Wideband Amplifiers

3/2/09
EE 242

Topics:

1- Broadband vs. Wideband

Open circuit time constants O.C.τ

Bootstraping the capacitors

2- F.B. Amplifiers

3- Increasing the gain by inserting zeros in the T.F.

Shunt Peaked Amplifiers

4- distributed Amplifiers

5- Tuned Amplifiers G.BW.

effect of C_{gd} and cancelling it

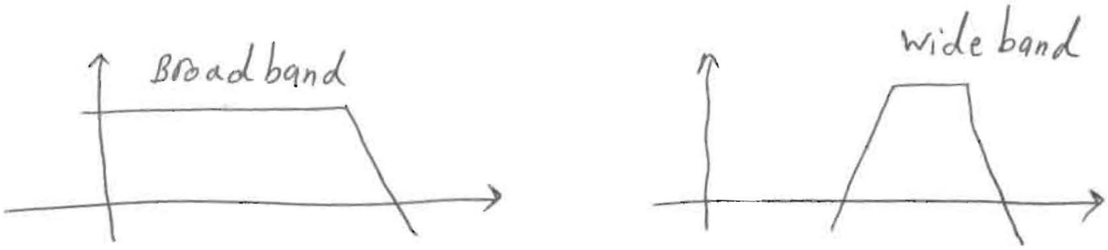
6- Multisection Matching Networks

Andrea's Amplifier example

Fano's S_{11}-BW relation

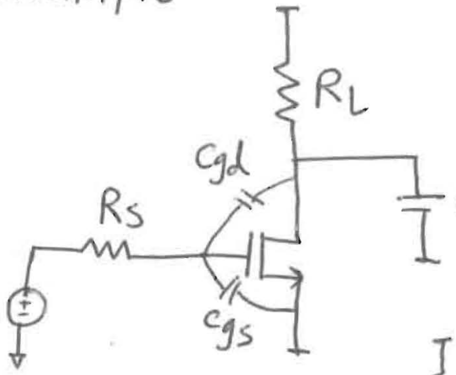
7- Transformer Matching Networks

Broad band & Wide band



- O.C.τ : - good for B.W. estimating of an all-pole system with one dominant pole
  - approximation fails when several poles are close on on top of each other

