ECE 614 Advanced Analog IC Design

BOISE STATE UNIVERSITY

Sept. 1, 2011

Lecture 4

$R_3 + R_{G1} \| R_{G2}$

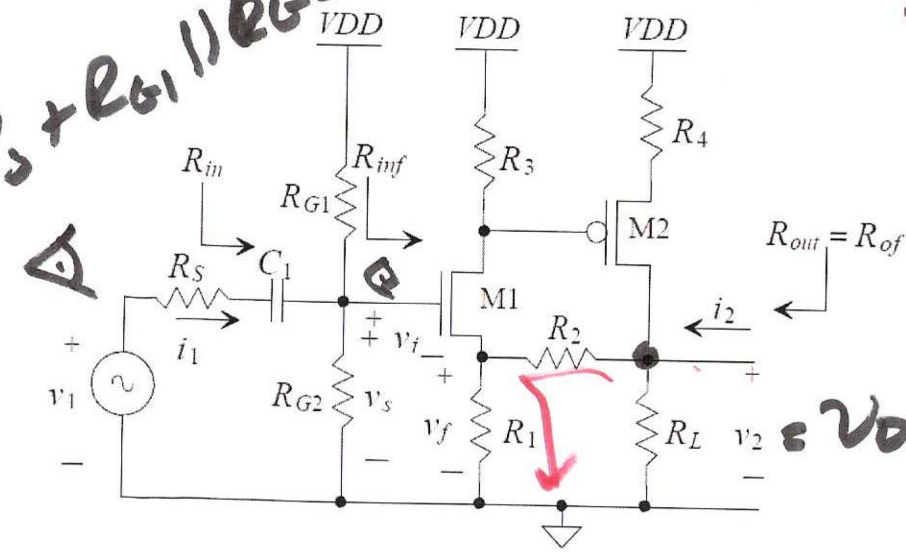


Figure 31.13 Transistor-level series-shunt feedback amplifier.

$R_{inf} = R_{in} = \infty$

$R_{in} = R_{G1} \| R_{G2}$

$R_{inf} = R_{in}(1+\beta A_{OL})$

$R_{outf} = \dfrac{R_o}{1+\beta A_{OL}}$

v_{sg}, v_{gs}

$i_d = g_{mp} \cdot v_{gs}$

$i_d = g_{mp} \cdot v_{sg}$

$i_d = g_{mp}(-v_{gs}) = g_{mp}(v_{sg})$

$-i_d = g_{mp}(v_s - v_g)$

$= -(v_g - v_s)$

$v_f = \beta \cdot v_o$

$\beta = \left(\dfrac{R_1 + R_2}{R_1}\right)^{-1}$

$A_{CL}\big|_{ideal} \approx \dfrac{1}{\beta}$

1)

open-loop gain

$A_{ol} = \frac{v_2}{v_s} = \frac{v_o}{v_s}$

include loading from β network

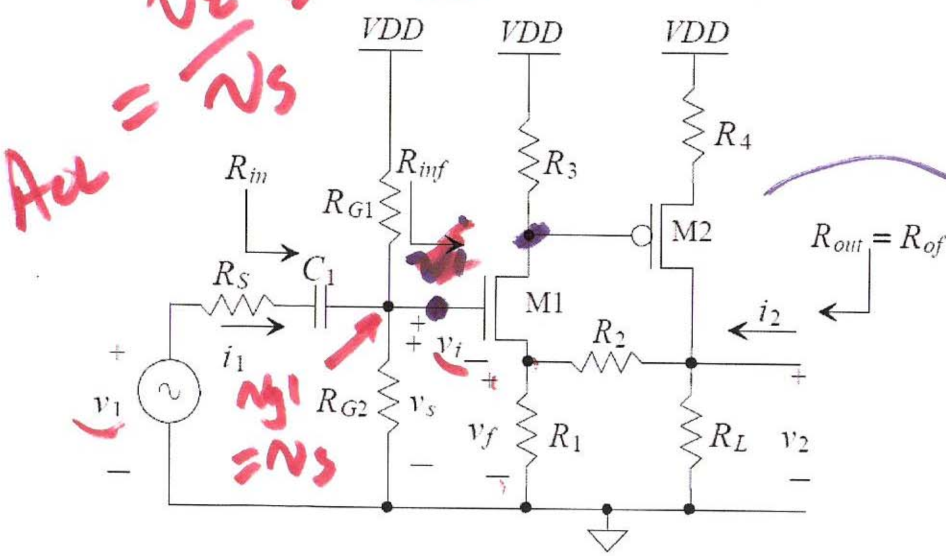
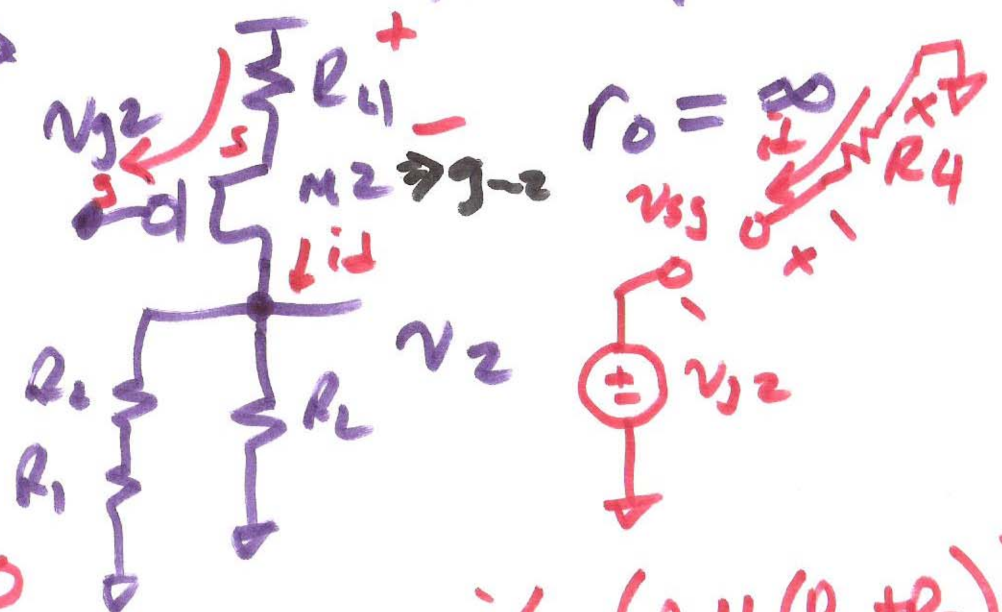


