# LOSSLESS FEEDBACK AMPLIFIERS

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- Circuit Topologies which allow low frequency Stability
- Examples
- Future Research
- Conclusions

# REFERENCES/HISTORY


1. S. J. Mason, "Power Gain in Feedback Amplifiers," Trans. IRE Professional Group on Circuit Theory, vol. CT-1, no. 2, pp. 20-25, June 1954.
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3. L. Besser, "Stability Consideration of Low-Noise Transistor Amplifiers with Simultaneous Noise and Power Match," MTT Symposium, pp. 327-329, 1975.
4. G. D. Vendelin, "Feedback Effects on The Noise Performance of GaAs MESFETS," MTT Symposium, pp. 324-326, 1975.
5. G. D. Vendelin, "Feedback Effects in the GaAs MESFET Model," IEEE Trans. MTT, pp. 383-385, June 1976.
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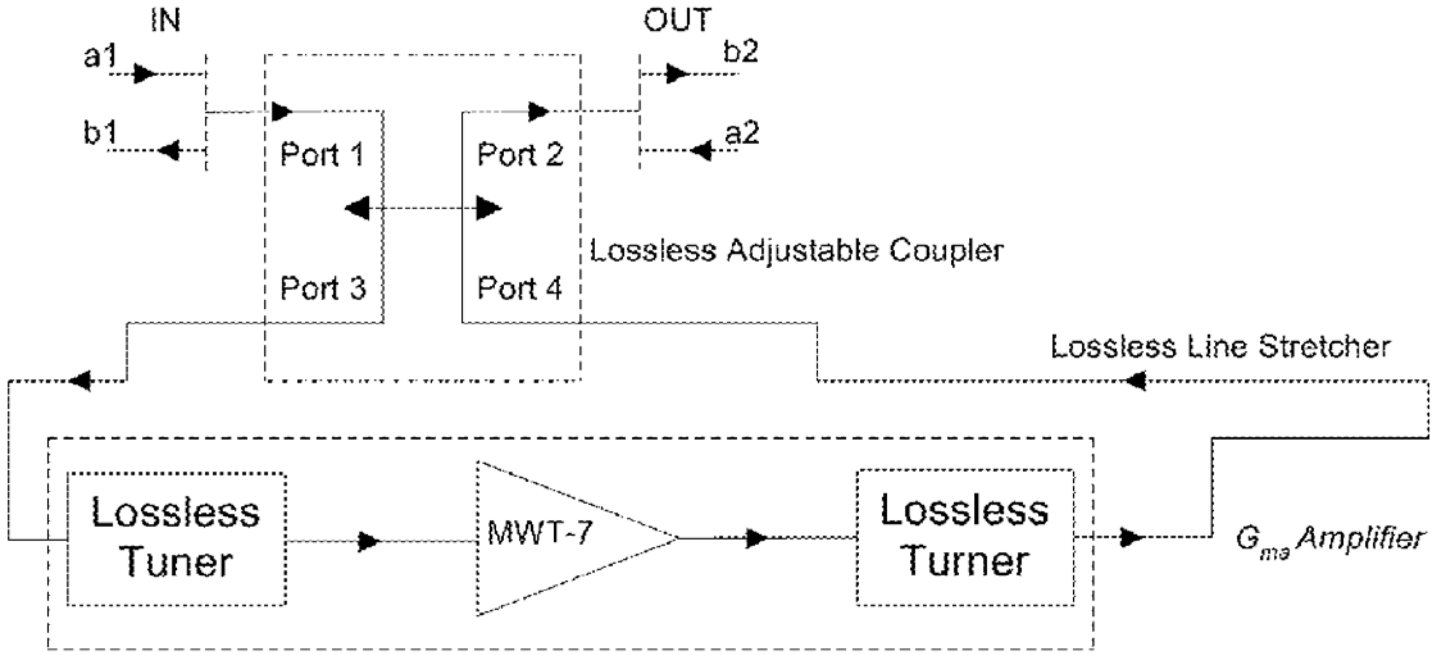
# Three types of Lossless FB-Amps – (1) High Gain Amplifiers (HGA)

- Unilateral Gain
  - Using lossless feedback network to make $y_{12}$ and $z_{12}$ approach zero to achieve high gain.



# High Gain Amplifiers (HGA)

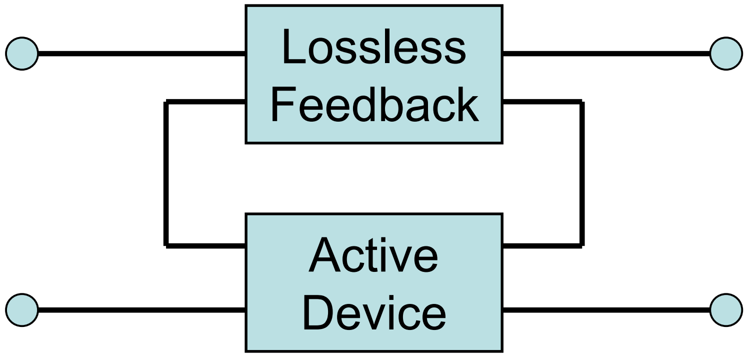
- Mason's Unilateral Gain ( U = 1 at $F_{max}$)

$$\mathrm{U} = \left|(S_{21}/S_{12}) - 1\right|^2 / 2\left[k\left|S_{21}/S_{12}\right| - \mathrm{Re}(S_{21}/S_{12})\right]$$

- How to unilateralize an active device?
  - 1955, C. C. Cheng showed 5 ways :
    - Series-Series feedback
    - Parallel-Parallel feedback
    - Series-Parallel feedback
    - Parallel-Series feedback
    - Series-oppositely Parallel feedback

# High Gain Amplifiers (HGA)

- General Design Procedure :
  - Build the bias circuits for the active device. Find S, Y, and Z-parameters of the device.
  - Choose proper feedback networks to unilateralize the active device.
    1. $Im(Y_{12}) = - Im(Y_{12FB})$
    2. $Im(Z_{12}) = - Im(Z_{12FB})$
    3. Optimize for U



# High Gain Amplifiers (HGA)

– Determine the values of feedback elements for $S_{12} = 0$.

