Feedback Laboratory

Dr. Lynn Fuller
Webpage: http://people.rit.edu/lffeee/
Microelectronic Engineering
Rochester Institute of Technology
82 Lomb Memorial Drive
Rochester, NY 14623-5604
Tel (585) 475-2035

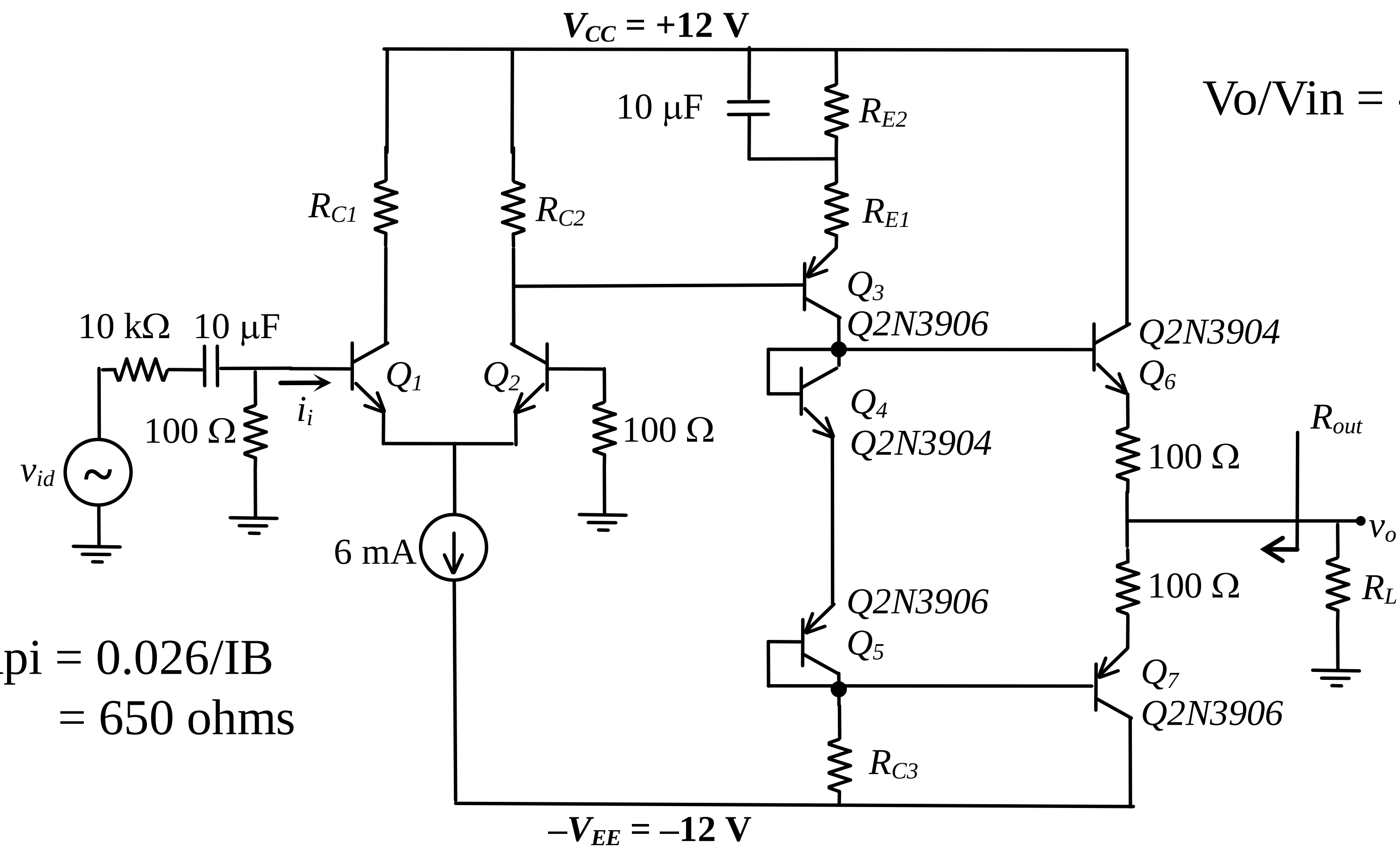
Email: Lynn.Fuller@rit.edu
MicroE webpage: http://www.microe.rit.edu

10-14-14 Feedback_Lab.ppt

INTRODUCTION

In the two prior labs we investigated current sources and the differential amplifier (Lab 1) and DC coupled amplifier and output stage (Lab 2). The result was a high gain (Av=-800), low output resistance (Ro ~ 100 ohms) DC amplifier. This lab will add global feedback as shown in the schematic on the following page (a single resistor from output back to the input). This configuration is called Voltage Sampling – Parallel Mixing or Voltage-Shunt feedback. The feedback will result in reduced but less sensitive voltage gain and will modify the input and output resistance. We will predict the results using hand calculations, and SPICE simulations. Then we will construct the circuit and make measurements for the gain with feedback and output resistance.