Figure 31.13 Transistor-level series-shunt feedback amplifier.



$R_4 \cdot i_d - v_{sg} - v_g = 0$

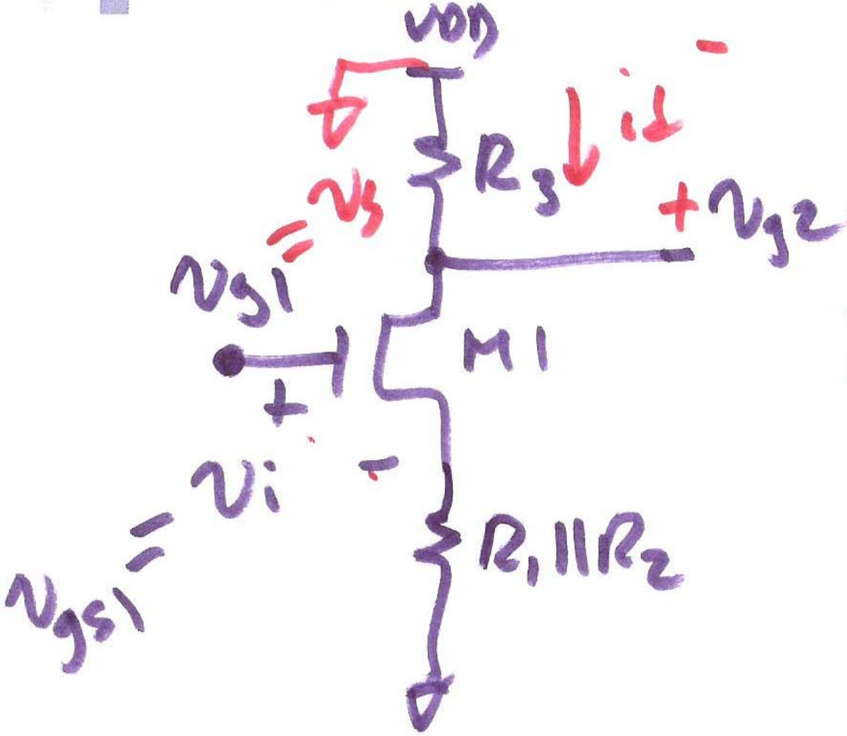
$v_s - v_f = v_i$ $\quad i_d = g_{mp} \cdot v_{sg}$

$$\frac{v_2}{v_{sg2}} = \frac{\cancel{i_d} \cdot (R_L \| (R_1 + R_2))}{\cancel{i_d}\left(\frac{1}{g_{mp}} + R_4\right)}$$

$$\frac{v_2}{v_{sg2}} = -g_{m2}(R_L \| (R_1 + R_2))$$

$$\frac{v_2}{v_{sg2}} = \frac{\cancel{i_d}(R_L \| (R_1 + R_2))}{\cancel{i_d}\left(-\frac{1}{g_{mp}}\right)}$$

2)



$$\frac{v_{g2}}{v_{g1}} = \frac{v_{g2}}{v_{s}} = \frac{-\cancel{i_d} \cdot R_3}{\cancel{i_d}\left(\frac{1}{g_{m1}} + R_1 \| R_2\right)}$$

$$\frac{v_{g2}}{v_{gs1}} = \frac{-R_3}{1/g_{m1}}$$

$v \downarrow I = \frac{V}{R}$ $\quad v_{gs1} = \frac{i_d}{g_{m1}}$

$$\frac{v_{g2}}{v_s} = \frac{g_{m1} R_3}{1 + g_{m1} \cdot (R_1 \| R_2)}$$

3)

