GTU
Electronics Engineering

ELEC 331
Electronic Circuits 2

Fall Semester

Instructor: Assist. Prof. Önder Şuvak

HW 2
Questions and Answers

Updated October 20, 2017 - 13:37

Assigned:

Due:

Answers Out:

Late Due:

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BJT Differential Amplifier Design **Razavi 10.31**

31. The circuit of Fig. 10.68 must provide a gain of 50 with $R_1 = R_2 = 5\ \mathrm{k}\Omega$. If $V_{A,n} = 5$ V and $V_{A,p} = 4$ V, calculate the required tail current.

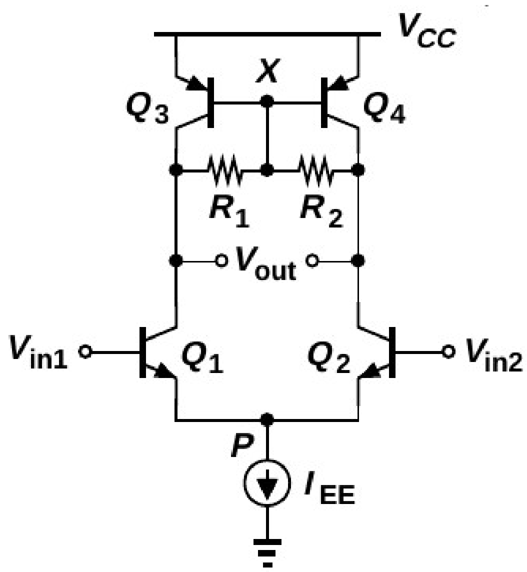
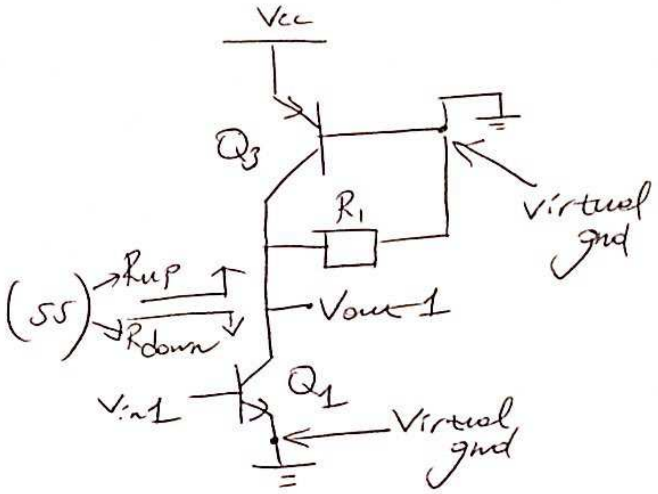


Figure 10.68

Necessary Knowledge and Skills: BJT small signal analysis, differential mode half circuit analysis, output impedance calculation, voltage gain calculation, parameter selection for design specification

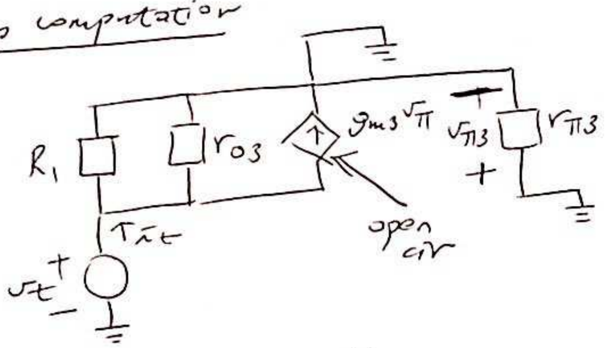
Razavi 10.31

Differential mode half cir



$R_{down} = r_{o1}$

Rup computation



$v_{\pi 3} = 0$

$$R_{up} = \frac{v_t}{i_t} = R_1 // r_{o3}$$

then $\dfrac{v_{out1}}{v_{in1}} = -g_{m1}\left[R_1 // r_{o3} // r_{o1}\right]$

(common emitter config.)

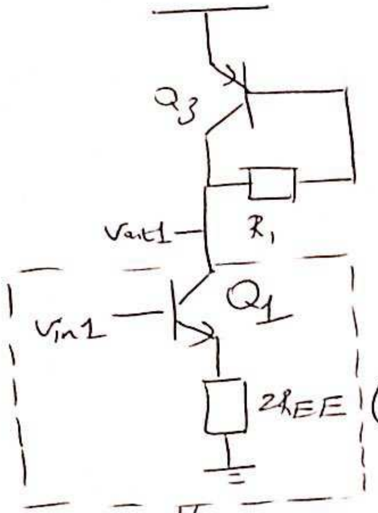
similarly (with $v_{in2} = -v_{in1}$) $\dfrac{v_{out2}}{v_{in2}}$ = the same

and $\dfrac{v_{out}}{v_{in1} - v_{in2}} = \dfrac{v_{out1} - v_{out2}}{v_{in1} - v_{in2}} = -g_{m1}\left[R_1 // r_{o3} // r_{o1}\right]$

(1)

Razavi 10.31 continued

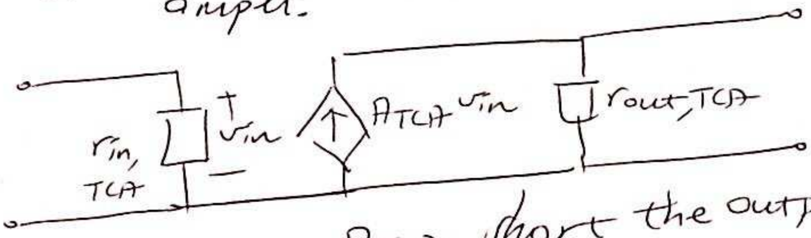
Common mode half cir.



