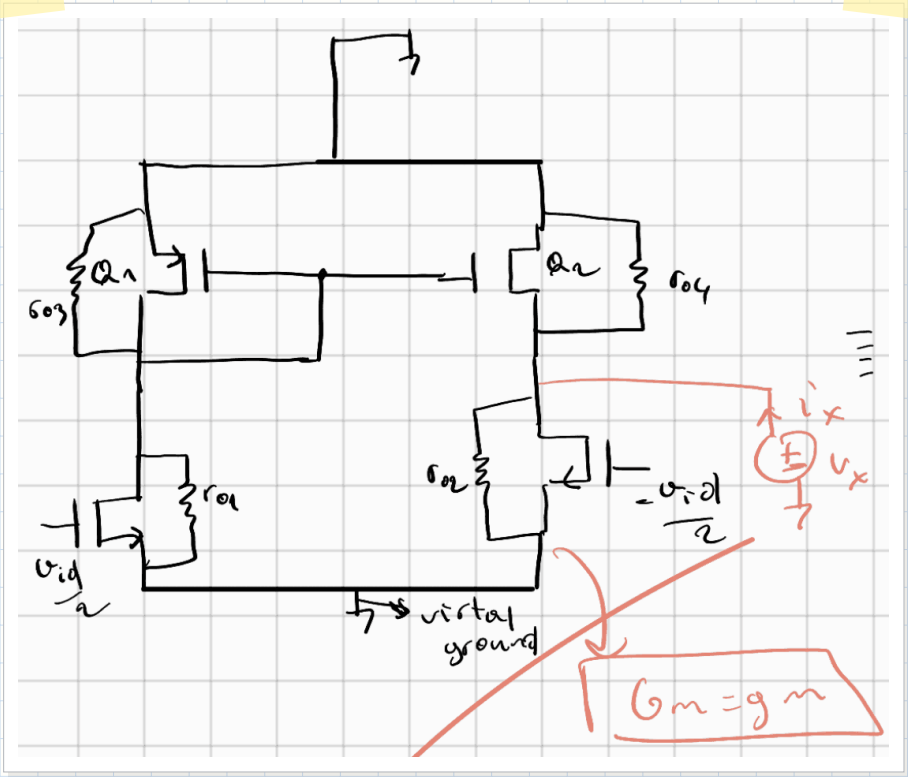
$$\frac{V_{th}}{I_{th}} = \frac{1}{g_m + 1/r_o}$$

$$= 1/g_m$$

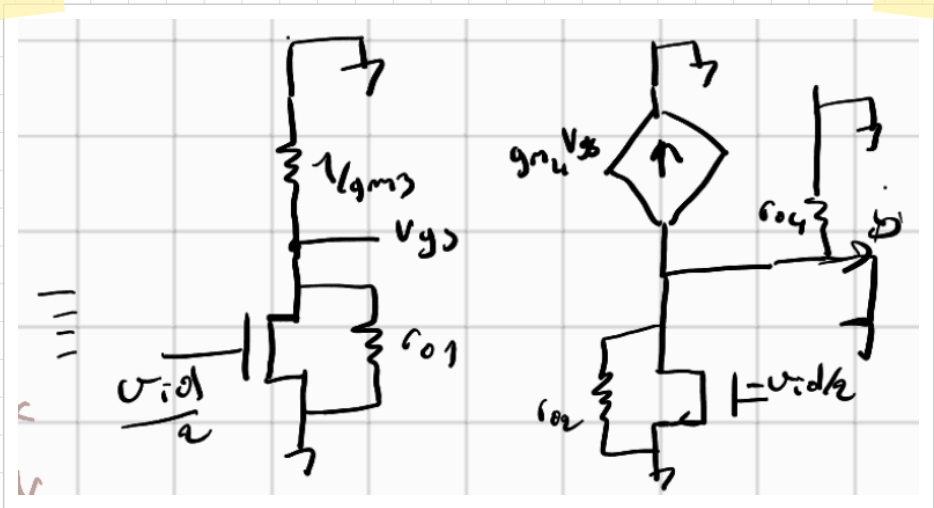
(Single-ended)