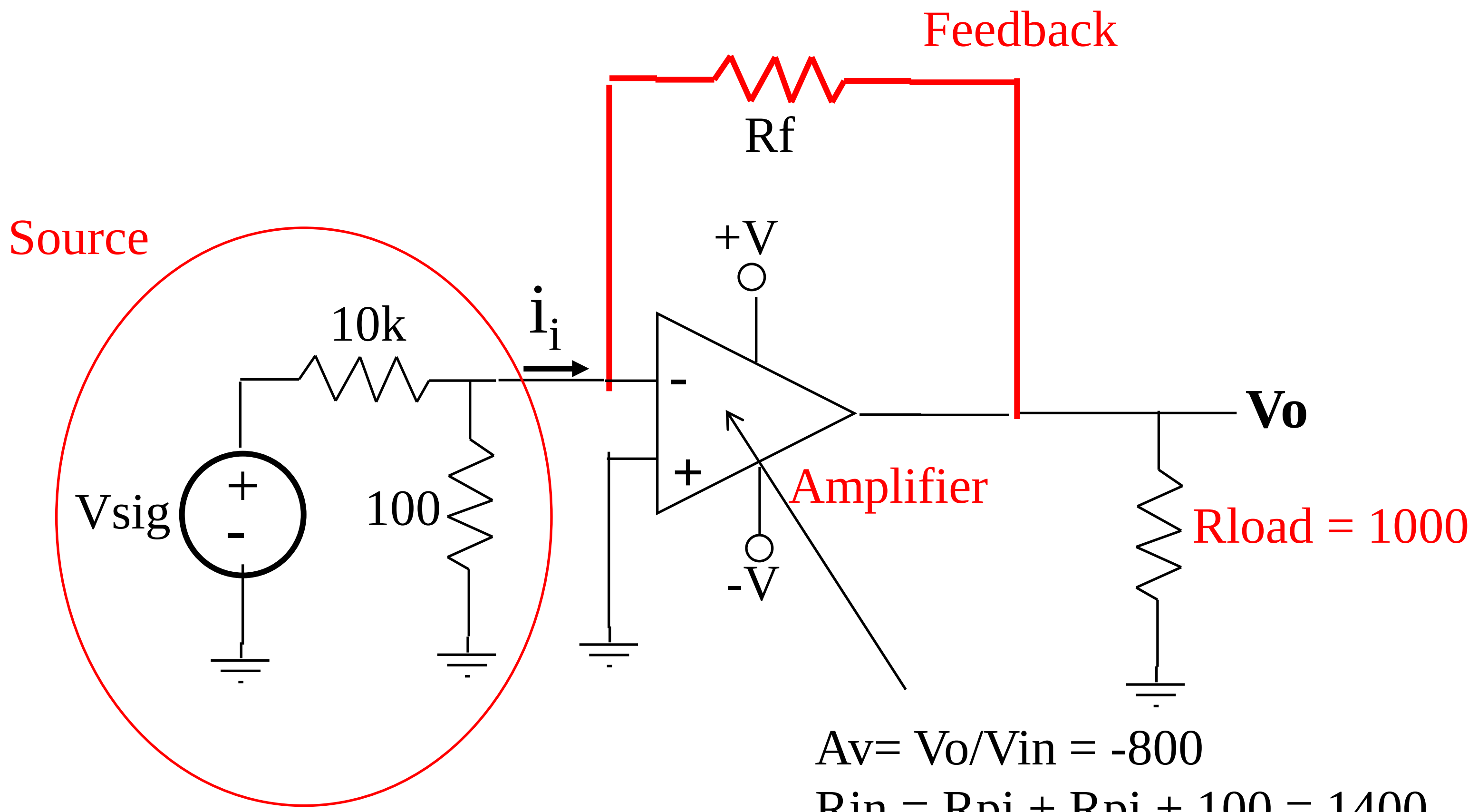
MULTISTAGE DIRECT COUPLED AMPLIFIER



Vo/Vin = -800

Rpi = 0.026/IB
= 650 ohms

WITH FEEDBACK