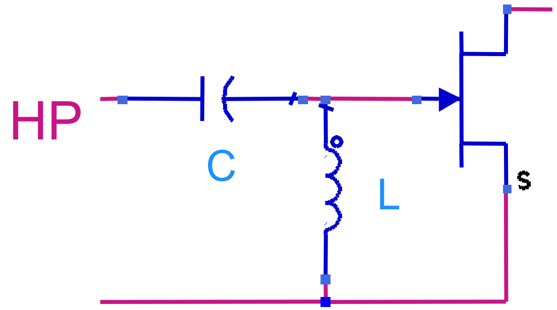
$$\mathbf{S} = \begin{bmatrix} 0 & 0 \\ \sqrt{U}\angle\theta & 0 \end{bmatrix}$$

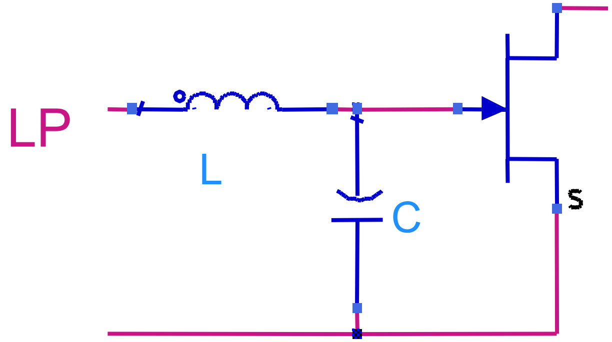
– Match the input and output impedance to the system characteristic impedance ($Z_0$). Make sure that the matching networks include shunt inductors to stabilize the amplifier.

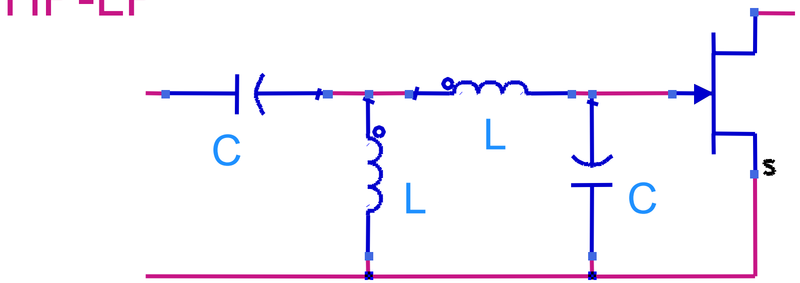
– Use stability circle method to verify the stability. If the circuit is still unstable, series a resister to the shunt inductor of the input or output.

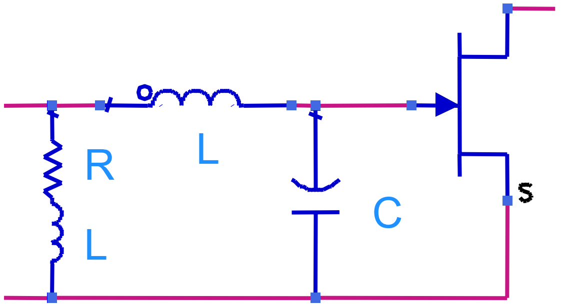
# Stability Considerations

Matching Topologies :



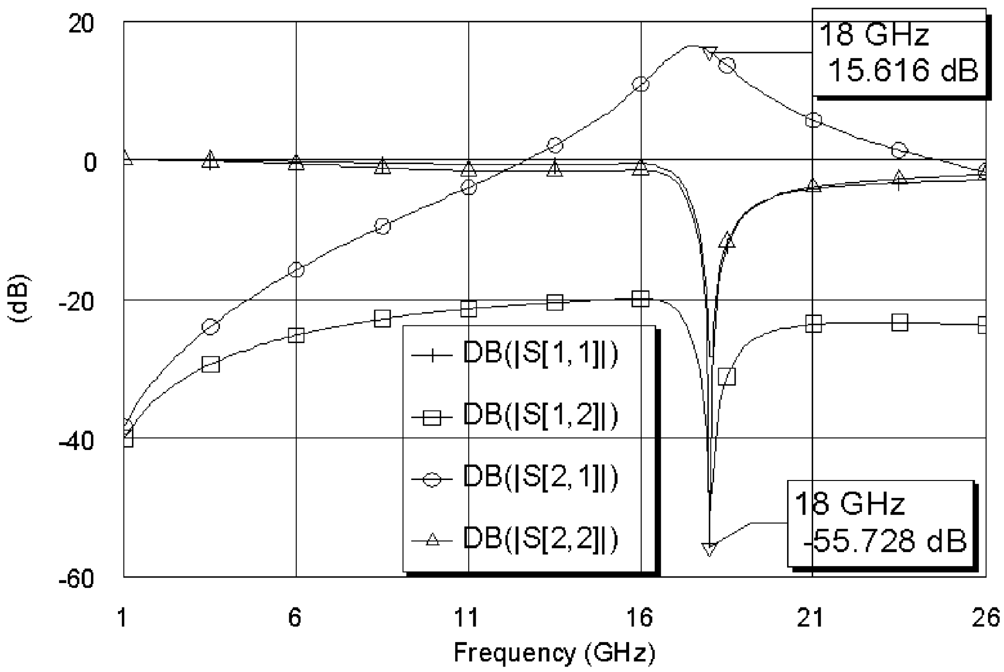

Resistor will help at low frequency.