Sadece sağ taraftan çıkış alabiliriz. Peki neden böyle bir şeye ihtiyaç duyuyoruz? Diğer devremiz sadece tek giriş alıyor. ? *Ona iletiyoruz.*

orj. s. 7



orijinal çizim, s. 7



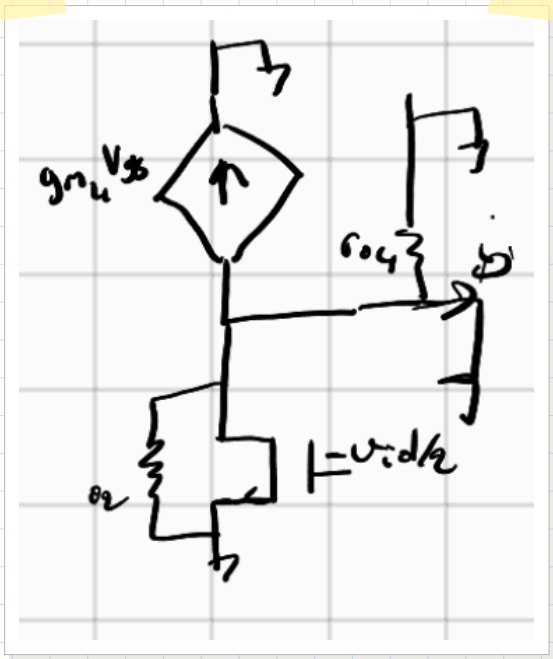
orijinal çizim, s. 7

$$V_{g3} = -g_{m1}\frac{v_{id}}{2}\,(1/g_{m3} \parallel r_{o3})$$
$$\simeq -\frac{g_{m1}}{g_{m3}}\frac{v_{id}}{2}$$

$$i_o = g_{m4} v_{g3} + g_{m2}\frac{v_{id}}{2}$$

$$i_o = \frac{g_{m4}\, g_{m1}}{g_{m3}}\frac{v_{id}}{2} + g_m \frac{v_{id}}{2}$$
$$= g_m v_{id}$$