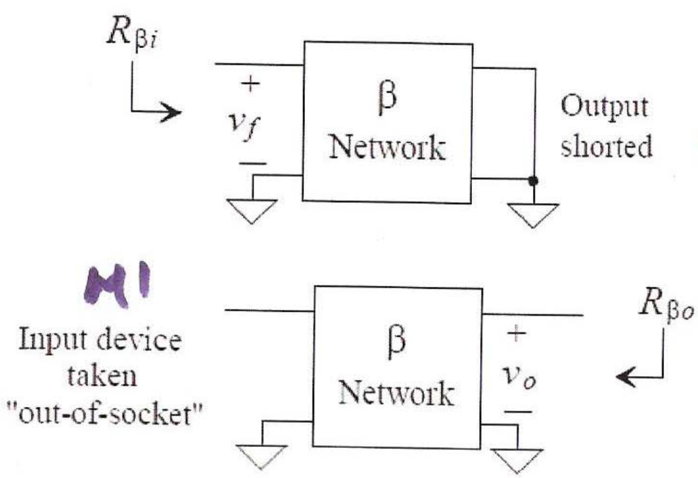
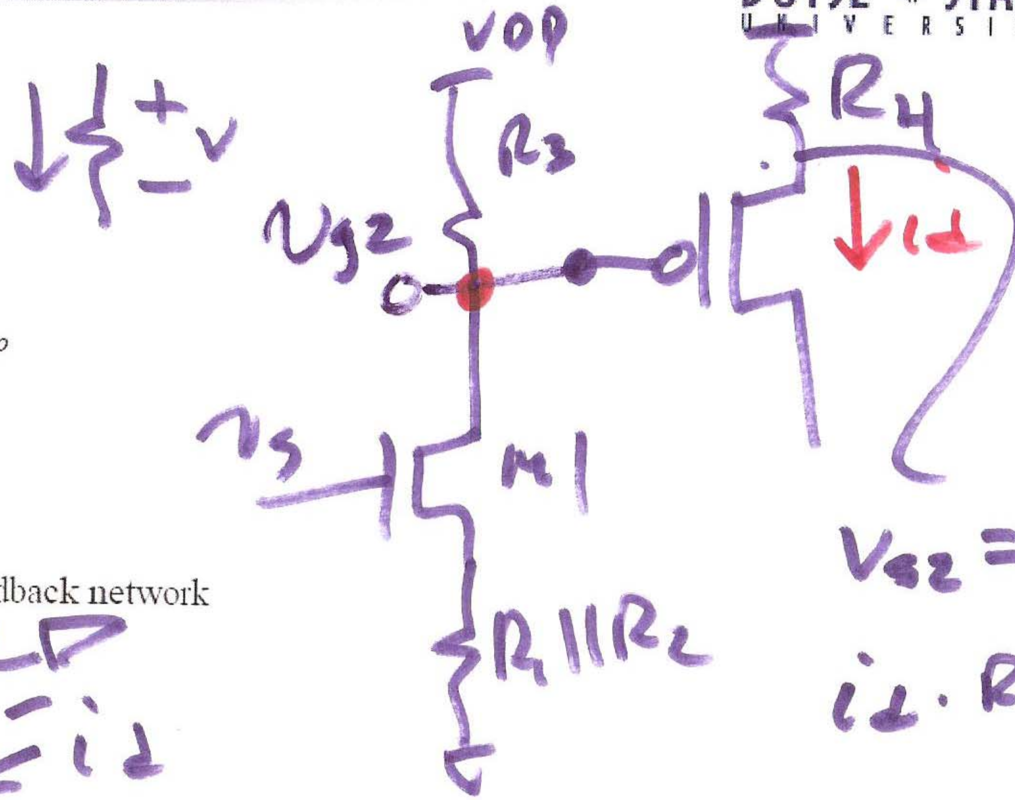
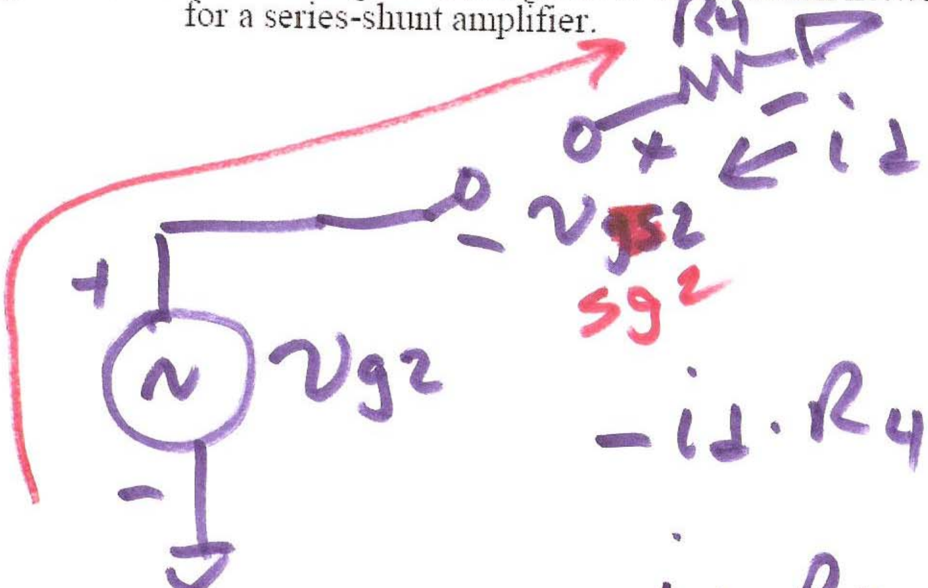


Figure 31.15 Determining the loading due to the feedback network for a series-shunt amplifier.