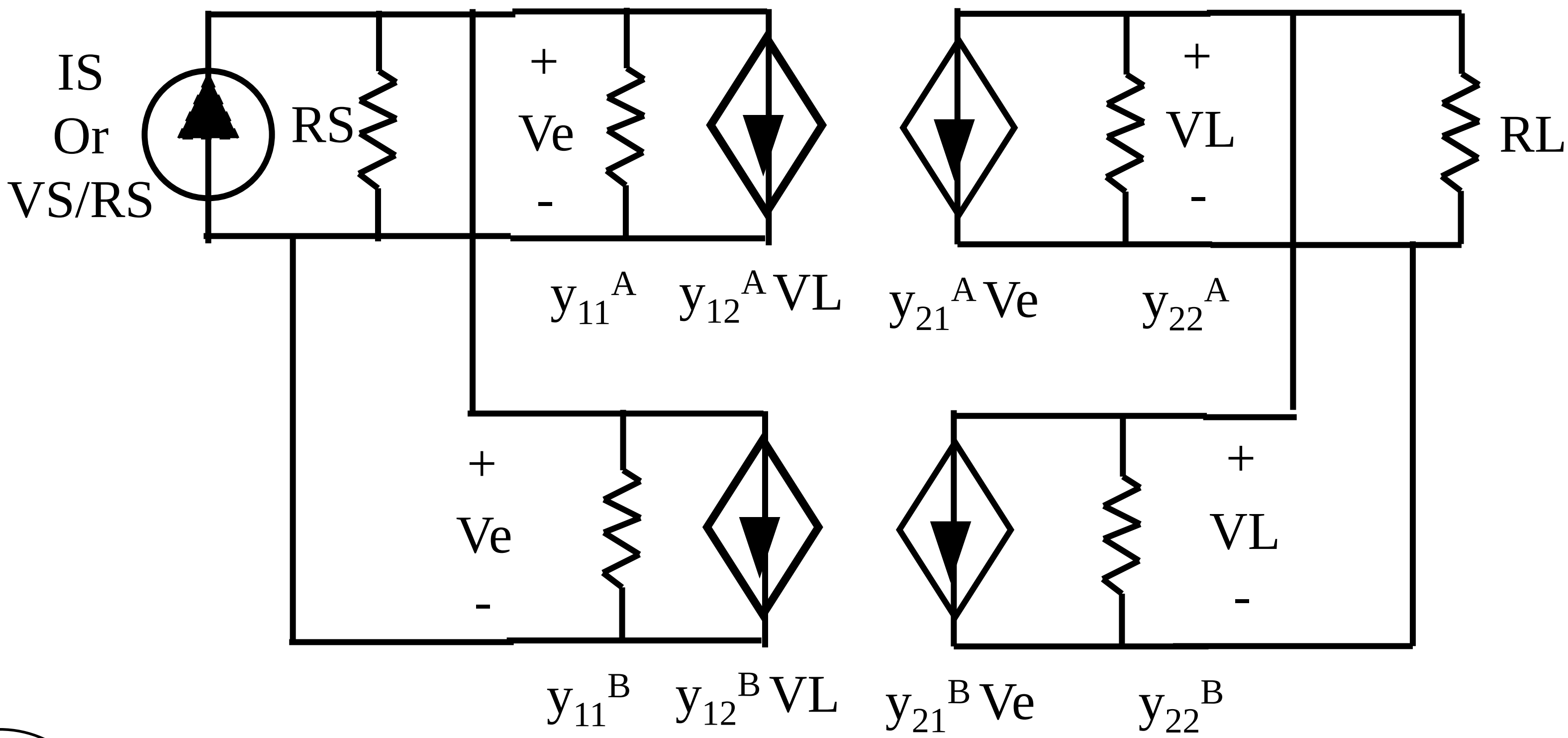
Av= Vo/Vin = -800

Rin = Rpi + Rpi + 100 = 1400

Rout = 100 + few ohms (use 100)