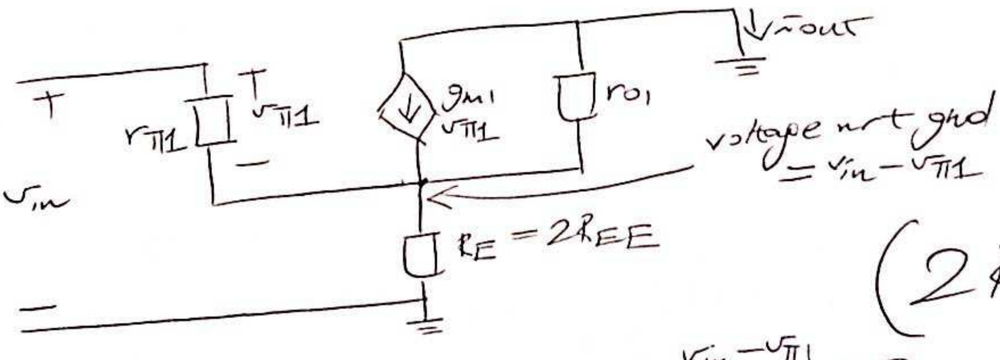
(if the output impedance of the current source is taken to be R_{EE})

⇓

model as a transconductance ampli.



to compute A_{TCA}, short the output, compute $\frac{i_{out}}{v_{in}}$.



(2 KCLs)

$$\frac{v_{in}-v_{\pi1}-v_{in}}{r_{\pi1}}+\frac{v_{in}-v_{\pi1}}{R_E}-g_{m1}v_{\pi1}+\frac{v_{in}-v_{\pi1}}{r_{o1}}=0$$

$$i_{out}-\frac{v_{in}-v_{\pi1}}{r_{o1}}+g_{m1}v_{\pi1}=0$$

2

Razavi 10.31 continued

(Assume r_{π}, r_o big)

$$\frac{v_{in}}{R_E // r_{o1}} = \frac{v_{\pi 1}}{r_{\pi} // R_E // \frac{1}{g_{m1}} // r_{o1}}$$

$$i_{out} + \frac{v_{\pi 1}}{r_{o1} // \frac{1}{g_{m1}}} = \frac{v_{in}}{r_{o1}}$$

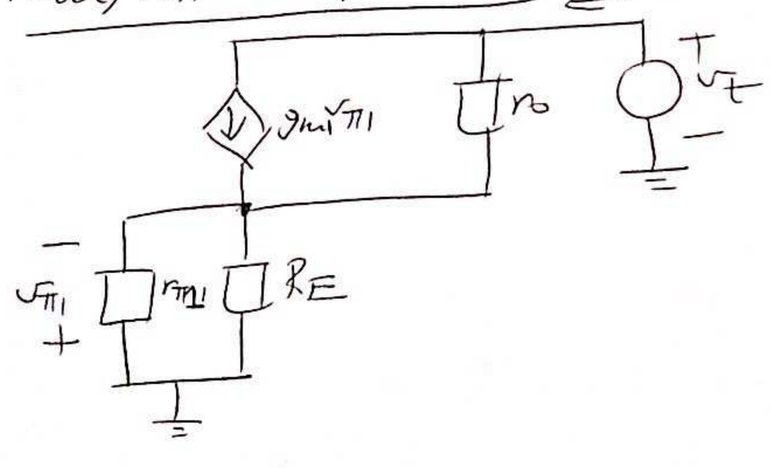
$$v_{in} \frac{1/g_{m1} // R_E}{R_E} = v_{\pi 1}$$

$$i_{out} + \frac{v_{\pi 1}}{1/g_{m1}} = 0$$

$$i_{out} + v_{in} \frac{\frac{\cancel{1/g_{m1} R_E}}{1/g_{m1} + R_E}}{\cancel{1/g_{m1} R_E}} = 0$$

then $$A_{TCA} = \frac{i_{out}}{v_{in}} = -\frac{g_{m1}}{1 + g_{m1} R_E}$$

r_{out}, TCA computation



3

(KVL)

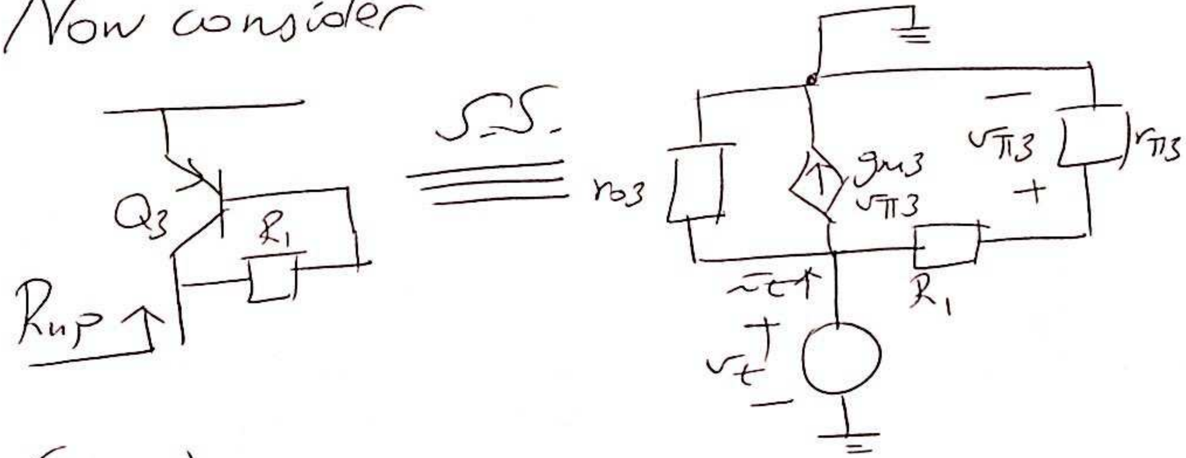
Razavi
10.31
continued

$$(i_t - g_{m1} v_{\pi 1}) r_{o1} + \underbrace{i_t (r_{\pi 1} // R_E)}_{-v_\pi} = v_t$$

$$i_t \left[r_{o1}\left(1 + g_{m1}(r_{\pi 1} // R_E)\right) + (r_{\pi 1} // R_E) \right] = v_t$$

$$\frac{v_t}{i_t} \cong r_{o1}(1 + g_{m1} R_E) = r_{out,\,TCA}$$

Now consider



(KCL) $$-i_t + \frac{v_t}{r_{o3}} + g_{m3} v_{\pi 3} + \frac{v_t}{R_1 + r_{\pi 3}} = 0$$

$$v_{\pi 3} = v_t \frac{r_{\pi 3}}{R_1 + r_{\pi 3}}$$

4

Razavi 10.31 continued

$$-i_t + \frac{v_t}{r_{o3} \parallel \frac{R_1 + r_{\pi 3}}{1+\beta_3}} = 0$$

$$R_{up} = \frac{v_t}{i_t} = r_{o3} \parallel \frac{R_1 + r_{\pi 3}}{1+\beta_3}$$