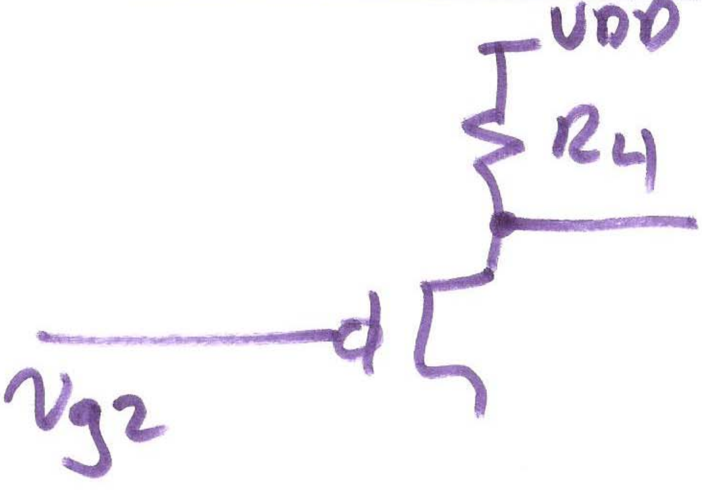
$$v_{s2} = i_d \cdot R_4$$



$$-i_d \cdot R_4 + v_{sg2} + v_{g2} = 0$$

$$-i_d \cdot R_4 + v_{s2} - \cancel{v_{g2}} + \cancel{v_{g2}} = 0$$

4)



$$v_{s2} = -i_d \cdot R_4$$

$$v_{sg2} = v_{s2} - v_{g2}$$

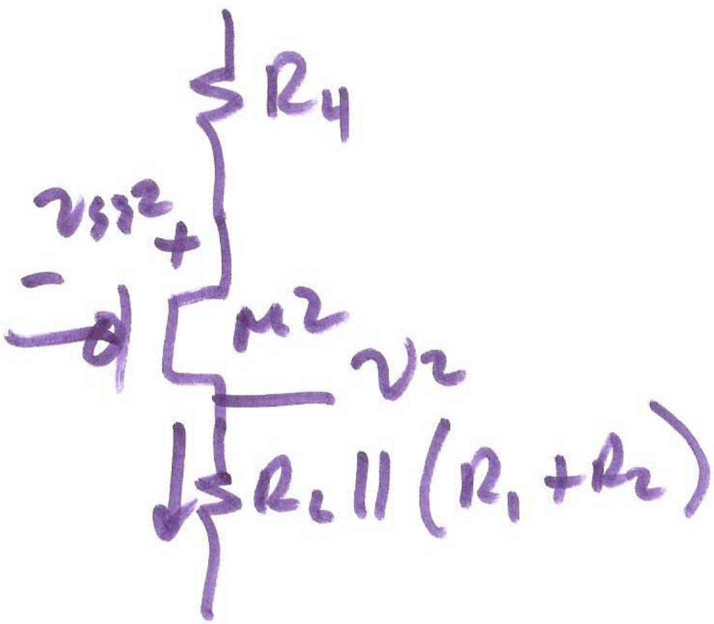
$$= -\underbrace{\cancel{i_{d2}}}_{v_{sg2}\cdot g_{m2}} \cdot R_4 - v_{g2}$$

$$-v_{g2} = v_{sg2}\,\underline{(1 + g_{m2})R_4}$$

$$(1 + g_{m2})R_4$$

5)

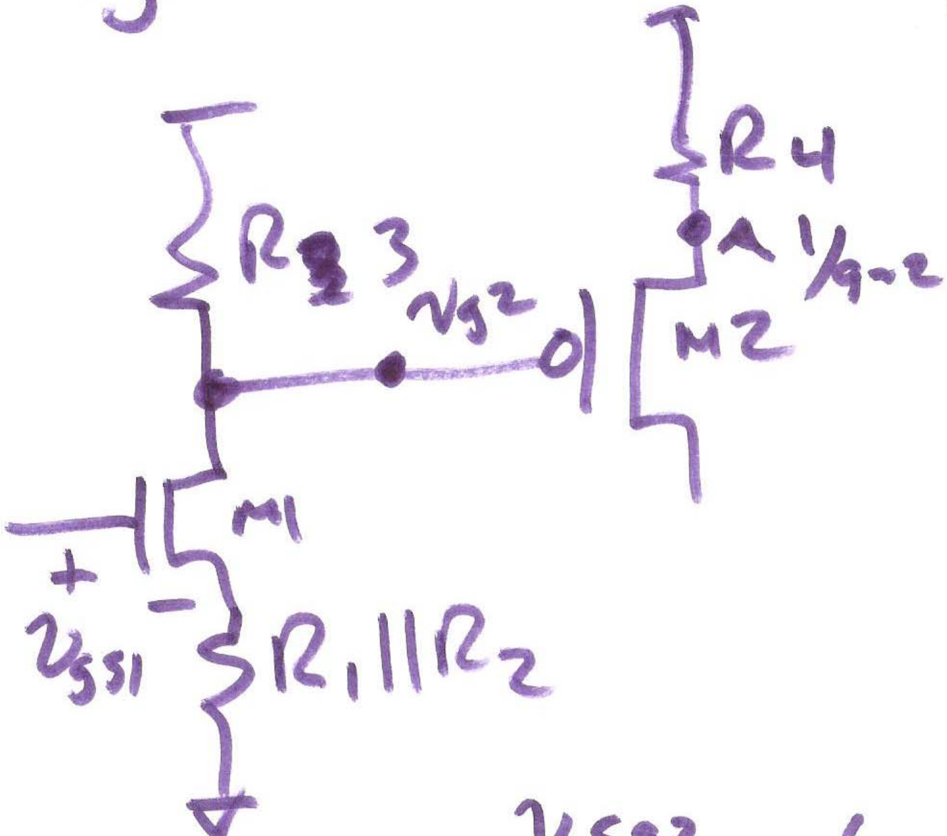
$$\left(\frac{v_2}{v_{sg2}}\right) = \frac{+R_L \| (R_1 + R_2)}{-1/g_{m2}} = -g_{m2} R_L \| (R_1 + R_2)$$



