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:

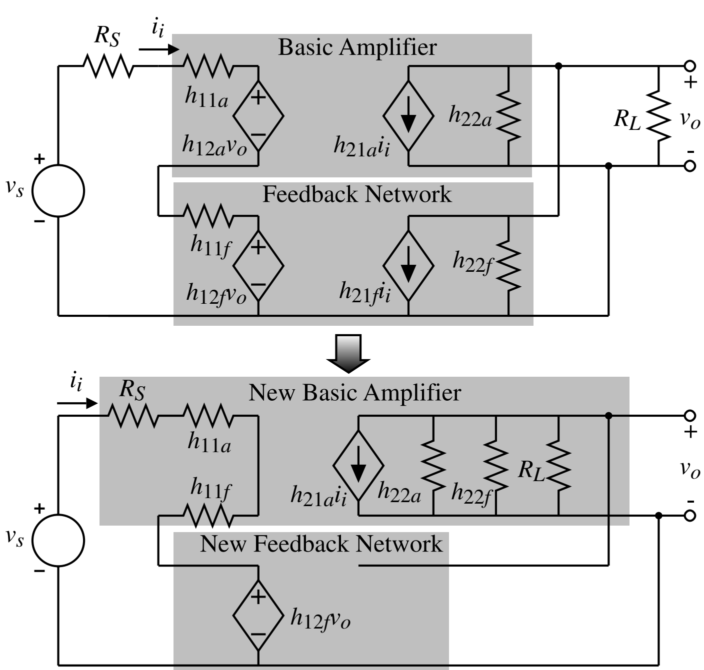

Fig. 280-01

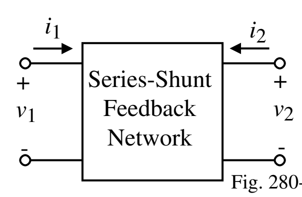

Fig. 280-015

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

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

where for the new basic amplifier,

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

$$h_{12} = \frac{v_1}{v_2}\Big|_{i_1=0} = 0$$

$$h_{21} = \frac{i_2}{i_1}\Big|_{v_2=0} = h_{21a}$$

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

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

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 $\beta_{F1} = \beta_{F2} = 100$, $V_{BEQ} \approx 0.7$V and $V_{A1} = V_{A2} = 100$V for the BJTs. Note that this circuit can be simulated using SPICE.

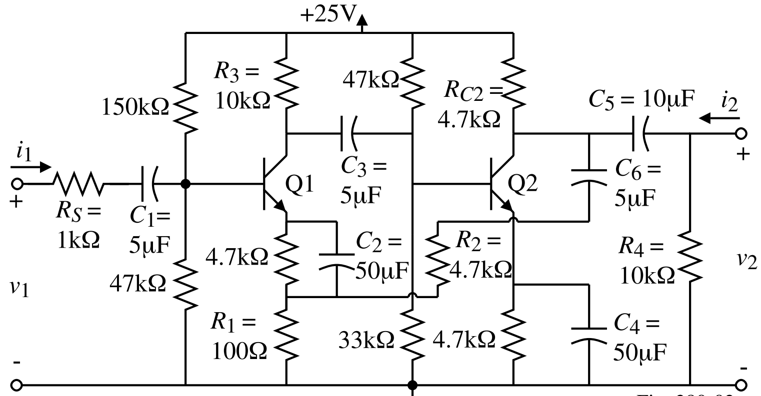

Fig. 280-02

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.

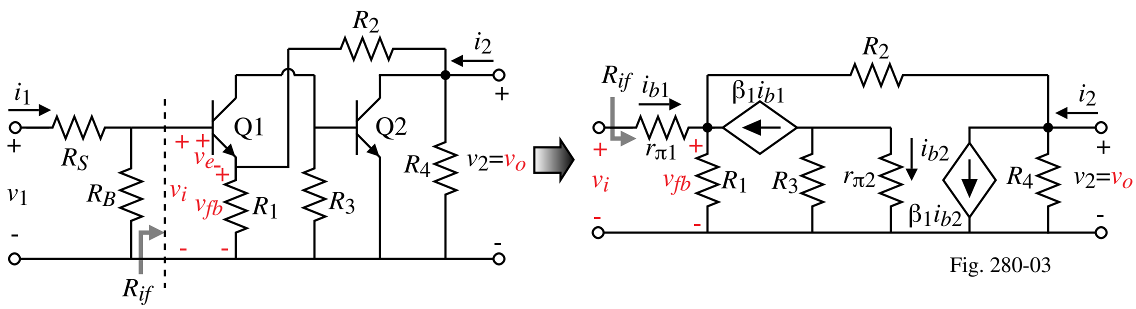

Fig. 280-03

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}.

$$h_{11f} = \left.\frac{v_{1f}}{i_{1f}}\right|_{v_{2f}=v_o=0} = R_1 \| R_2$$

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

4.) Open-circuit small-signal model:

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

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

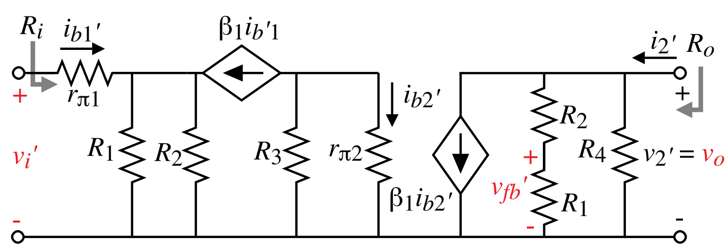

Fig. 280-04

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

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

Example 1 – Continued

5.) Input resistance, v_1/i_1.