(since $\beta_3 = g_{m3} r_{\pi 3}$)

$$\frac{v_{out1}}{v_{in1}} = A_{TCA}\left[r_{out,TCA} \parallel R_{up}\right]$$

for common mode

$$\text{Common mode gain} \simeq -\underbrace{\frac{g_{m1}}{1+g_{m1}2R_{EE}}}_{\text{lesser than } g_{m1}}\left[\overbrace{r_{o1}\left(1+g_{m1}2R_{EE}\right)}^{\text{bigger than } r_{o1}\text{, big}} \parallel \left(\underbrace{r_{o3}}_{\text{big}} \parallel \underbrace{\frac{R_1 + r_{\pi 3}}{1+\beta_3}}_{\text{may be very small if } R_1 \text{ is small}}\right)\right]$$

$$CMRR = \frac{\text{Diff mode gain}}{\text{Common mode gain}}$$

5

Razavi
10.31
continued

$$|CMRR| \simeq \frac{g_{m1}\left(\overset{\text{maybe small}}{R_1} \,//\, \overset{\text{big}}{r_{o3}} \,//\, \overset{\text{big}}{r_{o4}}\right)}{\dfrac{g_{m1}}{1+g_{m1}2R_{EE}} \; \dfrac{R_1+r_{\pi 3}}{1+\beta_3}}$$

$$\simeq \left(1+g_{m1}2R_{EE}\right)\frac{R_1(1+\beta_3)}{R_1+r_{\pi 3}}$$

6

Razavi 10.31 continued

Design question

$$I_{C,Q1} = I_{C,Q2} = I_{C,Q3} = I_{C,Q4} \cong \frac{I_{EE}}{2}$$

if the base currents of Q_3 and Q_4 are negligible.

$$g_{m1} = \frac{I_{C,Q1}}{V_T} = \frac{I_{EE}}{2V_T}$$

V_T = 26mV

$$R_1 = 5k\Omega$$

$$r_{o3} = \frac{V_{A,p}}{I_{C,Q3}} = \frac{4V}{I_{EE}/2} = \frac{8}{I_{EE}}$$

$$r_{o1} = \frac{V_{A,n}}{I_{C,Q1}} = \frac{5V}{I_{EE}/2} = \frac{10}{I_{EE}}$$

$$|Gain| = g_{m1}\left[R_1 // r_{o3} // r_{o1}\right]$$

$$= \frac{I_{EE}}{2V_T}\left[5k // \frac{8}{I_{EE}} // \frac{10}{I_{EE}}\right] = 50$$

design spec

calculate IEE!

(7)

MOS Amplifier **Razavi 10.51**

51. A student who has a single-ended voltage source constructs the circuit shown in Fig. 10.75, hoping to obtain differential outputs. Assume perfect symmetry but $\lambda = 0$ for simplicity.

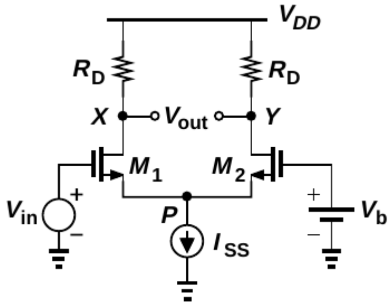


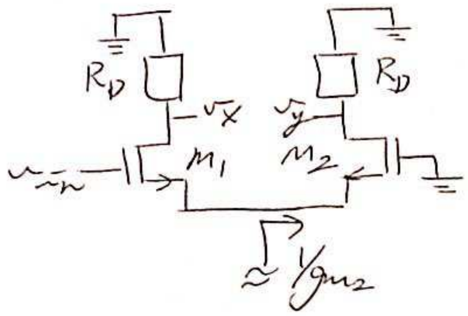
Figure 10.75

(a) Viewing M_1 as a common-source stage degenerated by the impedance seen at the source of M_2, calculate v_X in terms of v_{in}.
(b) Viewing M_1 as a source follower and M_2 as a common-gate stage, calculate v_Y in terms of v_{in}.
(c) Add the results obtained in (a) and (b) with proper polarities. If the voltage gain is defined as $(v_X - v_Y)/v_{in}$, how does it compare with the gain of differentially-driven pairs?

Necessary Knowledge and Skills: Common source/gate amplifiers, small signal equivalent MOS, differential pair gain and other calculations, performance comparisons

Razavi
10.51

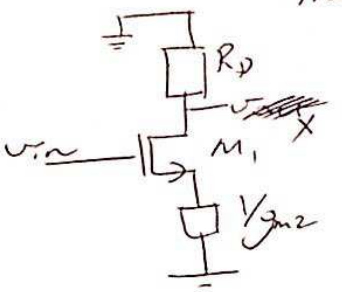
small signal equiv of the cir



(Need to replace M_1 and M_2 by their small signal equivalent cir)

a)

Calculate $\frac{v_X}{v_{in}}$



(See TCA related computations)

$$\frac{v_X}{v_{in}} = -g_{m1} \frac{1}{1 + g_{m1}\frac{1}{g_{m2}}} \left[R_D \,//\, r_{out,TCA} \right]$$

(Source degenerated common source amplifier)

where $r_{out,TCA} = (1 + g_{m1} r_{o1}) \frac{1}{g_{m2}} + r_{o1}$

since $\lambda = 0 \Rightarrow r_{o1} = +\infty$

$\Rightarrow$ We have, for perfectly symmetric diff-amp,

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

then $= \frac{v_X}{v_{in}} = -\frac{g_m}{2} R_D$

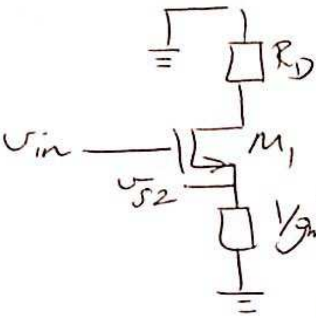
1

Razavi 10.51 continued

Calculate $\frac{v_y}{v_{in}}$

Analyze a cascade of amplifiers

Source follower (common drain) + Common gate

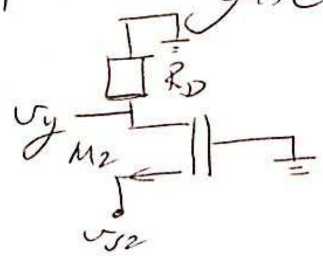


$1/g_{m2} = \frac{1}{g_m}$

$$\frac{v_{S2}}{v_{in}} = \frac{1/g_{m2}}{1/g_{m2} + \frac{1}{g_{m1}}}$$

$$= \frac{1/g_m}{1/g_m + 1/g_m} = \frac{1}{2}$$

(see source follower related derivations)



$$\frac{v_y}{v_{S2}} \simeq g_{m2} R_D$$

(see common-gate related deriv.)