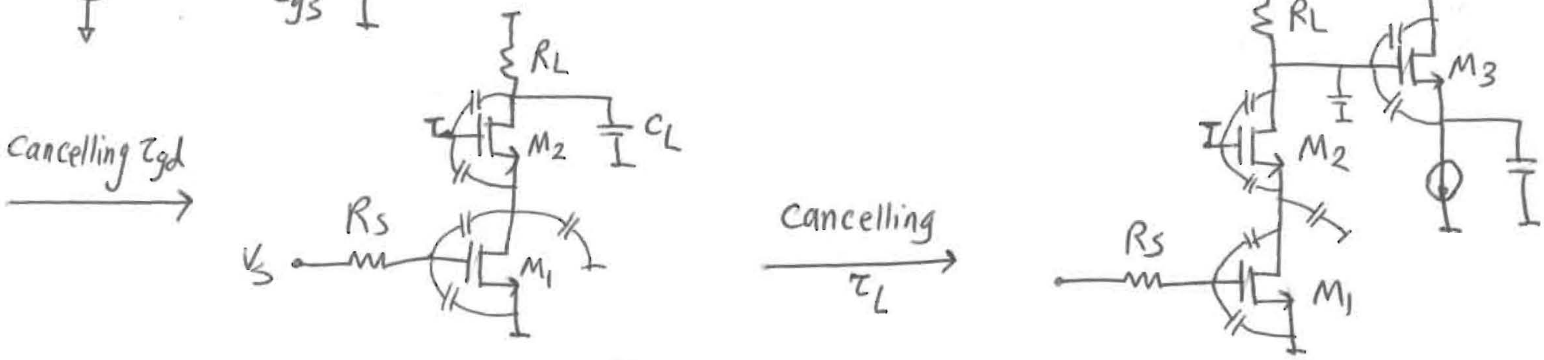
- example

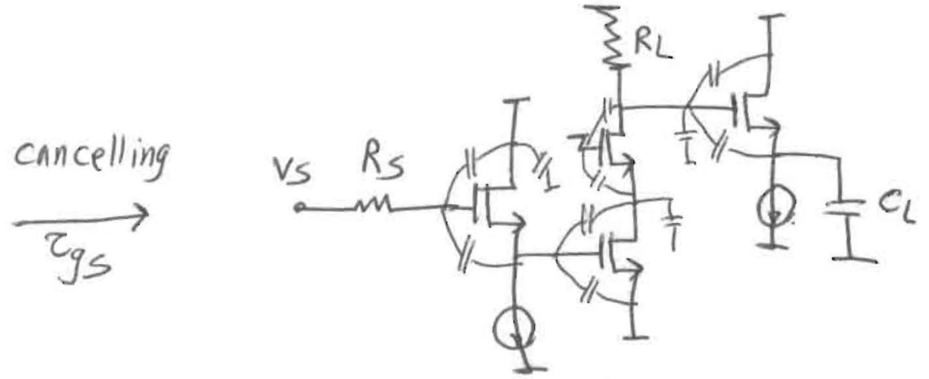


$\tau_{gs} = C_{gs} R_S$

$\tau_{gd} = C_{gd} (R_S + R_L + g_m R_S R_L)$

$\tau_L = C_L (R_L \| r_o)$



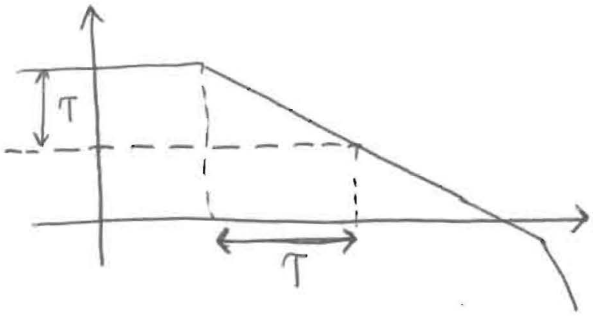


⇒ Power-speed Trade-off

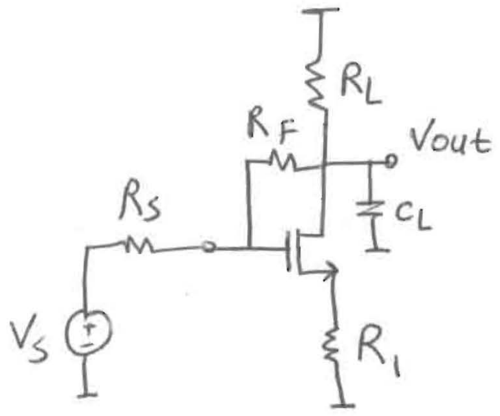
Feed back Amplifiers :

For low order systems [systems with one dominant Pole]

Product of Gain x B.W. is constant



shunt-series Amplifier



After using F.B.

G ↓

R_i, R_o ↓ ⇒ matching acquired

B.W. ↑

$$A_V = -\frac{R_L}{R_E}\,\frac{R_F - R_E}{R_F + R_E} \qquad R_E = \frac{g_m}{1 + g_m R_1}$$

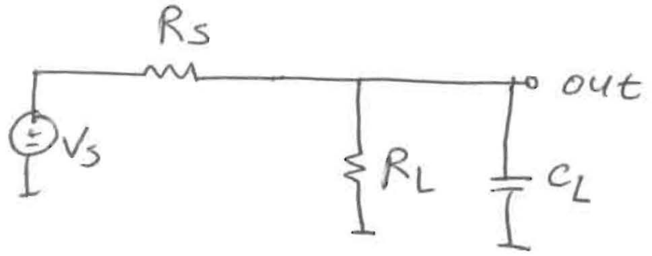
$$R_{in} = \frac{R_E (R_F + R_L)}{R_E + R_L}$$

$$R_{out} = \frac{R_E (R_F + R_S)}{R_E + R_S}$$

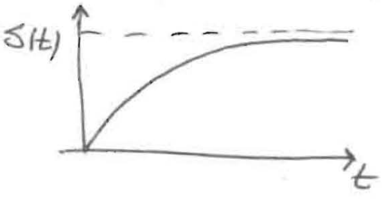
$$BW = 1/\left(A_V\left(\frac{c_{gs}}{g_m} + \frac{R_L c_{gd}}{2}\right)\right)$$