6)

$$\frac{v_{sg2}}{v_{gs1}}$$

$$\frac{v_{g2}}{v_{gs1}} = \frac{-R_3}{1/g_{m1}}$$



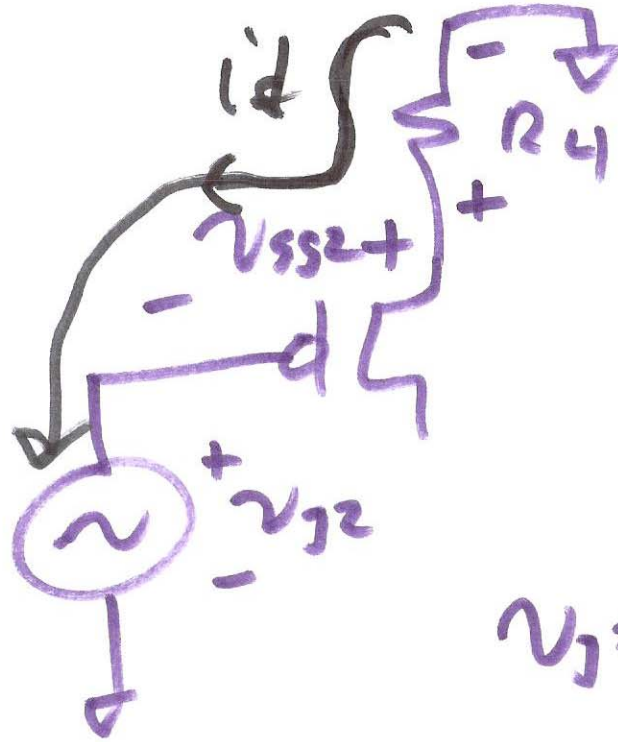
$$v_{s2} = v_{g2}\cdot\frac{R_4}{R_4+1/g_{m2}}$$

$$\boxed{\frac{v_{sg2}}{v_{g2}} = \frac{\frac{1}{g_{m2}}}{R_4+1/g_{m2}}}$$

$$\frac{v_{sg2}}{v_{gs1}} = \left(-g_{m1}R_3\right)\cdot\left(\frac{1}{1+g_{m4}\cdot R_4}\right)$$

7)

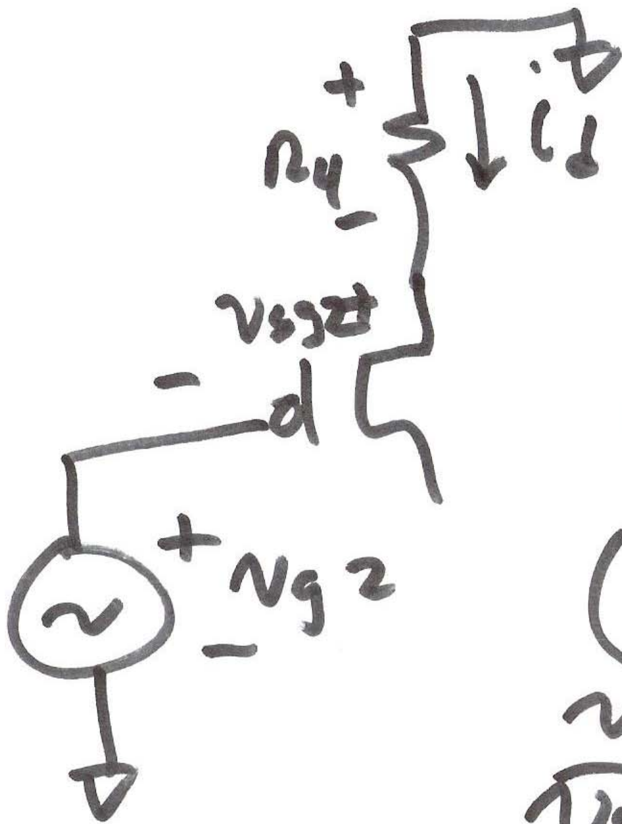
$$\frac{v_{sg2}}{v_{g2}}$$



$\rightarrow -i_d \cdot R_4$

$$v_{g2} = -v_{sg2} - i_d R_4$$

8)