$g_{m1} = g_{m2},\ g_{m3} = g_{m4}$ $\qquad = g_{m1,2}\, v_{id}$



orijinal çizim, s. 7

$$\frac{v_x}{i_x} = R_o \simeq (r_{o2} \parallel r_{o4})$$

$$\frac{v_{out}}{v_{id}} = g_m (r_{o2} \parallel r_{o4})$$

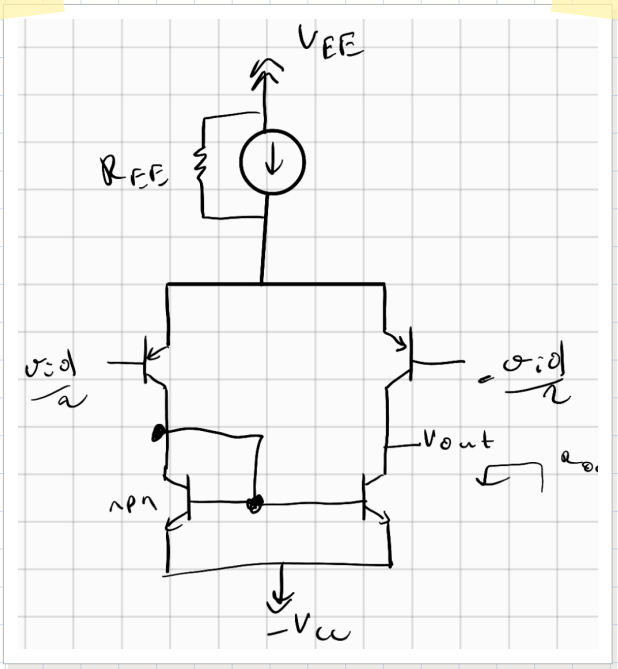
$$r_{o2} = r_{o4} = r_o$$

$$\Rightarrow \quad = \frac{1}{2} g_m r_o$$

$$A_{cm} \simeq -\frac{1}{2 g_{m3} R_{ss}}$$

$$CMRR = (g_m r_o)\, g_m R_{ss}$$

orj. s. 8



orijinal çizim, s. 8

p tipinin daha az noise var

$$G_m = g_{m1} = g_{m2} = g_m$$

$$R_{out} = r_{o2} \parallel r_{o4}$$

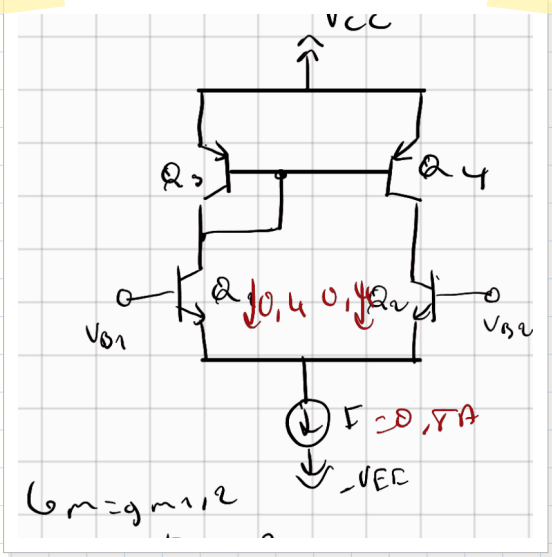
$$\frac{v_{out}}{v_{id}} = g_m (r_{o2} \parallel r_{o4})$$

$$r_{o2} = r_{o4} = r_o$$

$$\frac{v_{out}}{v_{id}} = \frac{1}{2} g_m r_o$$

$$A_{cm} = \frac{-r_{o4}}{\beta_3 R_{EE}}$$

$$CMRR = \frac{1}{2} \beta_3\, g_m R_{EE}$$



orijinal çizim, s. 8

Consider BJT diff amp $I = 0{,}8\,mA$ $V_A = 100\,V$, $\beta = 160$. Find G_m, R_o, A_d and R_{iod}. Find R_{EE}, A_{cm} and CMRR when the current source is implemented by a single npn current mirror

$$\left[A_{cm} = \frac{-r_{o4}}{\beta_3 R_{EE}}\right]$$

$$g_m = \frac{I_C}{V_T} = ? \qquad V_T \rightarrow 25\,mV$$

$$g_{m1,2} = \frac{0{,}4\,mA}{25\,mV} = 16\,m\Omega^{-1}$$

orj. s. 9

$$R_o = r_{o2} \parallel r_{o4}$$

$$= \frac{V_A}{I_C} \parallel \frac{V_A}{I_C} = \frac{1}{2}\frac{100}{0{,}4} = 125\,k\Omega$$

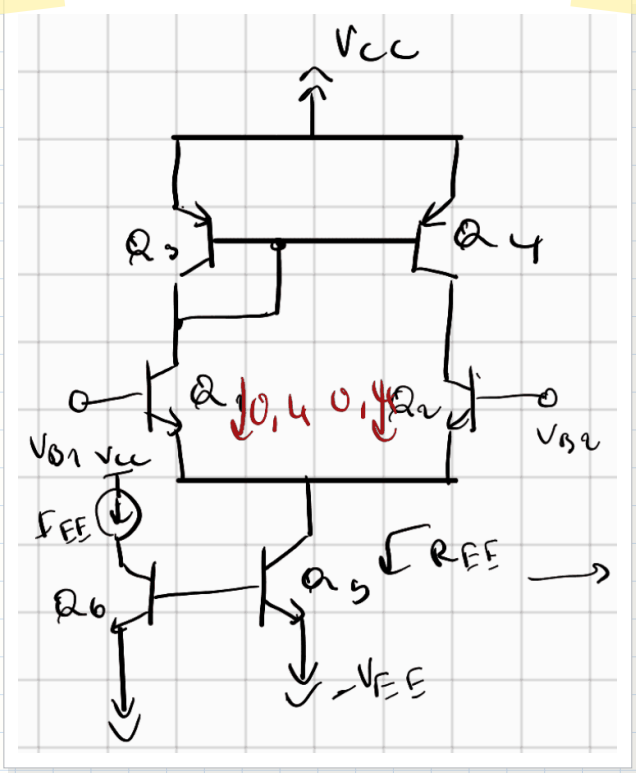
$$A_d = G_m R_o = 16\,m\Omega^{-1} \times 125\,k\Omega$$

$$A_d = 2000\ [V/V]$$

$$R_{id} = 2(\beta + 1)(r_e) \longrightarrow = \frac{1}{g_m}$$

$$= 2 \times 160 \times 62{,}5$$

$$\boxed{R_{id} = 20\,k\Omega}$$



orijinal çizim, s. 9

$$R_{EE} = r_{o5} = \frac{100}{0{,}8} = 125\,k\Omega$$

$$|A_{cm}| = \frac{250\,k}{160 \cdot 125\,k\Omega} = \frac{1}{80}$$

$$CMRR = \frac{A_d}{A_{cm}} = \frac{2000}{\frac{1}{80}} = 160\,000$$

$$= 20 \log 160\,000$$

$$= 104{,}08\ dB$$