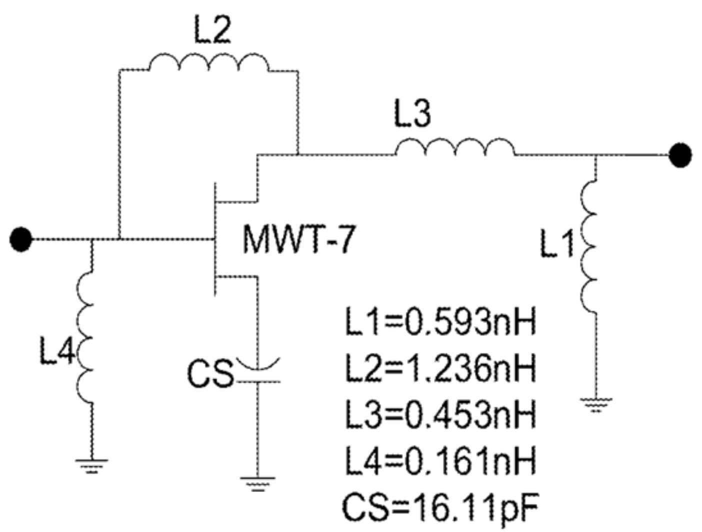
# Example for HGA

- Unilateral Amplifier

  U = 15 dB

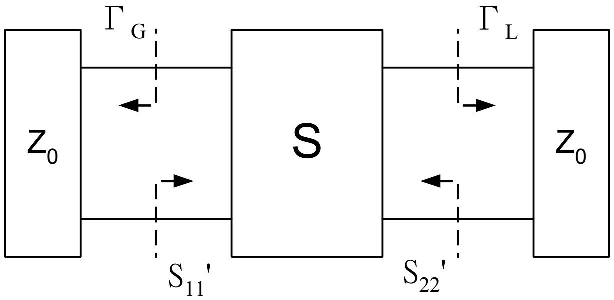
  Gma = 10 dB

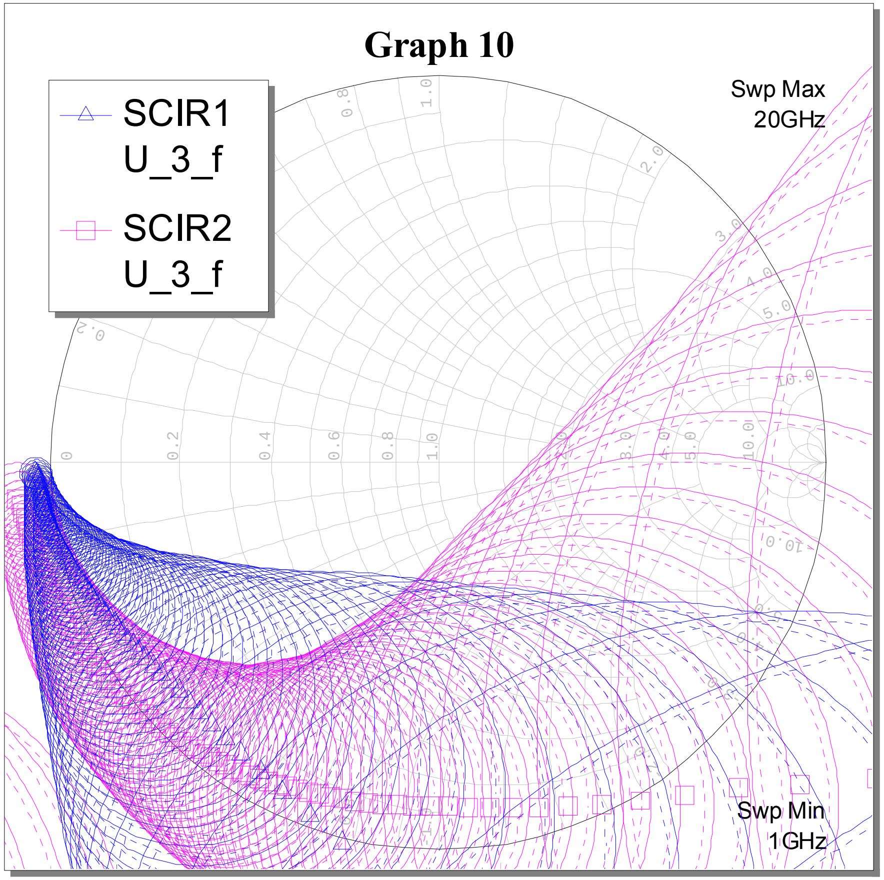


# Example for HGA

Stability Circles:
Blue lines are input Stability Circles.
Pink lines are output Stability Circles.
The concepts of the method are
$|\Gamma_G S_{11}'|<1$ and $|\Gamma_L S_{22}'|<1$ .

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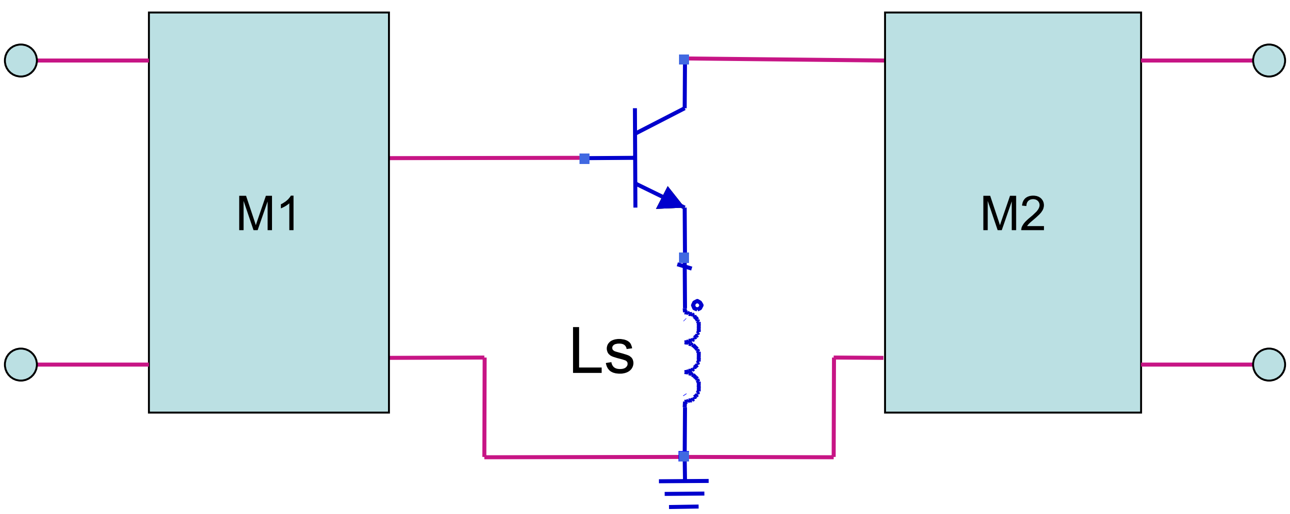
# Three types of Lossless FB-Amps – (2)
# Low Noise Amplifiers (LNA)

- Using lossless feedback network (For example Ls) and M1 to achieve low noise with S11'=0.
- Ls resonates Cgs.



