

LECTURE 280 – SERIES-SHUNT AND SHUNT-SERIES FEEDBACK (READING: GHLM – 579-587)

Objective

The objective of this presentation is:

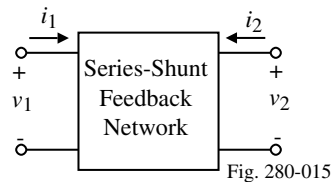
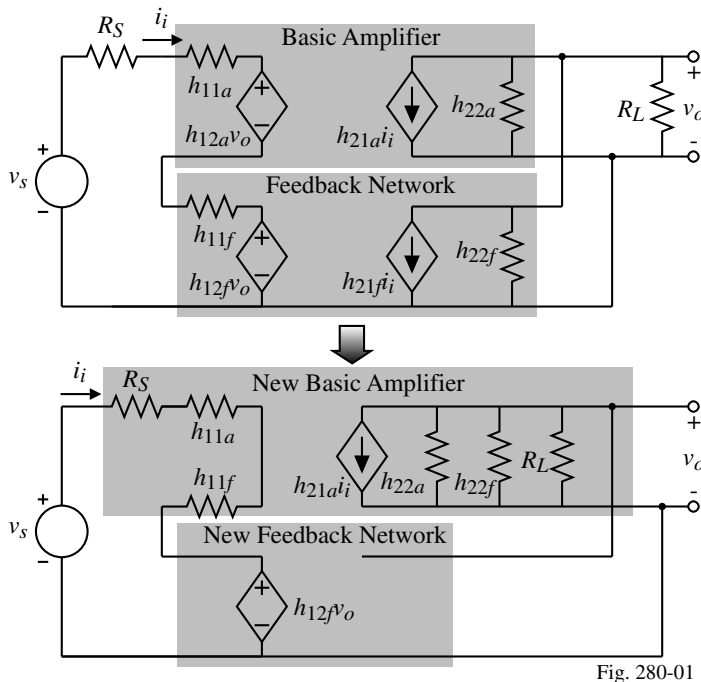
1.) Illustrate the analysis of series-shunt and shunt-series feedback circuits

Outline

- Series-shunt feedback with nonideal source and load
- Series-shunt example
- Shunt-series feedback with nonideal source and load
- Shunt-series example
- Summary

Series-Shunt Feedback including Source and Load Resistances

Configuration:



$$v_1 = h_{11}i_1 + h_{12}v_2$$

$$i_2 = h_{21}i_1 + h_{22}v_2$$

where for the new basic amplifier,

$$h_{11} = \left. \frac{v_1}{i_1} \right|_{v_2=0} = R_S + h_{11a} + h_{11f}$$

$$h_{12} = \left. \frac{v_1}{v_2} \right|_{i_1=0} = 0$$

$$h_{21} = \left. \frac{i_2}{i_1} \right|_{v_2=0} = h_{21a}$$

$$h_{22} = \left. \frac{i_2}{v_2} \right|_{i_1=0} = G_L + h_{22a} + h_{22f}$$

$$\frac{v_o}{v_s} = \frac{v_2}{v_1} = A = \frac{a}{1+af} = \frac{(-h_{21a}/h_{11}h_{22})}{1+(-h_{21a}/h_{11}h_{22})h_{12f}} \Rightarrow a = \frac{-h_{21a}}{h_{11}h_{22}} \quad \text{and} \quad f = h_{12f}$$

Example 1 – Series-Shunt Feedback Amplifier

For the amplifier shown, find v_2/v_1 , v_1/i_1 , and v_2/i_2 . Assume that $\beta_{F1} = \beta_{F2} = 100$, $V_{BEQ} \approx 0.7V$ and $V_{A1} = V_{A2} = 100V$ for the BJTs. Note that this circuit can be simulated using SPICE.

Solution

1.) Topology identification. We see that the circuit is series-shunt, negative feedback. Also, note that R_S is “outside” the feedback circuit.

2.) Closed loop small-signal model is shown below.