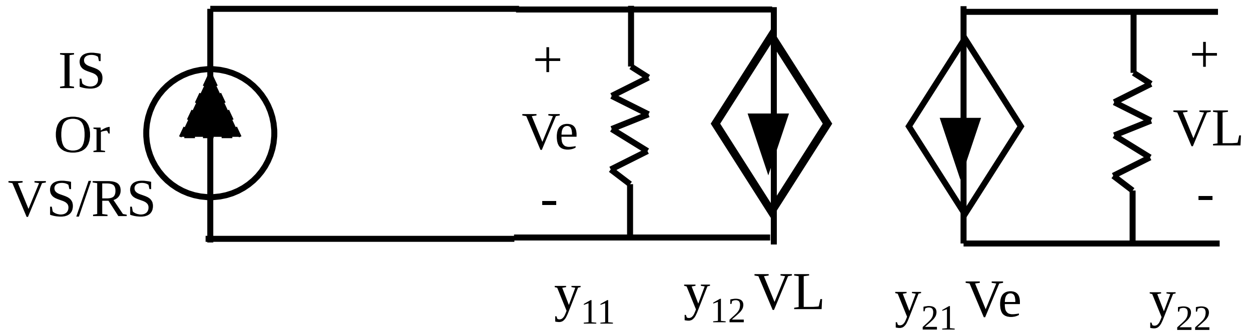
SMALL SIGNAL AC - VOLTAGE-SHUNT FEEDBACK

Select y-two port equivalent circuits and Norton equivalent circuits for voltage-shunt feedback:



SIMPLIFIED VOLTAGE-SHUNT FEEDBACK

From the previous page we combine current sources in parallel and conductances in parallel. (the equivalent circuit is simplified)



$$y_{11} = y_{11}^{A} + y_{11}^{B} + 1/Rs$$

$$y_{22} = y_{22}^{A} + y_{22}^{B} + 1/RL$$

$$y_{12} = y_{12}^{A} + y_{12}^{B}$$

$$y_{21} = y_{21}^{A} + y_{21}^{B}$$

VOLTAGE-SHUNT FEEDBACK SUMMARY

Voltage-Shunt

Input Admittance

$$Y_{If} = y_{11} \left(1 - T \right)$$

$$Y_{Of} = y_{22} \left(1 - T \right)$$

Output Admittance

Loop Gain

$$T = \frac{y_{12}y_{21}}{y_{11}y_{22}}$$

$$A_{Rf} \cong \frac{1}{y_{12}}$$

~ Gain

Exact Gain

$$A_{Rf} = \frac{\dfrac{-y_{21}}{y_{11}y_{22}}}{1 + \dfrac{-y_{12}y_{21}}{y_{11}y_{22}}}$$