# Low Noise Amplifiers (LNA)

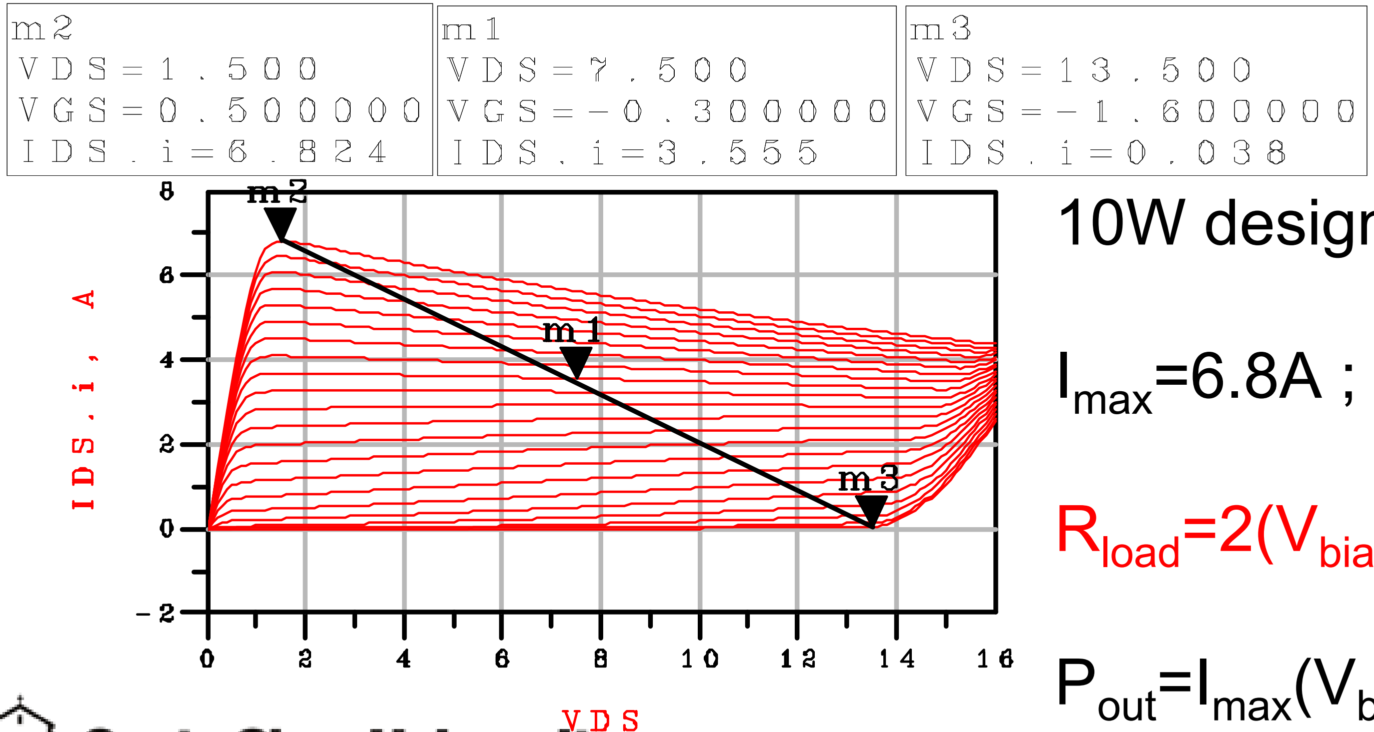
- LNA
  - -- $G_A = |S_{21}|^2 \left(1-|\Gamma_G|^2\right) / \left[|1 - S_{22}\Gamma_G|^2 \left(1-|S_{11}'|^2\right)\right]$
  - -- $S_{11}' = 0$
  - -- $F = F_{min}$

  Uses common lead inductor to resonate input capacitor

$$\mathbf{S} = \begin{bmatrix} 0 & S_{12}\angle\theta_2 \\ \sqrt{G_A}\angle\theta_1 & 0 \end{bmatrix}$$

# Three types of Lossless FB-Amps – (3)
# High Power Amplifiers (HPA)

- Maximum Power
  - Make $Z_{load}$ load impedance for maximum power output.
  - Class A Operation for best Linearity.




10W design ; $V_{m2}$=1.5V

$I_{max}$=6.8A ; $V_{m1}=V_{bias}$=7.5V

$R_{load}=2(V_{bias}-V_{m2})/I_{max}$

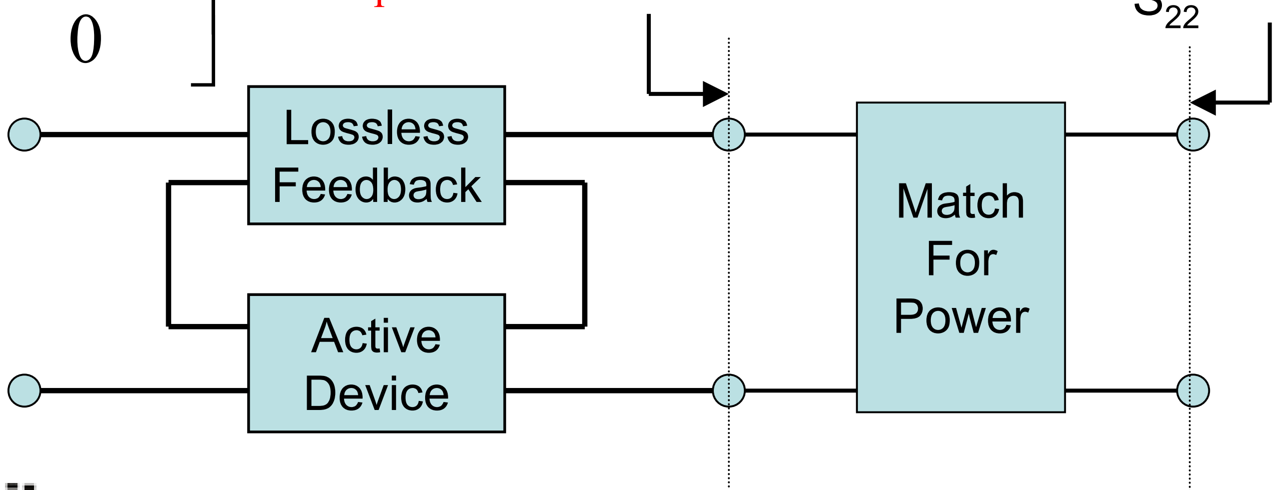
$P_{out}=I_{max}(V_{bias}-V_{m2})/4$

# High Power Amplifiers (HPA)

- HPA
  - $G = |S_{21}|^2 \left(1-|\Gamma_L|^2\right) / \left[|1 - S_{22}\Gamma_L|^2 \left(1-|S_{11}'|^2\right)\right]$
  - $S_{22}' = 0$
- Use losses FB to give $P_{out} = P_{1dBc}$ when $S_{22}' = 0$.