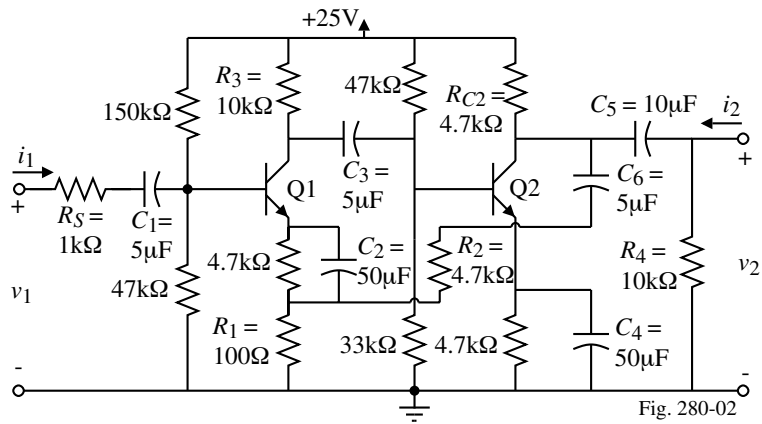


Fig. 280-02

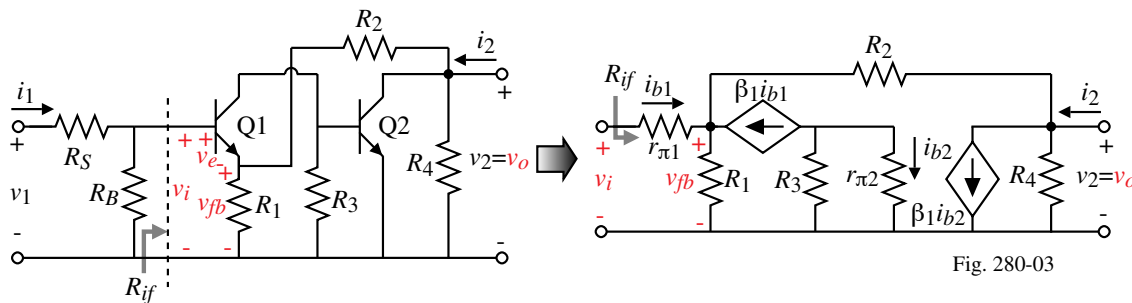


Fig. 280-03

Example 1 – Continued

3.) Break open the loop by finding the loading effects of the feedback network on the amplifier. This involves finding h_{11f} and h_{22f} .

$$h_{11f} = \left. \frac{v_{1f}}{i_{1f}} \right|_{v_2=v_o=0} = R_1 \parallel R_2$$

$$h_{22f} = \left. \frac{i_{2f}}{v_{2f}} \right|_{i_1=i_i=0} = 1/(R_1+R_2)$$

4.) Open-circuit small-signal model:

$$f = \frac{v_{fb}'}{v_o'} = \frac{R_1}{R_1+R_2}$$

$$= \frac{100}{4700+100} = \frac{1}{48} = 0.0208$$

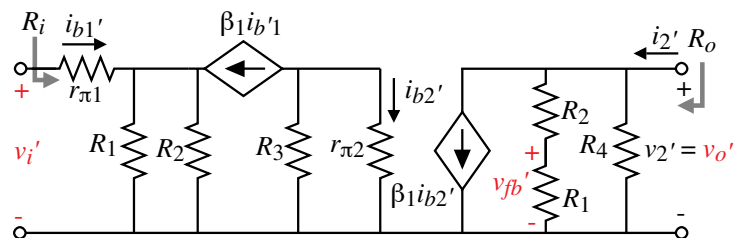


Fig. 280-04

$$a = \frac{v_o'}{v_i'} = \left(\frac{v_o'}{i_{b2}'} \right) \left(\frac{i_{b2}'}{i_{b1}'} \right) \left(\frac{i_{b1}'}{v_i'} \right) = (-\beta_2 [R_4 \parallel (R_1+R_2)]) \left(\frac{-\beta R_3}{R_3+r_{\pi 2}} \right) \left(\frac{1}{r_{\pi 1}+(1+\beta)[R_1 \parallel R_2]} \right)$$

$$= (-1.916 \times 10^5 \Omega)(-83.735) \left(\frac{1}{12.364 \text{ k}\Omega} \right) = 1298 \text{ V/V} \quad \Rightarrow \quad T = \frac{1298}{48} = 27$$

Example 1 – Continued

5.) Input resistance, v_1/i_1 .

$$R_i = r_{\pi 1} + (1 + \beta)[R_1 \parallel R_2] = 12.364 \text{ k}\Omega \rightarrow R_{if} = R_i(1 + T) = 12.364 \text{ k}\Omega \cdot 28 = 334.3 \text{ k}\Omega$$

However, v_1/i_1 , can be found as

$$v_1/i_1 = R_{in} = R_S + R_B \parallel R_{if} = 1 \text{ k}\Omega + (150 \text{ k}\Omega \parallel 47 \text{ k}\Omega \parallel 334.3 \text{ k}\Omega) = \underline{\underline{33.33 \text{ k}\Omega}}$$

6.) Voltage gain, v_2/v_1 . First find v_o/v_i .

$$\frac{v_o}{v_i} = \frac{a}{1 + af} = \frac{1298}{1 + 27} = 46.3 \text{ V/V}$$

$$\frac{v_2}{v_1} = \left(\frac{v_o}{v_i} \right) \left(\frac{v_i}{v_1} \right) = \left(\frac{v_o}{v_i} \right) \left(\frac{R_{if} \parallel R_B}{R_S + R_{if} \parallel R_B} \right) = (46.3) \left(\frac{32.33 \text{ k}\Omega}{33.33 \text{ k}\Omega} \right) = \underline{\underline{44.9 \text{ V/V}}}$$