$$g_m v_{sg} = i_d$$

$$R_4 \cdot i_d + v_{sg2} + v_{g2} = 0$$

$$(R_4 g_{m2} + 1) v_{sg2} = -v_{g2}$$

$$\frac{v_{sg2}}{v_{g2}} = \frac{1}{1 + g_{m2} R_4}$$

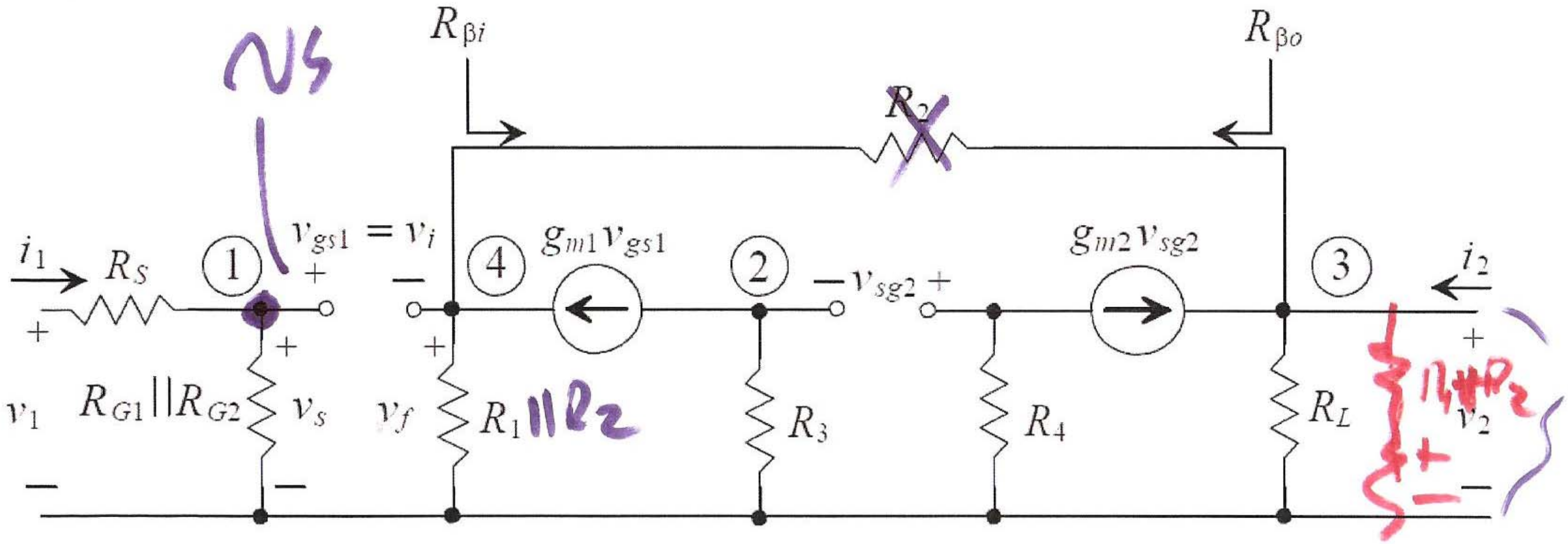


Figure 31.14 Closed-loop small-signal model of Fig. 31.13.

10)

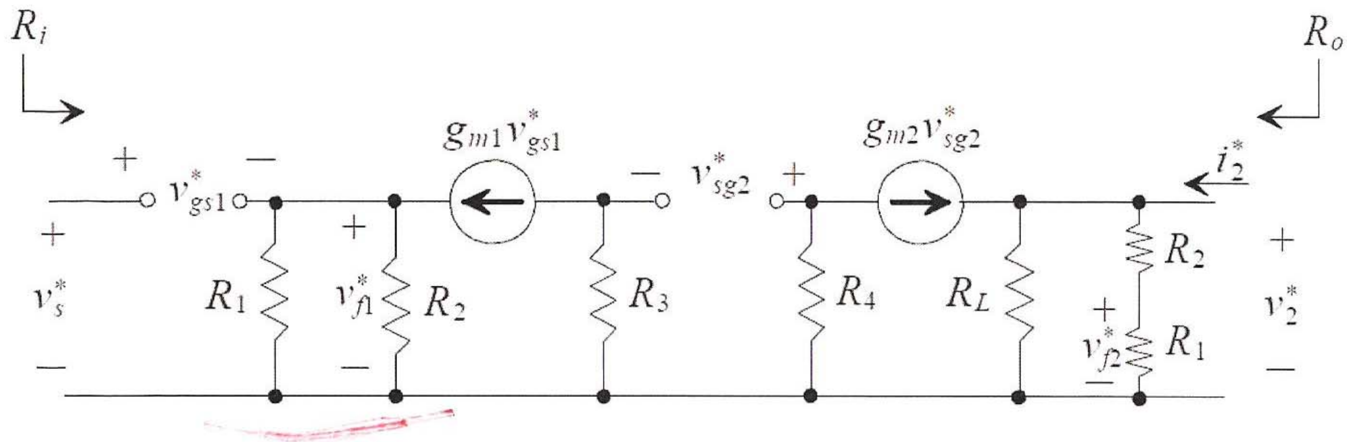


Figure 31.16 Open-loop small-signal model of Fig. 31.13.