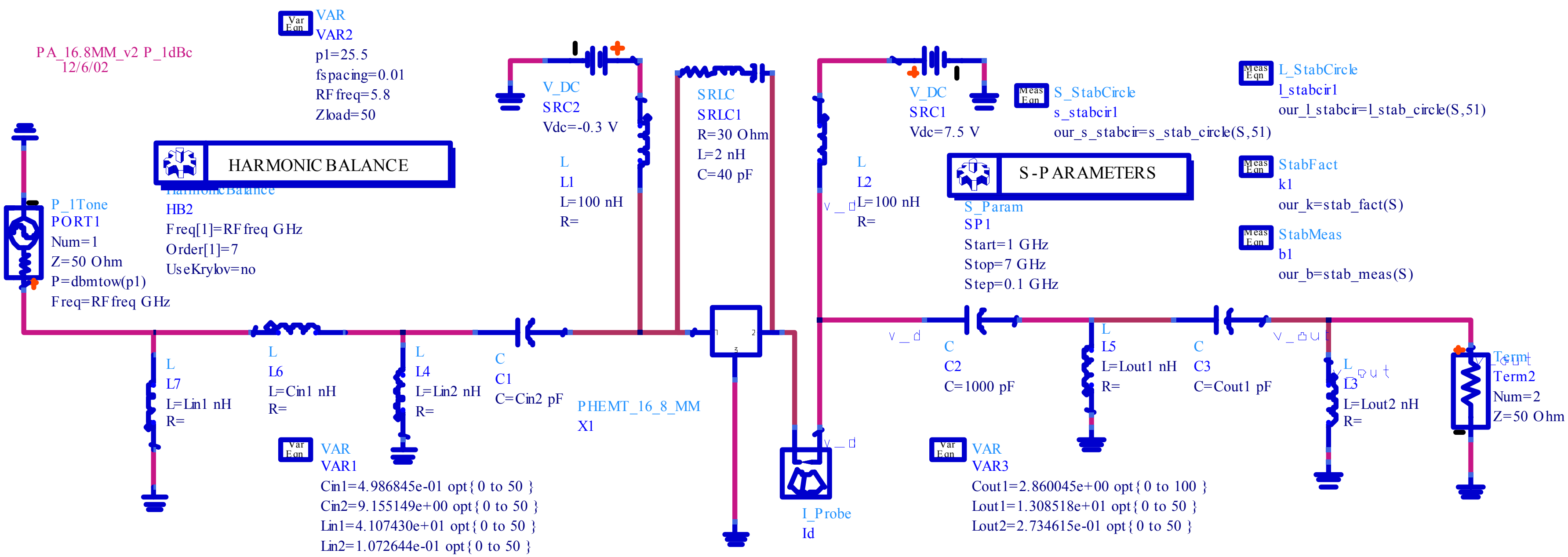
$$\mathbf{S} = \begin{bmatrix} 0 & S_{12}\angle\theta_4 \\ \sqrt{G}\angle\theta_3 & 0 \end{bmatrix}$$

$\Gamma_{opt} = (R_{Load} - Z_0) / (R_{Load} + Z_0)$



# Example for HPA (10W PA)

- 150um x 8 x 14 = 16.8 mm. PHEMT at 5.8GHz.
- 10 W output = 40 dBm for $P_{1dBc}$ ; TOI= $P_{1dBc}$ + 10dBm.
- PAE = 45% ; $R_{load}$= 1.2 Ohms.



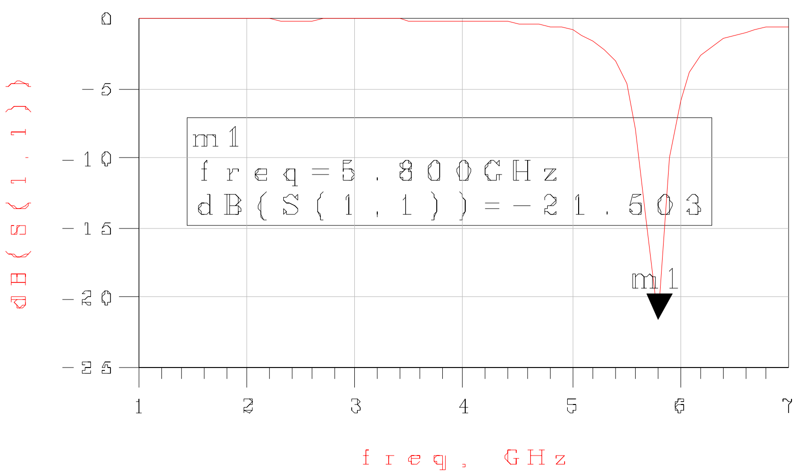
# Example for HPA (10W PA)

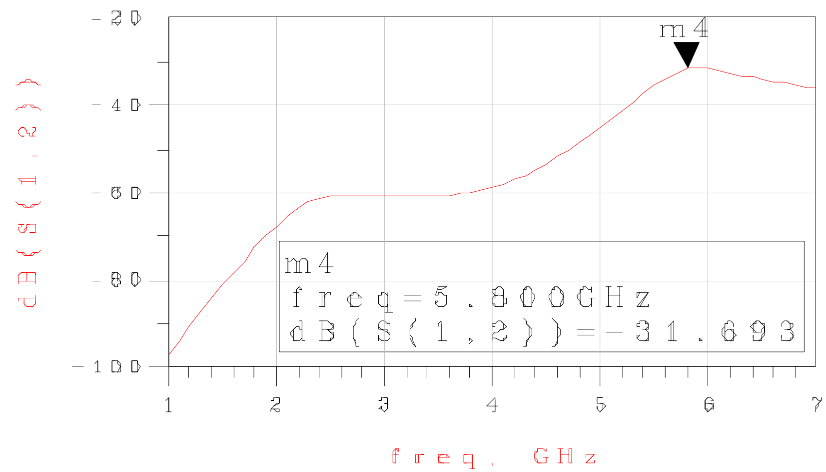
- Design Procedure :
  1. Get the Ids Vs Vds curves using the curve tracer. Choose the bias point.
  2. Choose the load line for high power and high linearity.
  3. Design the output match for the load line.
  4. Get the P_1dBc.
  5. Check the dynamic load line.
  6. Check $S_{11}$'. Design the input match for $S_{11}$'.