7.) Output resistance, v_2/i_2 .

$$R_o = R_4 \parallel (R_1 + R_2) = 1.916 \text{ K}\Omega$$

$$R_{of} = \frac{R_o}{1 + af} = \frac{1.916 \text{ K}\Omega}{28} = \underline{\underline{68.3 \Omega}}$$

Shunt-Series Feedback including Source and Load Resistances

Configuration:

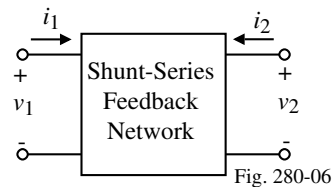
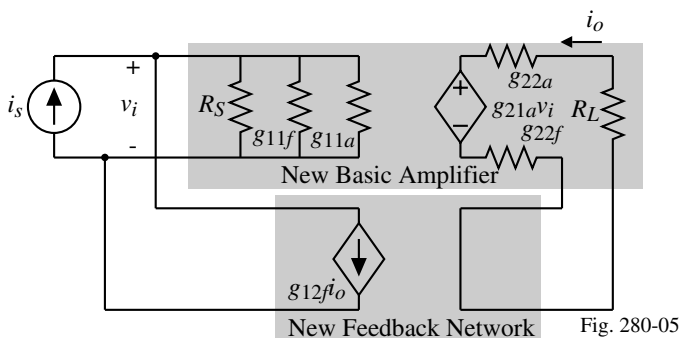
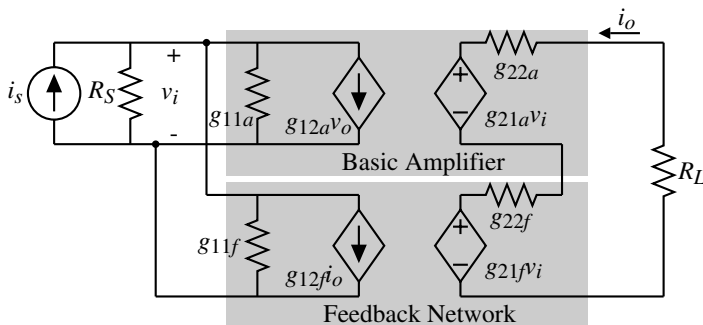


Fig. 280-06

$$i_1 = g_{11}v_1 + g_{12}i_2$$

$$v_2 = g_{21}v_1 + g_{22}i_2$$

where for the new basic amplifier,

$$g_{11} = \frac{i_1}{v_1} \Big|_{i_2=0} = G_S + g_{11a} + g_{11f}$$

$$g_{12} = \frac{i_1}{i_2} \Big|_{v_1=0} = 0$$

$$g_{21} = \frac{v_2}{v_1} \Big|_{i_2=0} = g_{21a}$$

$$g_{22} = \frac{v_2}{i_2} \Big|_{v_1=0} = R_L + g_{22a} + g_{22f}$$

$$\frac{i_o}{i_s} = \frac{i_2}{i_1} = A = \frac{a}{1 + af} = \frac{(-g_{21a}/g_{11}g_{22})}{1 + (-g_{21a}/g_{11}g_{22})g_{12f}} \Rightarrow a = \frac{-g_{21a}}{g_{11}g_{22}} \quad \text{and} \quad f = g_{12f}$$

Example 2 – Shunt-Series Feedback Amplifier

For the amplifier shown, find v_2/v_1 , v_1/i_1 , and v_2/i_2 .

Assume that all MOSFET transconductances are 1mS.

Solution

1.) Topology identification. We see that the circuit is shunt-series, negative feedback. Also, note that R_1 is “outside” the feedback circuit.

2.) Closed loop small-signal model is shown below.

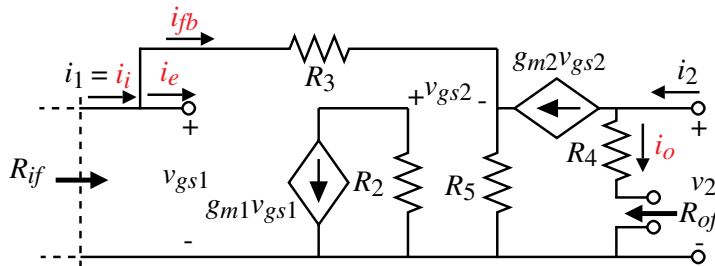


Fig. 280-08

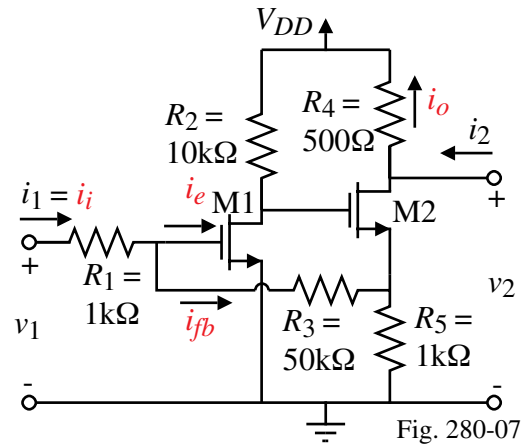


Fig. 280-07

3.) Break open the loop by finding the loading effects of the feedback network on the amplifier. This involves finding h_{11f} and h_{22f}