11

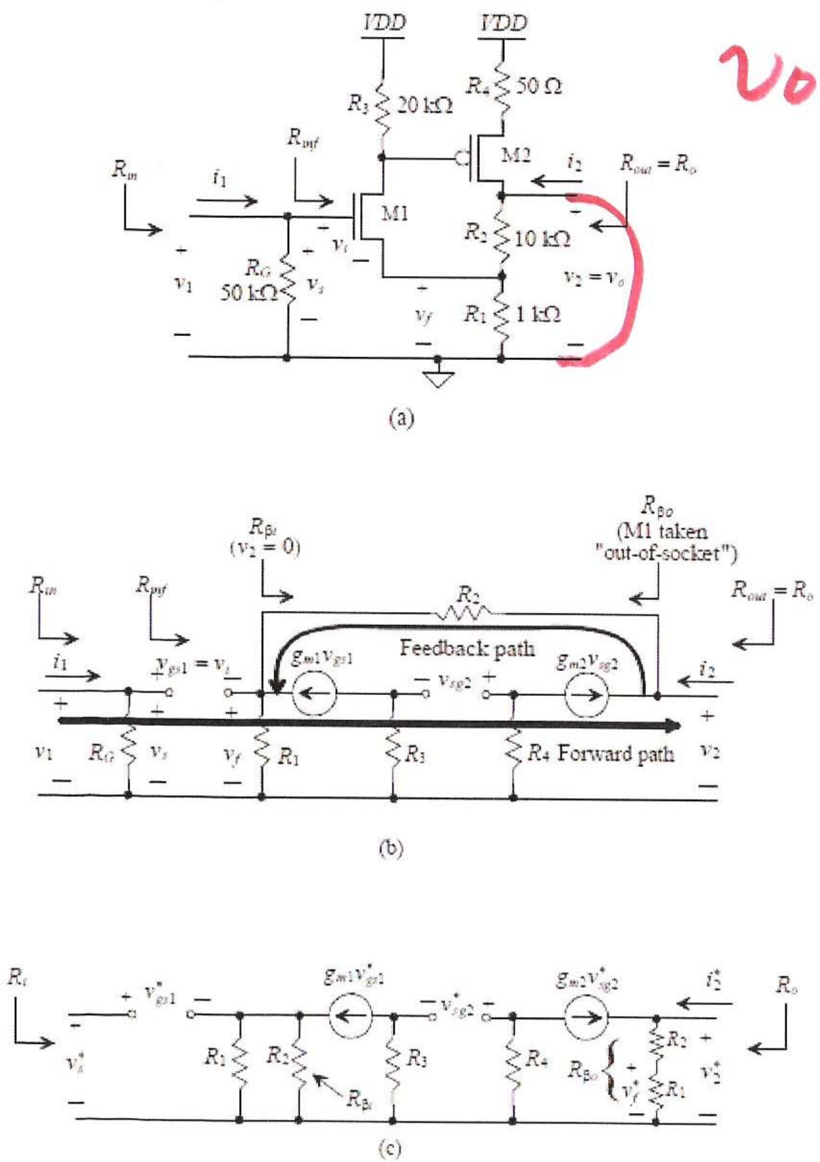


Figure 31.17 (a) Series-shunt circuit used in Ex. 31.1; (b) its closed-loop small-signal model; and (c) the resulting open-loop model.

$$v_o \cdot \beta = v_o \underbrace{\left(\frac{10K + 1K}{10K}\right)^{-1}}_{\beta} = v_f$$

$$v_f = v_o \cdot \underbrace{\frac{1K}{1K + 10K}}_{\beta}$$

$$A_{CL} \approx \frac{1}{\beta} = 11$$

$$R_{in} = R_{inf} = \infty$$

$$R_o = 11K$$

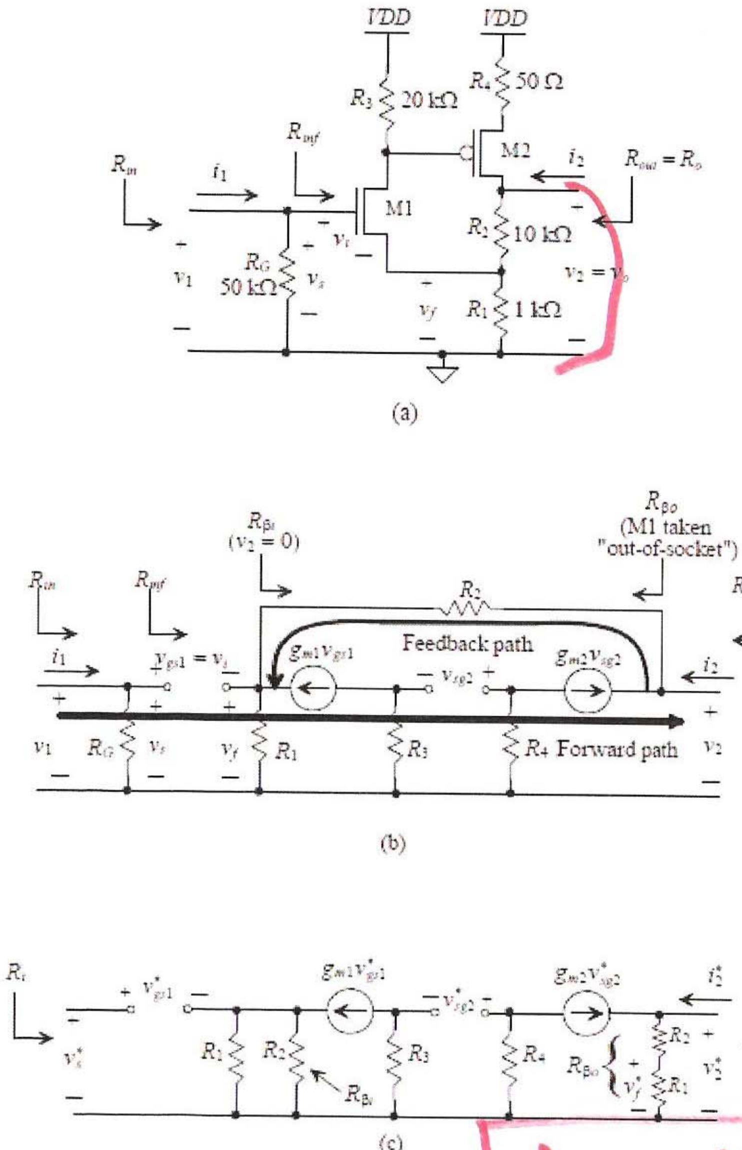
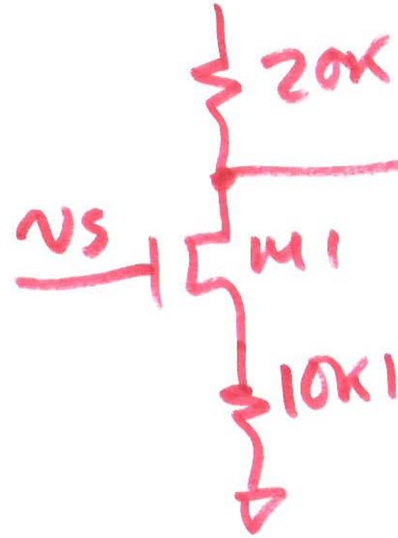