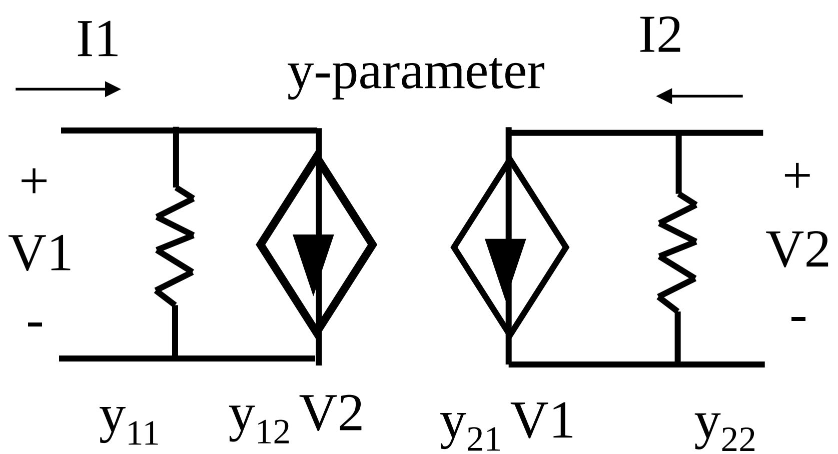
Transresistance

Voltage Gain

$$A_{Vf} = A_{Rf}\ (1/RS)$$

$$A_{If} = A_{Rf}\ (1/RL)$$

Current Gain



$$I1 = y_{11}\ V1 + y_{12}\ V2$$

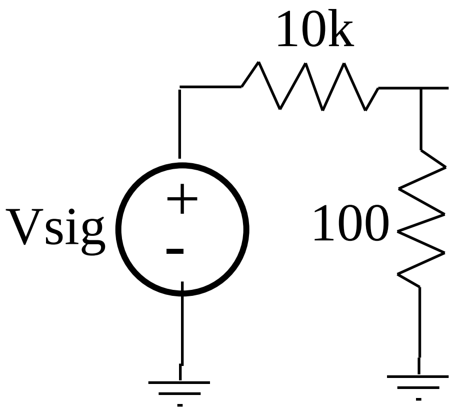
$$I2 = y_{21}\ V1 + y_{22}\ V2$$

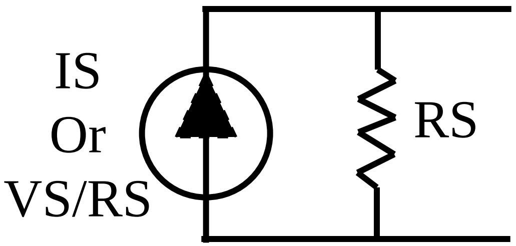
Rochester Institute of Technology
Microelectronic Engineering

Reference: See Dr. Fuller's Webpage

THE SOURCE

The source is represented by its Norton equivalent circuit.





Norton

Is = Vsig/10K

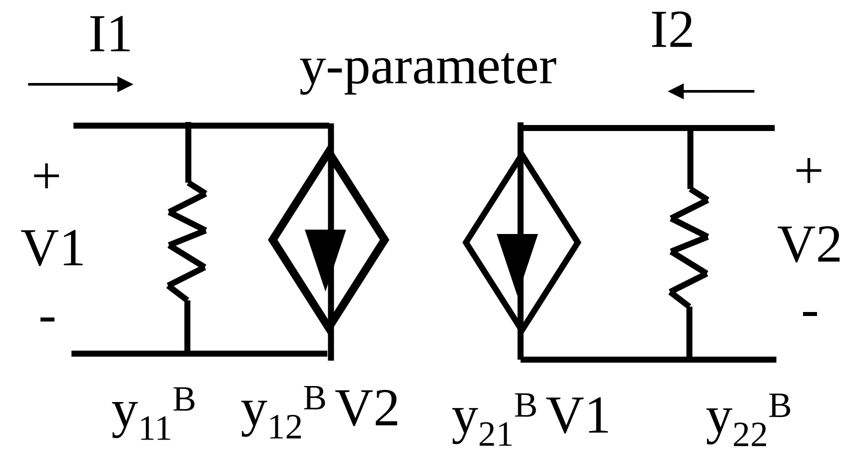
Rs = 10K // 100 = 99

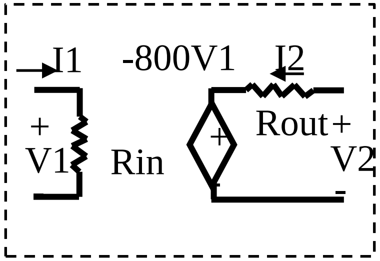
VOLTAGE-SHUNT FEEDBACK Y PARAMETERS

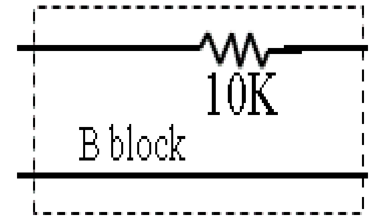
Find two port parameters for A block and B block.

$I1 = y_{11}\,V1 + y_{12}\,V2$

$I2 = y_{21}\,V1 + y_{22}\,V2$







$y_{11}{}^{A} = 1/1400 = 7.14E\text{-}4$

$y_{12}{}^{A} = 0$ (almost always)

$y_{21}{}^{A} = 800/100 = 8$

$y_{22}{}^{A} = 1/100 = 1E\text{-}2$

$y_{11}{}^{B} = 1/10K = 1E\text{-}4$

$y_{12}{}^{B} = -1/10K = -1E\text{-}4$

$y_{21}{}^{B} = -1/10K = -1E\text{-}4$

$y_{22}{}^{B} = 1/10K = 1E\text{-}4$

VOLTAGE-SHUNT FEEDBACK

Find the combined parameters

$y_{11} = y_{11}^A + y_{11}^B + 1/RS \quad = 7.14e\text{-}4 + 1e\text{-}4 + 1/99 \quad = 1.09e\text{-}2$

$y_{12} = y_{12}^A + y_{12}^B \quad = 0 + \text{-}1e\text{-}4 \quad = \text{-}1e\text{-}4$