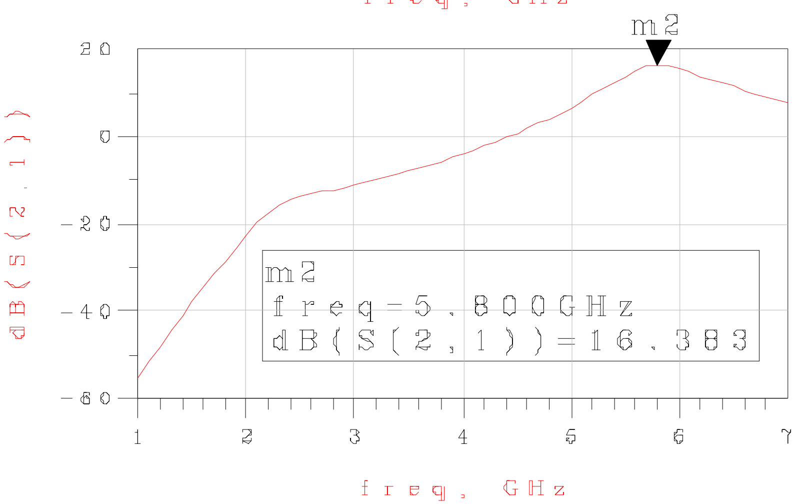
# Example for HPA (10W PA)

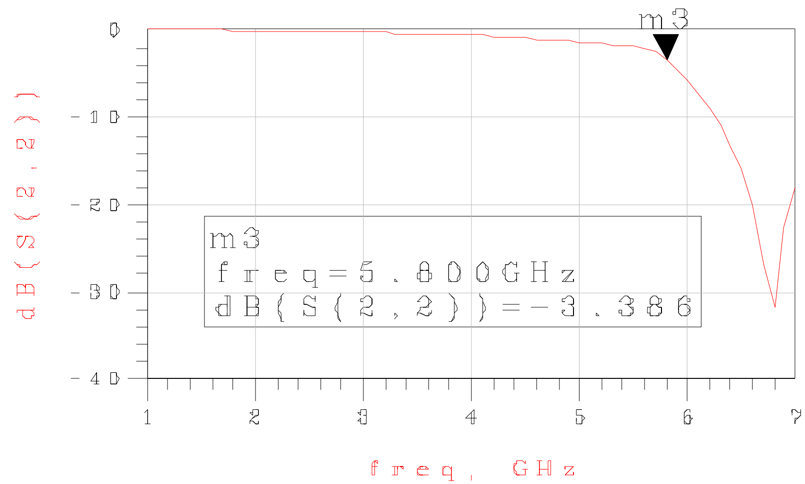
7. Get TOI.
8. Check for stability.
9. Put a feedback on.
10. Adjust as required to meet the specifications. Use no resistors. For TOI, a resistor may be necessary.

# Example for HPA (10W PA)

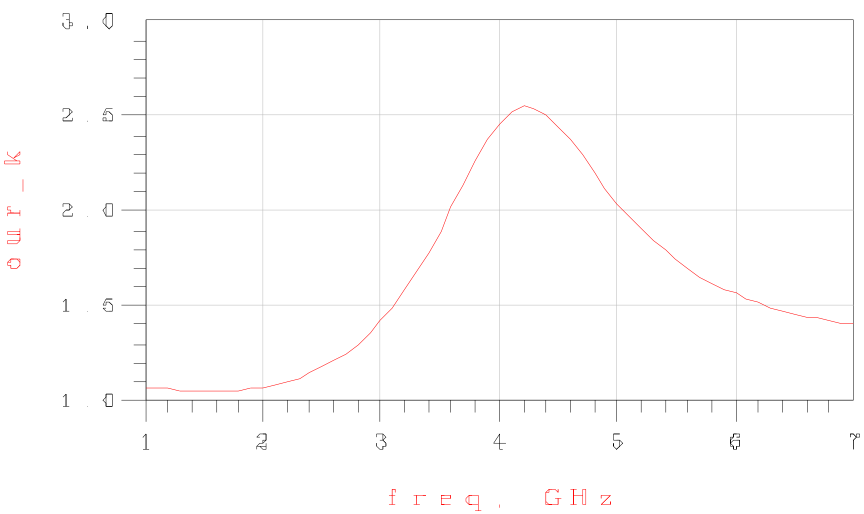


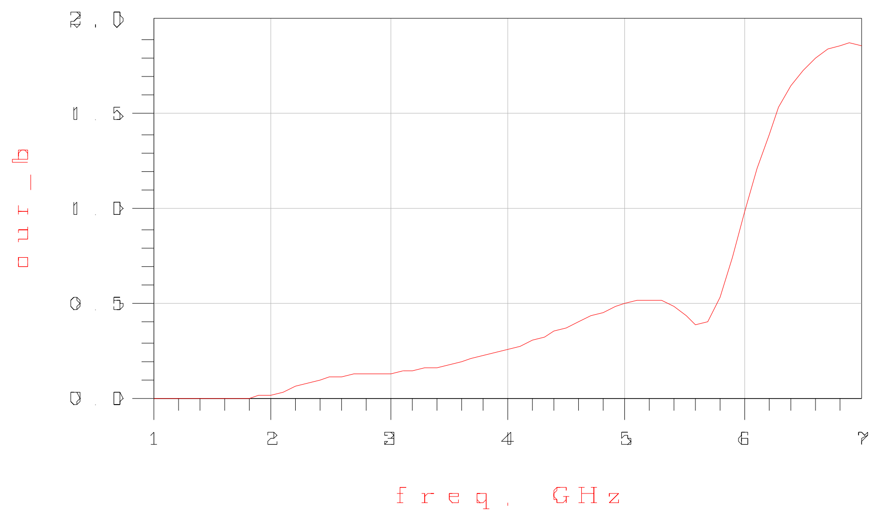



# Example for HPA (10W PA)




K > 1 & B > 0. The circuits is unconditional stable.