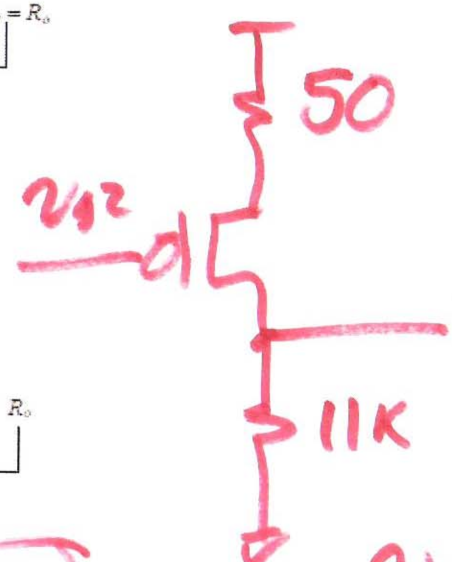
Figure 31.17 (a) Series-shunt circuit used in Ex. 31.1; (b) its closed-loop small-signal model; and (c) the resulting open-loop model.



$$\frac{v_{g2}}{v_s} = \frac{-20K}{\frac{1}{g_{m1}} + 10K||1K}$$

$$g_{m1,2} = 1\,mA/V$$

$$\frac{1}{g_{m1,2}} = 1K$$



$$\frac{v_o}{v_{g2}} = \frac{-11K}{50 + \frac{1}{g_{m2}}}$$

$$A_{OL} = \frac{v_o}{v_s} = \frac{20K \cdot 11K}{(1K+900)(1,050)}$$

$$\frac{220 \cdot 10^6}{2 \cdot 10^6} \approx 110$$

$$\boxed{A_{OL} = 110}$$

13)

$$\beta = \frac{1K}{1K + 10K} = .09$$

$$A_{CL} = \frac{110}{1 + .09 \cdot 110} = \frac{1}{\frac{1}{110} + .09}$$

$$\approx 10$$

$$R_{of} = \frac{11K}{1 + 0.09 \cdot 110} = \underline{\underline{1K}}$$

14)

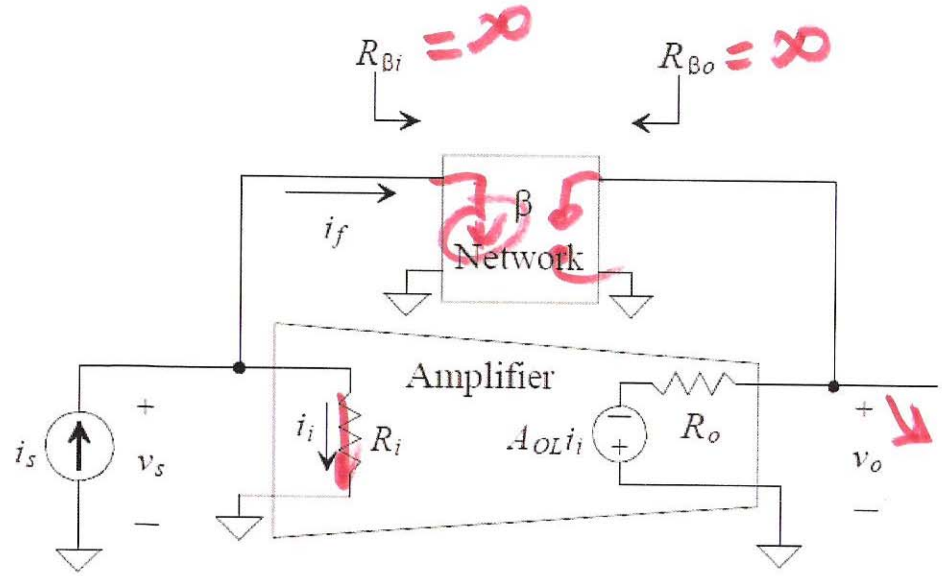


Figure 31.18 An ideal transimpedance (shunt-shunt) amplifier.

current – voltage

$R_{\beta o} \to \infty$

$$R_{if} = \frac{R_i}{1+\beta A_{OL}}$$

$$R_{of} = \frac{R_o}{1+\beta A_{OL}}$$

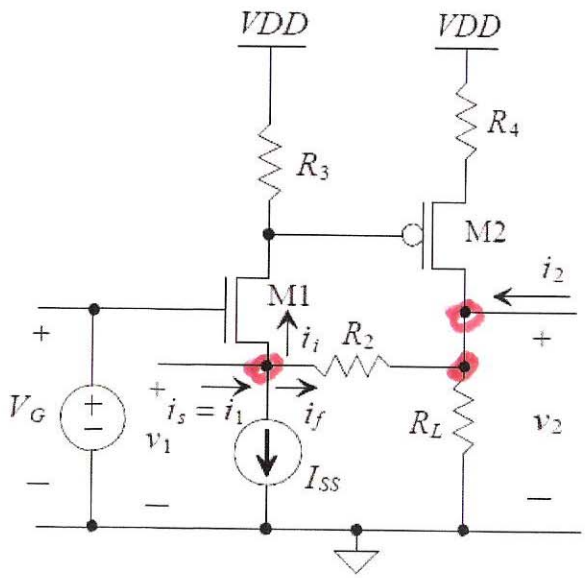


Figure 31.19 Shunt-shunt feedback amplifier.

trans resistance.

16)