$y_{21} = y_{21}^A + y_{21}^B \quad = 8 \text{ -}1e\text{-}4 \quad = 8$

$y_{22} = y_{22}^A + y_{22}^B + 1/RL \quad =1e\text{-}2 + 1e\text{-}4 + 1e\text{-}3 \quad = 1.11e\text{-}2$

Compute quantities of interest

Gain with feedback (transresistance)

$$A_{Rf} = \frac{\dfrac{-y_{21}}{y_{11}y_{22}}}{1 + \dfrac{-y_{12}y_{21}}{y_{11}y_{22}}} = \frac{\dfrac{-8}{(1.09e\text{-}2)(1.11e\text{-}2)}}{1 + \dfrac{-8(-1e\text{-}4)}{(1.09E\text{-}2)(1.11e\text{-}2)}} = -8680 \text{ ohms}$$

Voltage gain with feedback

$$A_{Vf} = A_{Rf}\,(1/RS) = -8680\ (1/99) = -87.7$$

VOLTAGE-SHUNT FEEDBACK

Current Gain with Feedback

$$A_{If} = A_{Rf}\ (1/RL) = -8680\ (1/1000) = -8.68$$

Approximate Gain

$$A_{Rf} \sim = 1/y_{12} = -1/1e\text{-}4 = -10000 \text{ ohms}$$
$$A_{Vf} \sim = -10000\ (1/RS) = -101$$
$$A_{If} \sim = -10000\ (1/RL) = -10$$

$$\text{Loop gain} = T = -\frac{y_{12}y_{21}}{y_{11}y_{22}} = (-1e\text{-}4)(-8)/(1.09E\text{-}2)(1.11E\text{-}2) = -6.61$$

VOLTAGE-SHUNT FEEDBACK

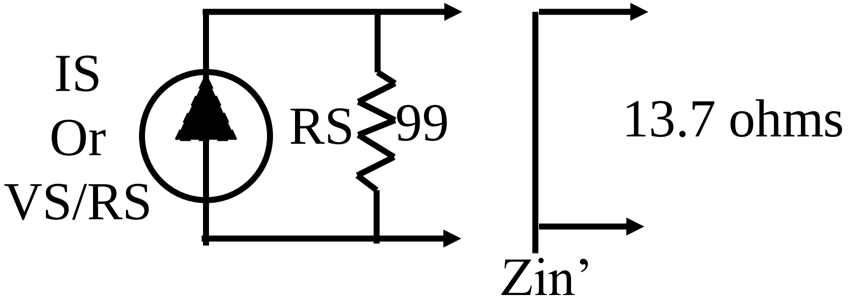
Input admittance $YIf = y_{11}\,(1 - T) = y_{11}\left(1 - \frac{y_{12}y_{21}}{y_{11}y_{22}}\right)$

$YIf = (1.09E\text{-}2)(1 - -6.61) = 82.9\ mS$

Input impedance $ZIf = 1/YIf = 12$ ohms

Note: this ZIf = 12 ohms is equal to the 99 ohms RS in parallel with Zin' the amplifier input impedance.

So 99//Zin' = 12 therefore we can find Zin' = 13.7 ohms



VOLTAGE-SHUNT FEEDBACK

Output Impedance Zof = 1/Yof

$$Yof = y_{22}\ (1\text{-}T) = y_{22}\ (1\text{- -}2.27) = 82.9\ mS$$

Zof = 1 / Yof = 12 ohms

Note: this 146 includes the 1000 ohm RL
so Zo’ (without RL) is = 12.1 ohms

SUMMARY

Amplifier Transresistance with no Feedback	1.12Meg ohms
Amplifier Voltage Gain with no Feedback	-800 V/V
Input Resistance with no Feedback	1400 ohms
Output Resistance with no Feedback	100 ohms
Amplifier Transresistance with Feedback	-8680 ohms
Amplifier Voltage Gain with Feedback	-87.7 V/V
Input Resistance with Feedback	13.7 ohms
Output Resistance With Feedback	12.1 ohms
Approximate Transresistance with Feedback	-10,000 ohms
Approximate Voltage Gain with Feedback	-101 V/V

REFERENCES

1. Sedra and Smith, 5.1-5.4
2. Device Electronics for Integrated Circuits, 2nd Edition, Kamins and Muller, John Wiley and Sons, 1986.
3. The Bipolar Junction Transistor, 2nd Edition, Gerald Neudeck, Addison-Wesley, 1989.