$$\frac{v_y}{v_{S2}} \simeq g_m R_D$$

$g_m = g_{m2}$

$$\text{overall} \Rightarrow \frac{v_y}{v_{in}} = \frac{g_m R_D}{2}$$

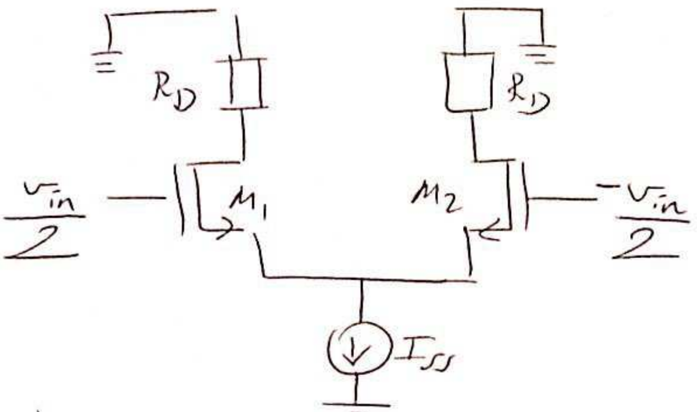
$$\frac{v_{out}}{v_{in}} = \frac{v_X - v_y}{v_{in}} = \frac{\left(-\frac{g_m R_D}{2} - \frac{g_m R_D}{2}\right) v_{in}}{v_{in}}$$

$$= -g_m R_D$$

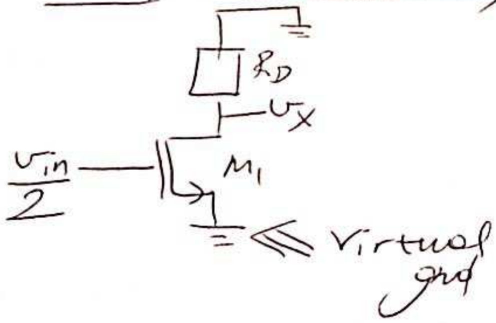
(2)

Razavi 10.51 continued

With diff. driven pairs (on the other hand)



half cir (diff mode)



$$v_X = \left(\frac{v_{in}}{2}\right)\left[\underbrace{-g_{m1}}_{g_m}\left(R_D // \underbrace{r_{o1}}_{+\infty\ (\lambda=0)}\right)\right]$$

$$= -g_m R_D \frac{v_{in}}{2}$$

similarly

$$v_y = \left(-\frac{v_{in}}{2}\right)\left[\underbrace{-g_{m2}}_{g_m}\left(R_D // \underbrace{r_{o2}}_{+\infty}\right)\right]$$

$$= g_m R_D \frac{v_{in}}{2}$$

Then

$$\frac{v_X - v_y}{v_{in}} = \frac{-g_m R_D \frac{\cancel{v_{in}}}{2} - g_m R_D \frac{\cancel{v_{in}}}{2}}{\cancel{v_{in}}}$$

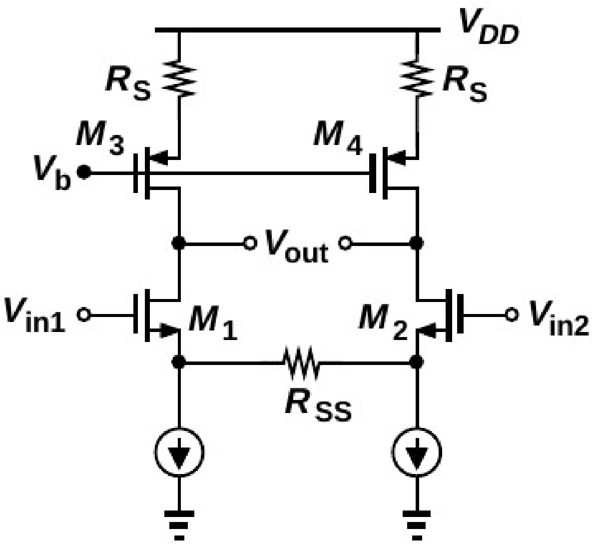
$$= -g_m R_D$$

We get the same result!

3

MOS Differential Pair **Razavi 10.53 c**

53. Calculate the differential voltage gain of the circuits depicted in Fig. 10.77. Assume perfect symmetry and $\lambda > 0$. You may need to compute the gain as $A_v = -G_m R_{out}$ in some cases.

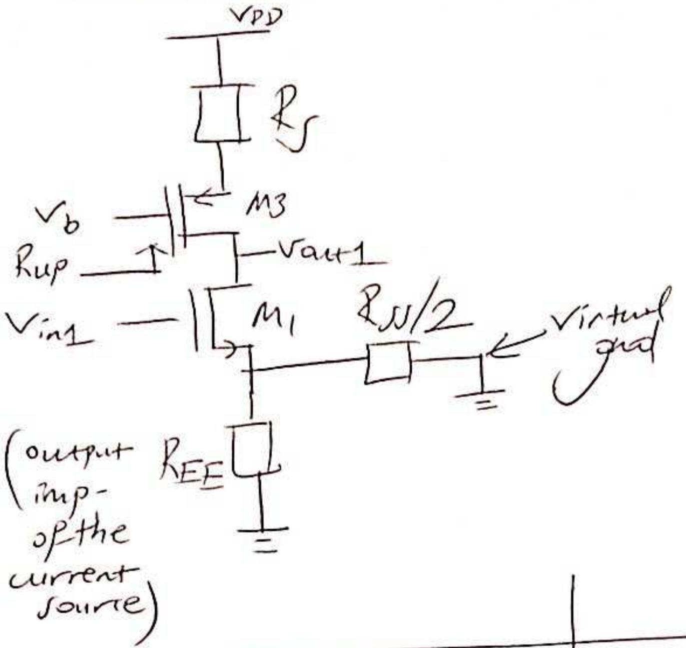


(c)

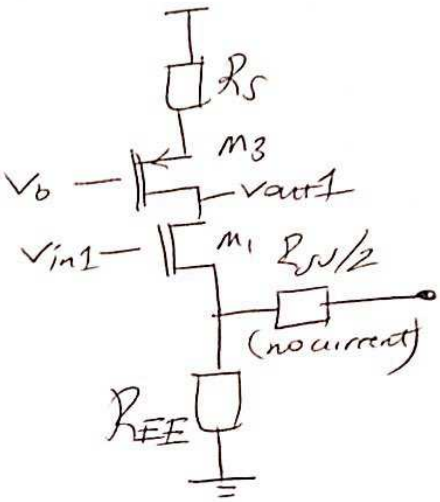
Necessary Knowledge and Skills: MOS small signal analysis, output impedance calculation, common/differential mode half circuits, cascode structure, virtual ground in differential mode, voltage gain computation

Razavi 10.53

Diff-mode half cir.