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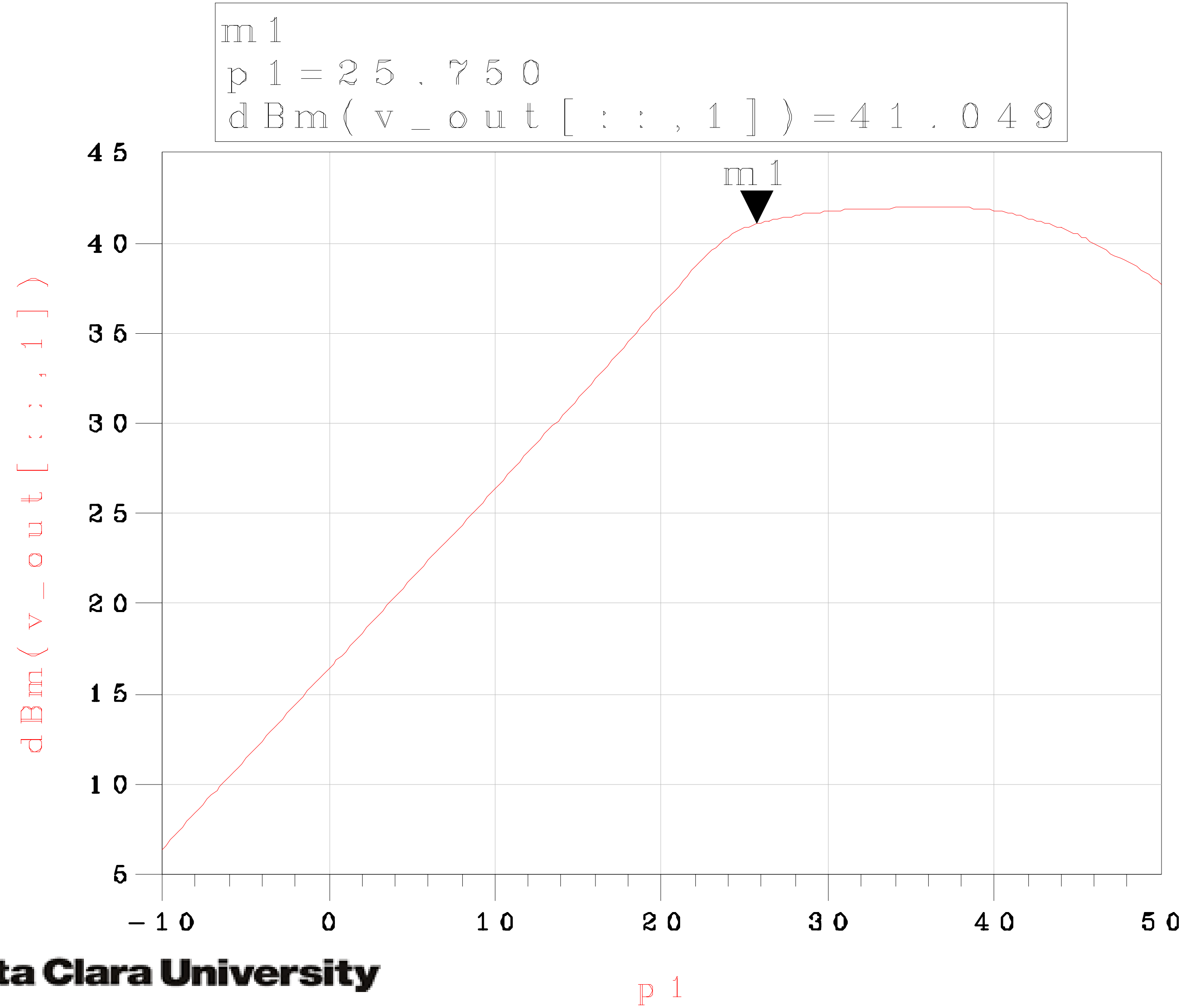
# Example for HPA (10W PA)

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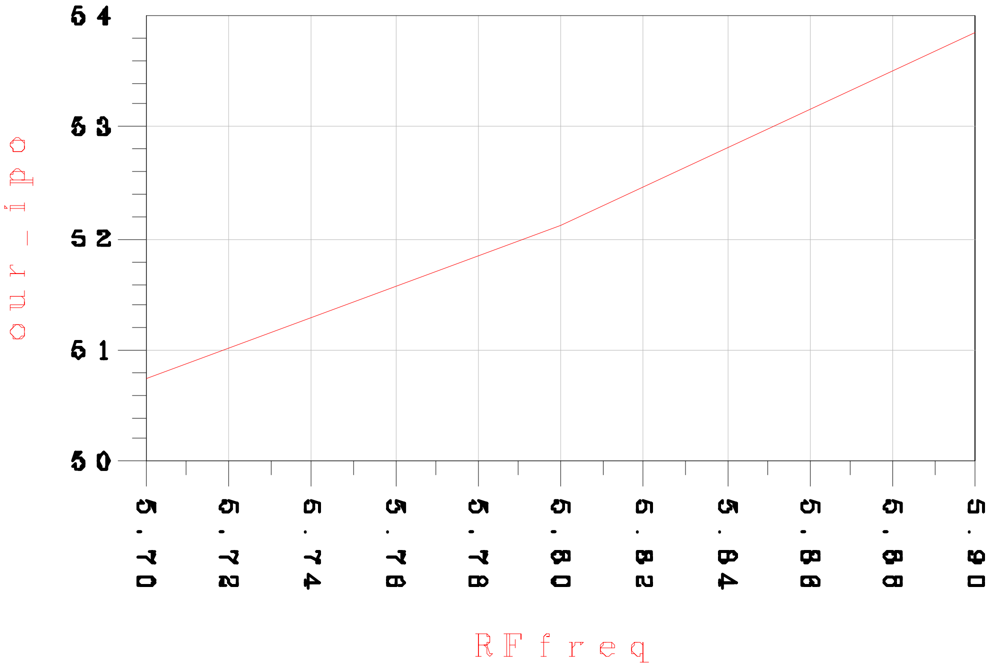
# Example for HPA (10W PA)