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

However, v_1/i_1, can be found as

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

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

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

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

7.) Ouput resistance, v_2/i_2.

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

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

Shunt-Series Feedback including Source and Load Resistances

Configuration:

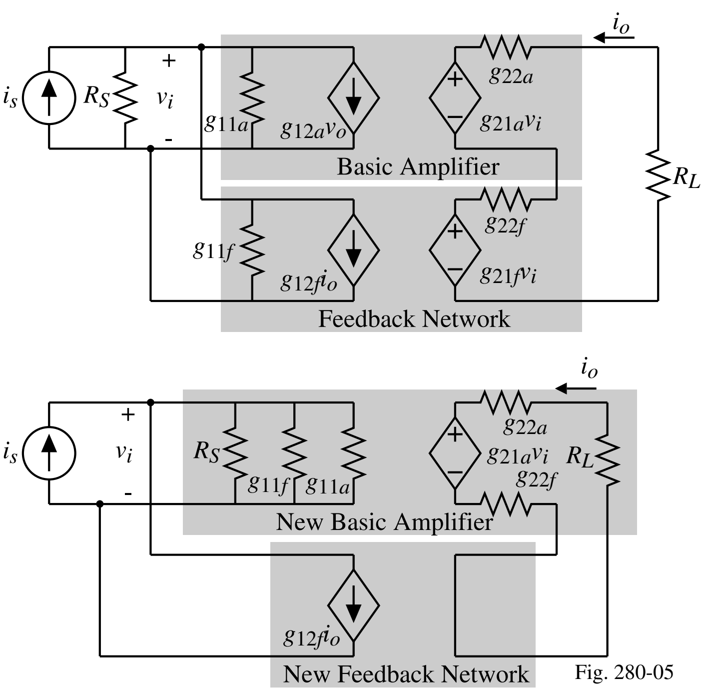

Fig. 280-05

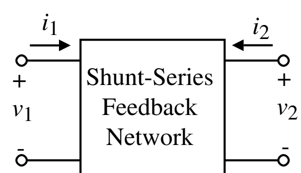

Fig. 280-06

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

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

where for the new basic amplifier,

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

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

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

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

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

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.

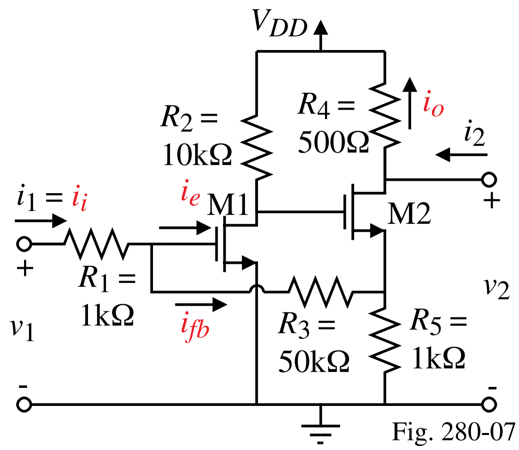

Fig. 280-07

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

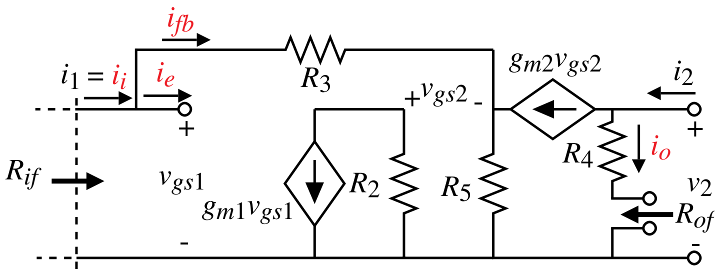

Fig. 280-08

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}.

$$g_{11f} = \left.\frac{i_{1f}}{v_{1f}}\right|_{i_{2f}=i_o=0} = 1/(R_3+R_5) \qquad \text{and} \qquad g_{22f} = \left.\frac{v_{2f}}{i_{2f}}\right|_{v_{1f}=v_i=0} = R_3||R_5$$

Example 2 - Continued

4.) Open-circuit small-signal model:

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

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

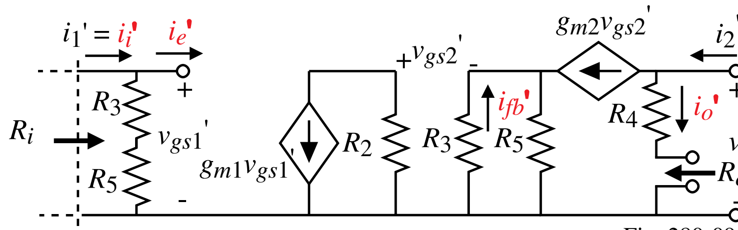

Fig. 280-09

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

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

5.) Input resistance, v_1/i_1.

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

However, v_1/i_1, can be found as

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

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

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

Example 2 - Continued

7.) Ouput resistance, v_2/i_2.

First find R_o.

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

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

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

$i_2/i_1 = -i_o/i_i = -42.56$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}.