Common mode half cir.



Diff. mode analysis	Common mode analysis
see TCA (transconductance ampl. analysis) in other answers and lecture notes →	needed here as well
see cascode output impedance comput. in other answers →	needed here

Diff. mode analysis

$$\overset{\circ\!-\!\circ}{A_{TCA,d}} = -\frac{g_{m1}}{1+g_{m1}R_{E,d}}$$

$$R_{E,d} = R_{EE} // \frac{R_{SS}}{2}$$

$$r_{out,TCA,d} = r_{o1}(1+g_{m1}R_{E,d})$$

$$R_{up} = (1+g_{m3}r_{o3})R_S + r_{o3} \Longrightarrow \text{the same}$$

Common mode analysis

$$\overset{\circ\!-\!\circ}{A_{TCA,c}} = -\frac{g_{m1}}{1+g_{m1}R_{E,c}}$$

$$R_{E,c} = R_{EE}$$

$$r_{out,TCA,c} = r_{o1}(1+g_{m1}R_{E,c})$$

Razavi
10.53
continued

Diff. mode

$$\frac{v_{out1}}{v_{in1}} = A_{TCA,d}\left[r_{out,TCA,d} \,//\, R_{up}\right]$$

Common mode

$$\frac{v_{out,1}}{v_{in1}} = A_{TCA,c}\left(r_{out,TCA,c} \,//\, R_{up}\right)$$

if $\frac{R_{SS}}{2} \ll R_{EE}$ (desired) $(*)$

$$|CMRR| = \frac{\text{Diff mode gain}}{\text{common mode gain}} = \frac{\frac{g_{m1}}{1+g_{m1}\left(R_{EE} \,//\, \frac{R_S}{2}\right)}}{\frac{g_{m1}}{1+g_{m1}R_{EE}}} \cdot \frac{r_{out,TCA,d} \,//\, R_{up}}{r_{out,TCA,c} \,//\, R_{up}}$$

$\approx \frac{R_{SS}}{2}$

could be comparable

altogether

$$\frac{1+g_{m1}R_{EE}}{1+g_{m1}\frac{R_S}{2}} \gg 1$$

this ratio is smaller than 1

$(r_{out,TCA,d} < r_{out,TCA,c})$

see $(*)$

(2)

BJT Differential Amplifier with Parasitics **Razavi 10.55**

55. Due to a manufacturing error, a parasitic resistance, R_P, has appeared in the circuit of Fig. 10.78. Calculate the voltage gain.

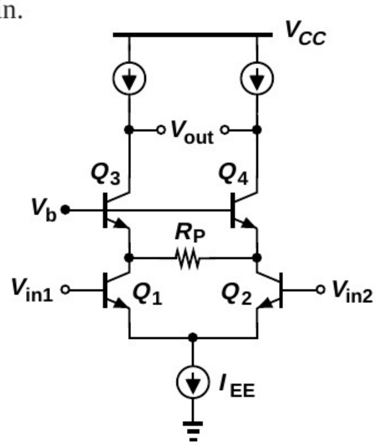
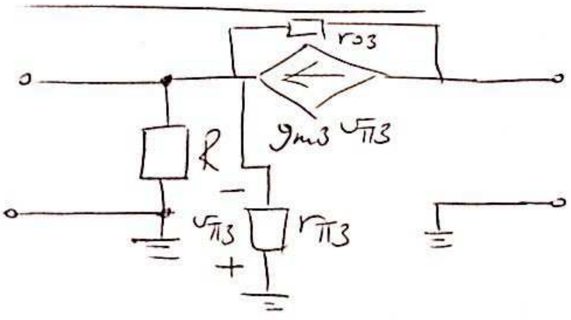


Figure 10.78

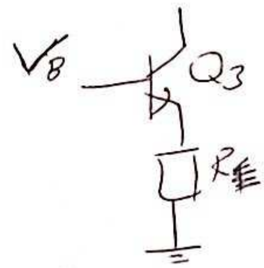
Necessary Knowledge and Skills: BJT small signal analysis, differential mode half circuit analysis, voltage gain computation, virtual ground in differential mode

Razavi 10.55

Study the common base amplf as a ~~transconductance~~ current amplifier



in large signal



$r_{in,CA}$ computation (connect v_t at the input, short the output)

$$-i_t + \frac{v_t}{R} + \frac{v_t}{r_{\pi 3}} + \frac{v_t}{r_{o3}} - g_{m3} v_{\pi 3} = 0$$

$$v_t = -v_{\pi 3}$$

$$\frac{v_t}{i_t} = r_{in,CA} = R // r_{\pi 3} // r_{o3} // \frac{1}{g_{m3}}$$

$$\simeq R // \frac{1}{g_{m3}} \quad \left(\text{if } r_{\pi 3}, r_{o3} \text{ are very big}\right)$$

$$r_{out,CA} = \left(1 + g_{m3} r_{o3}\right)\left(r_{\pi 3} // R\right) + r_{o3}$$

(see other answers and lecture notes for the derivation

1

A_{CA} computation (connect i_{in} at the input, short the output)