TOI

| RFfreq | our_ipo |
|---|---|
| 5.700 | 50.746 |
| 5.800 | 52.125 |
| 5.900 | 53.855 |

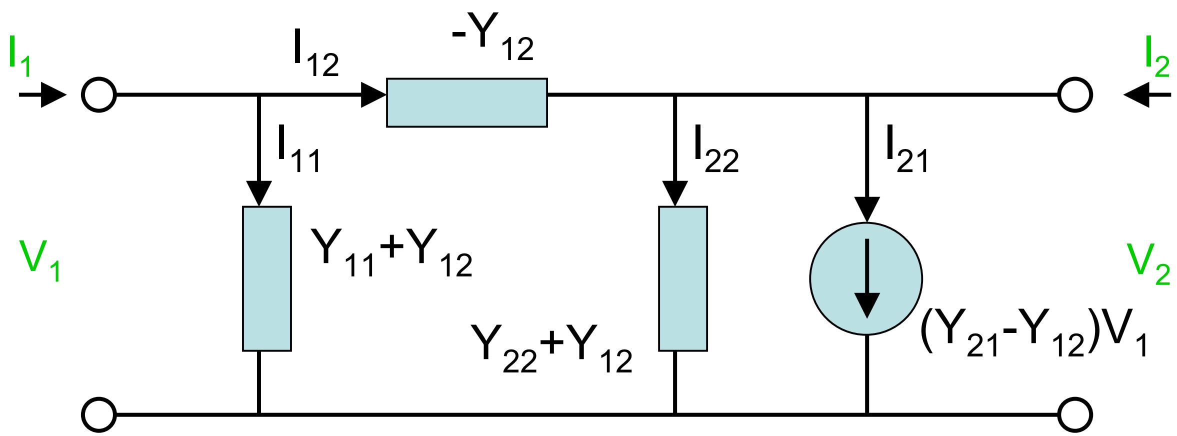


# Future Research

- Future Research on HPA.
  - LNA has been published for $F_{min}$ & $S_{11}' = 0$.
  - HPA has not been analytically solved for $P_{1dBc}$ & $S_{22}' = 0$.
- Explain cause of $Re(Y_{12}) < 0$ for FET.
  - For BJT, $Re(Y_{12}) > 0$ .
  - For FET, $Re(Y_{12}) < 0$ . 1976, Vendelin.

# Future Research

Y Parameter Equivalent Circuits.




- $I_{11} = (Y_{11}+Y_{12})\, V_1 \quad ; \quad I_{12} = (-Y_{12})(V_1-V_2)$ .
- $I_{21} = (Y_{21}-Y_{12})\, V_1 \quad ; \quad I_{22} = (Y_{22}+Y_{12})\, V_2$ .
- $I_1 = I_{11}+I_{12} = (Y_{11}+Y_{12})\, V_1 + (-Y_{12})(V_1-V_2)$

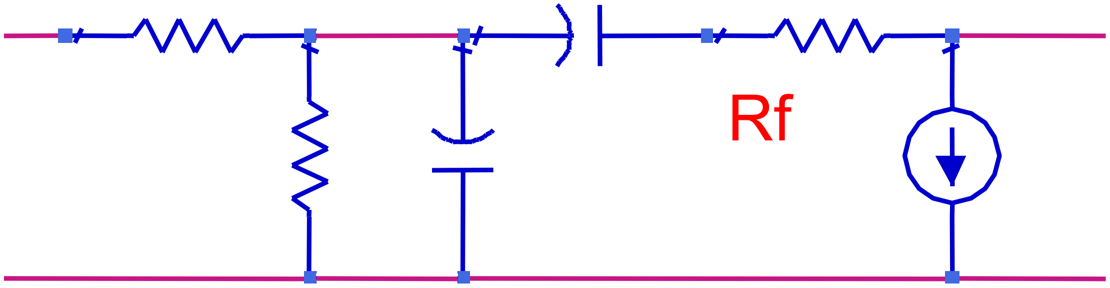
  $= Y_{11}V_1 + Y_{12}V_2$ .
- $I_2 = (Y_{21}-Y_{12})\, V_1 + (Y_{22}+Y_{12})\, V_2 - (-Y_{12})(V_1-V_2)$

  $= Y_{21}V_1 + Y_{22}V_2$ .

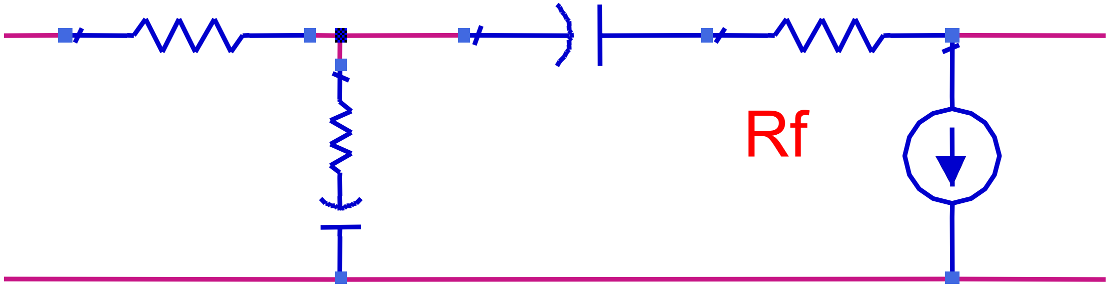
# Future Research

## $Y_{12}$ Resistor

BJT Rf > 0.




FET Rf < 0. (Low Freq.)



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# Conclusions

- Lossless feedback improves performance of HGA, LNA, & HPA.
- Stability is a biggest issue.
- Read IEEE Microwave Wireless Components Letters, March 2003 for details
- Read 2nd Edition of Wiley Book due Sep. 2003