$$g_{11f} = \left. \frac{i_{1f}}{v_{1f}} \right|_{i_2 = i_o = 0} = 1/(R_3 + R_5)$$

and

$$g_{22f} = \left. \frac{v_{2f}}{i_{2f}} \right|_{v_{1f} = v_i = 0} = R_3 \parallel R_5$$

Example 2 - Continued

4.) Open-circuit small-signal model:

$$f = \frac{i_{fb}'}{i_o'} = \frac{R_5}{R_3 + R_5}$$

$$= \frac{1}{1+50} = \frac{1}{51} = 0.0196$$

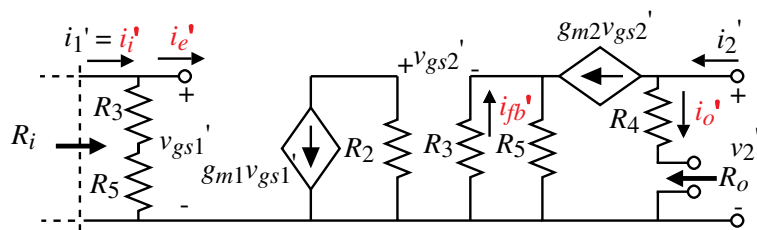


Fig. 280-09

$$a = \frac{i_o'}{i_i'} = \left(\frac{i_o'}{v_{gs2}'} \right) \left(\frac{v_{gs2}'}{v_{gs1}'} \right) \left(\frac{v_{gs1}'}{i_i'} \right) = (-g_{m2}) \left(\frac{-g_{m1}R_2}{1 + g_{m2}(R_3 \parallel R_5)} \right) (R_3 + R_5)$$

$$= (-1 \times 10^{-3} \text{S})(-5.0495)(51 \times 10^3 \Omega) = 257.5 \text{ A/A} \quad \Rightarrow \quad T = \frac{257.5}{51} = 5.05$$

5.) Input resistance, v_1/i_1 .

$$R_i = R_3 + R_5 = 51 \text{ k}\Omega \rightarrow R_{if} = \frac{R_i}{1+T} = \frac{51 \text{ k}\Omega}{6.05} = 8.43 \text{ k}\Omega$$

However, v_1/i_1 , can be found as

$$v_1/i_1 = R_{in} = R_S + R_{if} = 1 \text{ k}\Omega + 8.43 \text{ k}\Omega = \underline{9.43 \text{ k}\Omega}$$

6.) Voltage gain, v_2/v_1 . First find i_o/i_i .

$$\frac{i_o}{i_i} = \frac{a}{1+af} = \frac{257.5}{1+5.05} = 42.56 \text{ A/A} \rightarrow \frac{v_2}{v_1} = \left(\frac{i_o}{i_i} \right) \left(\frac{R_4}{R_{in}} \right) = (42.56) \left(\frac{500 \Omega}{9.43 \text{ k}\Omega} \right) = \underline{2.257 \text{ V/V}}$$

Example 2 - Continued

7.) Output resistance, v_2/i_2 .

First find R_o .

$$R_o = \infty \text{ because it includes the drain of M2 and } r_{ds2} = \infty.$$

$$\therefore \frac{v_2}{i_2} = R_4 \parallel (R_{of} - R_4) = 500\Omega \parallel \infty = \underline{500\Omega}$$

What about i_2/i_1 ? Assume the output is shorted, then

$$i_2/i_1 = -i_o/i_i = -42.56\text{A/A}$$

SUMMARY

- Series-Shunt:
 - Increases the input resistance with feedback
 - Decreases the output resistance with feedback
- Shunt-Series:
 - Decreases the input resistance with feedback
 - Increases the output resistance with feedback
- Analysis of transistor feedback circuits:
 - 1.) Identify the topology.
 - 2.) Draw the closed-loop small signal model.
 - 3.) Break the loop by calculating the new basic amplifier with the new basic feedback network consisting of only a controlled source.
 - 4.) Draw the open-loop small-signal model using primed variables.
 - 5.) Find a , f , R_i , and R_o .
 - 6.) Calculate A , R_{if} , and R_{of} .