Razavi 10.55 continued

$$-i_{in} + \frac{v_{in}}{R} + \frac{v_{in}}{r_{\pi 3}} - g_{m3} v_{\pi 3} + \frac{v_{in}}{r_{o3}} = 0$$

$$i_{out} + g_{m3} v_{\pi 3} - \frac{v_{in}}{r_{o3}} = 0$$

$$v_{\pi 3} = -v_{in}$$

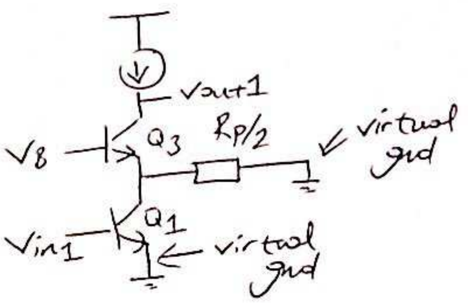
$$\frac{v_{in}}{R // r_{\pi 3} // r_{o3} // \frac{1}{g_{m3}}} = i_{in}$$

$$i_{out} = \frac{v_{in}}{1/g_{m3} // r_{o3}}$$

(if $r_{\pi 3}$ and r_{o3} are very big)

$$A_{CA} = \frac{i_{out}}{i_{in}} \simeq \frac{R // \frac{1}{g_{m3}}}{1/g_{m3}} = \frac{R \cdot \frac{1}{g_{m3}}}{R + \frac{1}{g_{m3}}} \cdot g_{m3} = \frac{g_{m3} R}{1 + g_{m3} R} < 1$$

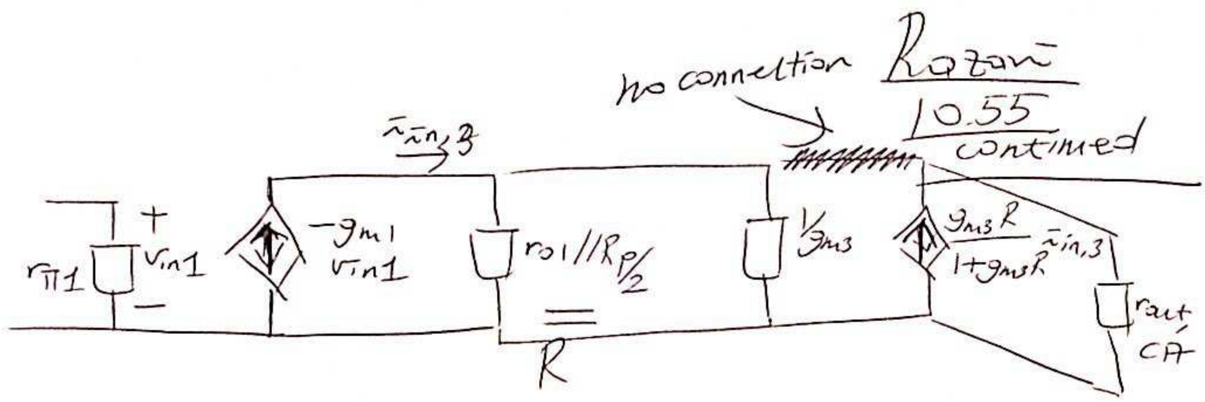
Differential mode half cir



transconductance of Q_1 $\Rightarrow -g_{m1}$

$$R\left(\text{as in the deriv. above}\right) = r_{o1} // \frac{R_P}{2}$$

2



Transconductance of the whole ampl. (cascaded TCA and CA)

$$G = -g_{m1} \frac{g_{m3} R}{1+g_{m3} R}$$

$$R_{out} = r_{out, CA}$$

then voltage gain of diff mode $= \frac{v_{out,1}}{v_{in1}} = G R_{out}$

$$= -g_{m1} \underbrace{\frac{g_{m3}\left[r_{o1} // \frac{R_P}{2}\right]}{1+g_{m3}\left[r_{o1} // \frac{R_P}{2}\right]}} \left[(1+g_{m3} r_{o3})\left(r_{\pi 3} // r_{o1} // \frac{R_P}{2}\right) + r_{o3}\right]$$

smaller than would be if $R_P = +\infty$ it were that

can replace with $\frac{R_P}{2}$ with $\frac{R_P}{2} \ll r_{o1}$

note that $\frac{R_P}{2} \ll r_{o1}$ and in any case the whole expr $< \frac{g_{m3} r_{o1}}{1+g_{m3} r_{o1}}$

3

MOS Diff. Amp. (Mismatch) **Sedra 7.14**

7.14 A design error has resulted in a gross mismatch in the circuit of Fig. P7.14. Specifically, Q_2 has twice the W/L ratio of Q_1. If v_{id} is a small sine-wave signal, find:

(a) I_{D1} and I_{D2}.
(b) V_{OV} for each of Q_1 and Q_2.
(c) The differential gain A_d in terms of R_D, I, and V_{OV}.

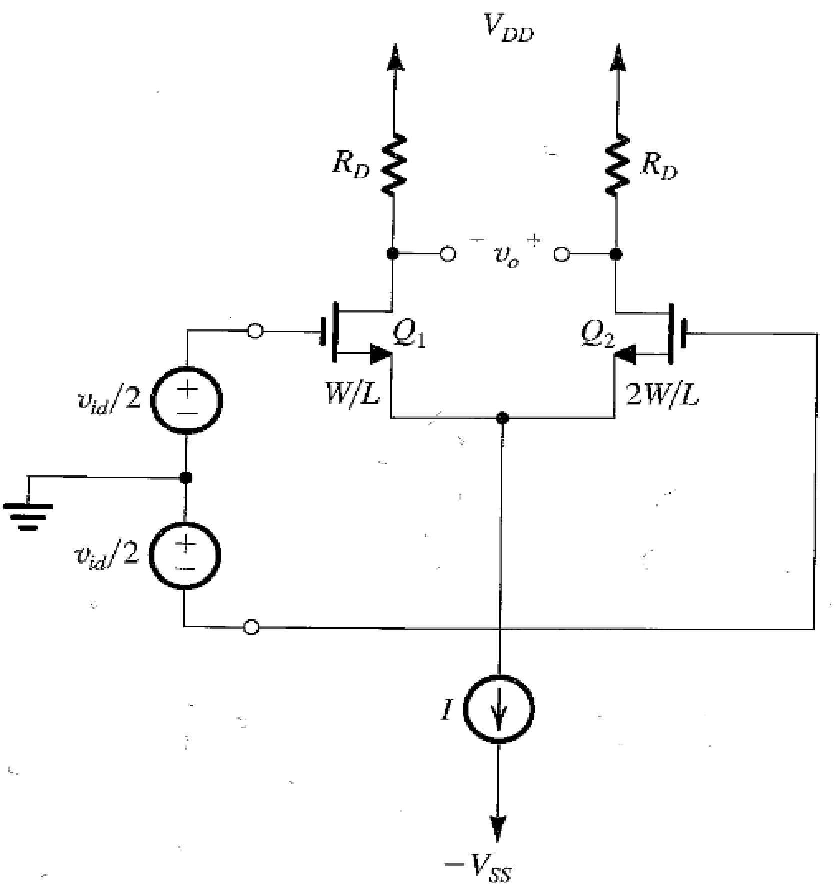


FIGURE P7.14

Necessary Knowledge and Skills: MOS differential, transistor mismatch, differential gain computation

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_t)^2$$

Sedra 7.14

in DC $\Rightarrow V_{G1}=V_{G2}=0V$

$V_{S1}-V_{S2}=V_S$ (common)

$$I = I_{D1}+I_{D2}$$

$$= \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(0-V_S-V_t)^2$$

$$+\frac{1}{2}\mu_n C_{ox}\frac{2W}{L}(0-V_S-V_t)^2$$

$$= \frac{3}{2}\mu_n C_{ox}\frac{W}{L}(-V_S-V_t)^2$$

$$\Longrightarrow I_{D1} = \frac{I}{3} \quad I_{D2} = \frac{2I}{3}$$

$$\left.\begin{aligned} V_{ov1} &= V_{GS,1}-V_t \\ V_{ov2} &= V_{GS,2}-V_t \end{aligned}\right\} V_{ov} = \sqrt{\frac{2I}{3\mu_n C_{ox}\frac{W}{L}}}$$

(the same)

formula for $g_m = \frac{2I_D}{V_{ov}}$

$$g_{m1} = \frac{2I}{3\sqrt{\frac{2I}{3\mu_n C_{ox}\frac{W}{L}}}} \qquad g_{m2} = \frac{2\cdot 2I}{3\sqrt{\frac{2I}{3\mu_n C_{ox}\frac{W}{L}}}}$$

$$= \frac{2I}{3V_{ov}} \qquad\qquad = \frac{4I}{3V_{ov}}$$

1

Note that virtual gnd in transistor mismatch is questionable ⇒ needs further analysis

Sedra 7.14 cont.

Accept for now that virt. gnd exists.

$$\left.\begin{aligned} v_{o1} &= -g_{m1} \frac{v_d}{2} R_D \\ v_{o2} &= g_{m2}\left(-\frac{v_d}{2}\right) R_D \end{aligned}\right\}$$

$$\frac{v_{o2}-v_{o1}}{\underbrace{v_d}_{\frac{v_d}{2}-\left(-\frac{v_d}{2}\right)}} = \frac{1}{v_d}\left[\frac{4I}{3V_{ov}}\frac{1}{2}v_d R_D - \left(-\frac{2I}{3V_{ov}}\frac{1}{2}v_d R_D\right)\right]$$

$$= \frac{1}{\cancel{v_d}}\frac{1}{\cancel{2}}\cancel{v_d} R_D \frac{I}{V_{ov}}\cancel{\left(\frac{4}{3}+\frac{2}{3}\right)}$$

$$\text{Diff mode gain} = \frac{I R_D}{V_{ov}}$$

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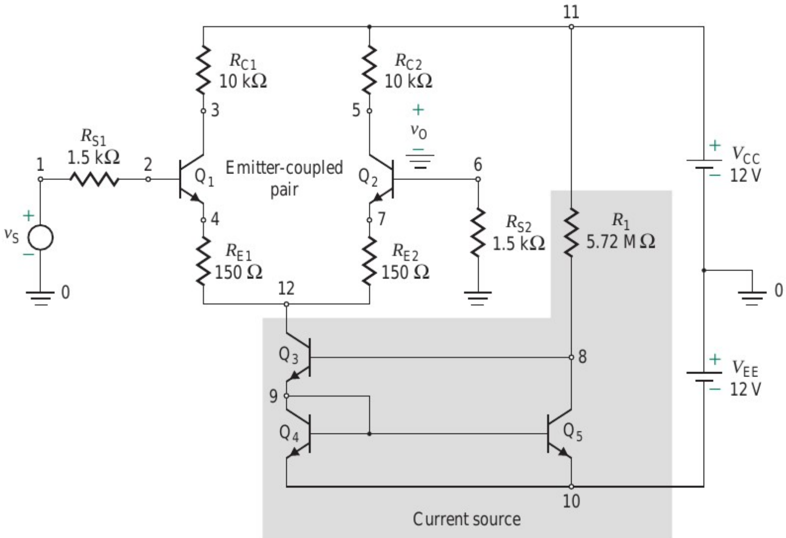
2

BJT Differential Amp. With Current Source **Rashid 9.39**

9.39 A differential amplifier is shown in Fig. P9.39. The transistors are identical. Assume $V_{BE} = 0.7$ V, $V_T = 26$ mV, $\beta_F = 50$, and $V_A = 40$ V. Calculate the values of A_d, R_{id}, A_c, R_{ic}, and CMRR.

FIGURE P9.39



Necessary Knowledge and Skills: Current source output current and impedance computation, BJT differential pair, BJT small signal analysis, common/differential mode half circuit analysis, voltage gain computations in common/differential modes, CMRR calculation

Rashid 9.39

Calculate the tail current

$V_{11} = 12\,V$

$V_{10} = -12\,V$

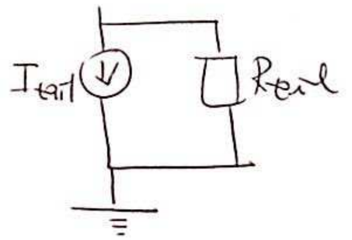
$V_8 = -V_{10} + V_{BE4} + V_{BE3}$

$= -12 + 0.7 + 0.7$

$= -10.6\,V$

$$\frac{V_{11} - V_8}{R_1 = 5.72\,M\Omega} = I_{ref} \approx I_{tail}$$

The current can as usual be modeled as



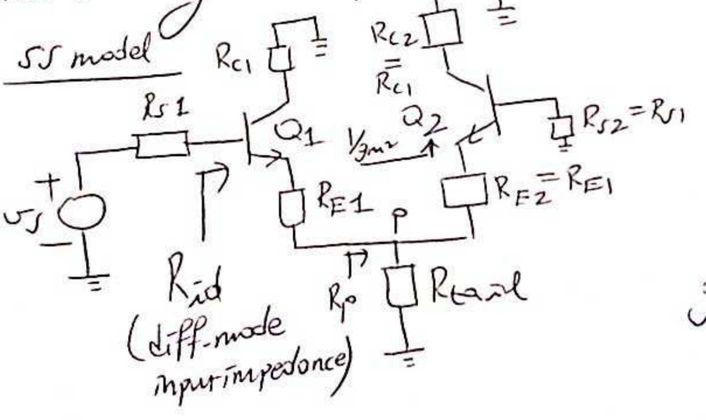
soln of the problem
See Rashid 9.31 for the calculation of R_{tail}

$$R_{tail} \approx r_{o3}\left(1 + \frac{\beta_3}{2}\right) \text{ given}$$

$$r_{o3} = \frac{V_A}{I_{tail}}$$

The small signal output v_o from node (5) to the gnd.

SS model



Let $R_C = R_{C1} = R_{C2}$

$R_E = R_{E1} = R_{E2}$

$R_S = R_{S1} = R_{S2}$

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

$$g_m = \frac{I_C}{V_T} = \frac{I_{tail}/2}{26\,mV} = \frac{I_{tail}}{52\,mV}$$

Rashid 9.39 cont.

R_p at node P

$$R_p = R_{tail} \, // \, \left[R_E + 1/g_m\right]$$

$$R_{id} \cong \left[1 + g_m\left(R_{E1} + R_p\right)\right] r_{\pi 1}$$ (make use of TCA related deriv.)

The amplifier in diff. mode can be analyzed as a cascade of two amplifiers:

emitter follower + common base

$$\frac{v_{e1}}{v_{b1}} = \frac{R_E + R_p}{R_E + R_p + 1/g_m}$$ (see emitter follower related deriv.)

$$\frac{v_{b1}}{v_s} = \frac{R_{id}}{R_s + R_{id}}$$ (voltage divider)

$$\frac{v_p}{v_{e1}} = \frac{R_p}{R_p + R_E}$$ (voltage divider)

$$\frac{v_{e2}}{v_p} = \frac{1/g_m}{1/g_m + R_E}$$ (voltage divider)

$$\frac{v_5}{v_{e2}} = \frac{v_{c2}}{v_{e2}} \cong g_m R_C$$

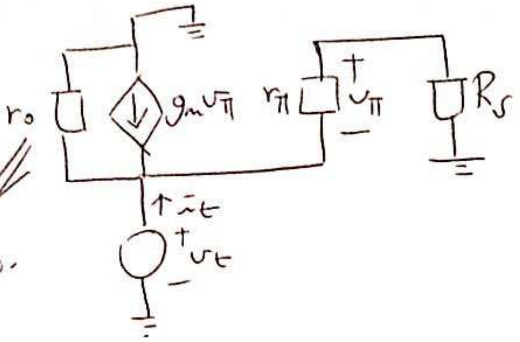
(see related derivations)

$$A_d = \frac{v_{c2}}{v_s} = \frac{v_{b1}}{v_s} \cdot \frac{v_{e1}}{v_{b1}} \cdot \frac{v_p}{v_{e1}} \cdot \frac{v_{e2}}{v_p} \cdot \frac{v_{c2}}{v_{e2}}$$

$\Longrightarrow$ multiply the related terms given above

 2

Rashid 9.39 cont



r_o is very big.

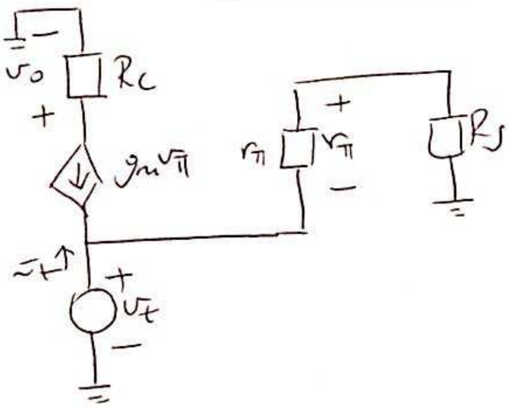
common base input imp.

$$-g_m v_\pi - i_t + \frac{v_t}{r_\pi + R_s} = 0$$

$$v_t \frac{r_\pi}{r_\pi + R_s} = -v_\pi$$

$$v_t \left(\frac{1 + g_m r_\pi}{r_\pi + R_s}\right) = i_t$$

$$\frac{v_t}{i_t} = \frac{r_\pi + R_s}{1 + \beta} \approx \frac{1}{g_m} \text{ if } r_\pi \gg R_s$$



common base gain

$$v_o = -g_m v_\pi R_C$$

$$v_o = -g_m R_C \left(-v_t \frac{r_\pi}{r_\pi + R_s}\right)$$

$$\frac{v_o}{v_t} = g_m R_C \frac{r_\pi}{r_\pi + R_s}$$

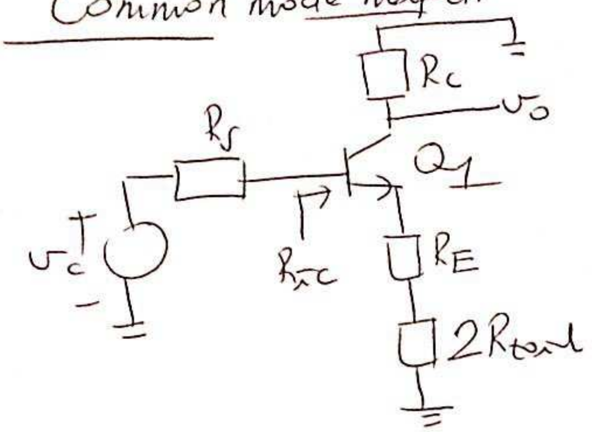
$$\approx g_m R_C \text{ if } r_\pi \gg R_s$$

Above are better approx in the analysis of the common base stage (when R_s is nontrivially big compared to r_π)

2

Common mode half cir

Rashid
9.39
Cont.



generally $R_C \ll r_{out,TCA}$

$$A_c = \frac{v_o}{v_c} = \frac{v_{b1}}{v_c}\,\frac{v_o}{v_{b1}}$$

$$= \frac{R_{ic}}{R_{ic}+R_s}\left[-g_m \frac{1}{1+g_m(R_E+2R_{tail})}\left(R_C // r_{out,TCA}\right)\right]$$

(see TCA related computations)

$$R_{ic} \cong \left[1+g_m(R_E+2R_{tail})\right] r_\pi$$

$$r_{out,TCA} \cong \left[1+g_m(R_E+2R_{tail})\right] r_o$$

Then $CMRR = \left|\frac{A_d}{A_c}\right|$ (Substitute all the terms and calculate)

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