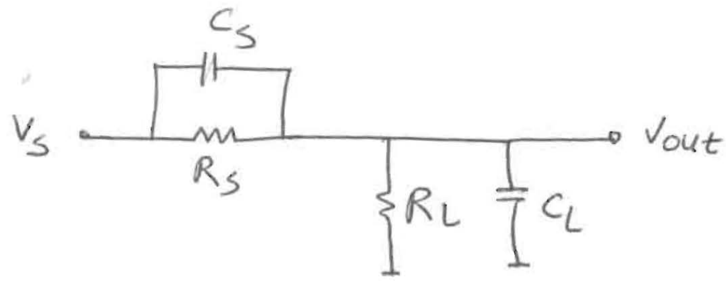
Addition of Zeros to the T.F.

concept:



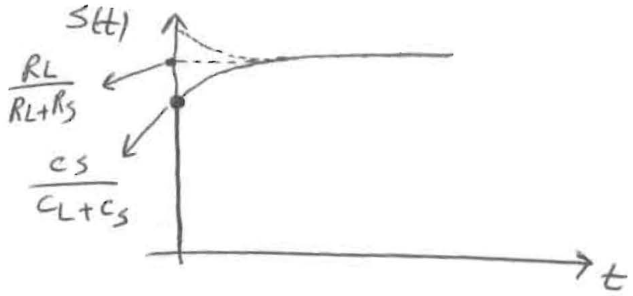
$\tau = C_L (R_S \| R_L)$





at $t=0^+$ $\quad V_{out} = \dfrac{C_S}{C_L + C_S} V_S$

$t=\infty$ $\quad V_{out} = \dfrac{R_L}{R_L + R_S} V_S$

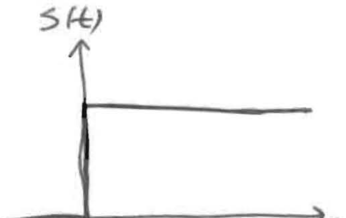


$$\tau = (R_L \| R_S)(C_L + C_S)$$

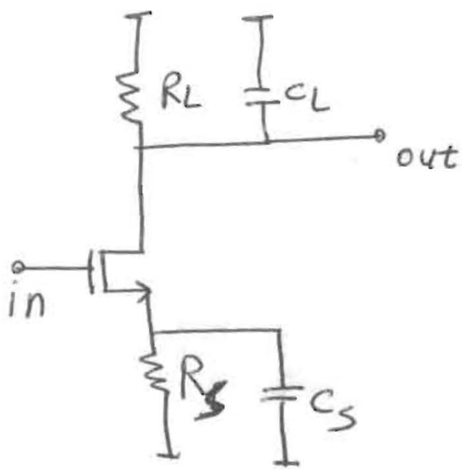
$$\frac{V_{out}}{V_S} = \frac{\dfrac{R_L}{1+R_L C_L s}}{\dfrac{R_L}{1+R_L C_L s} + \dfrac{R_S}{1+R_S C_S s}} = \frac{R_L}{R_L + R_S} \; \frac{1 + R_S C_S s}{1 + (R_L \| R_S)(C_L + C_S) s}$$

$$z = \frac{-1}{R_S C_S}, \quad P = \frac{-1}{(R_L \| R_S)(C_L + C_S)}$$

if $P = z \rightarrow R_S C_S = R_L C_L \Rightarrow$



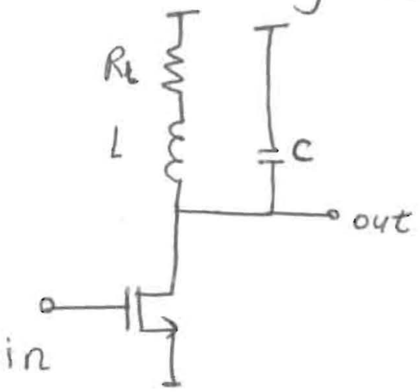
- Application

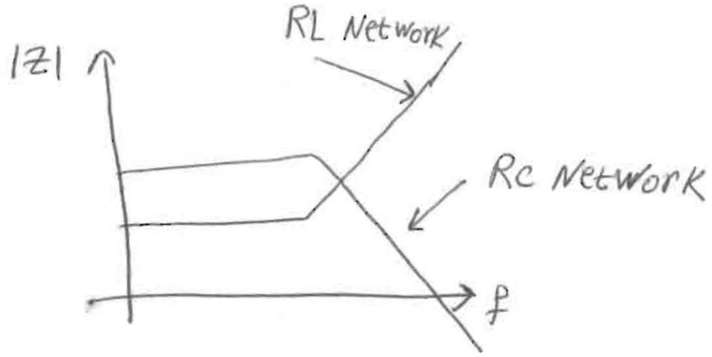


if $R_S C_S = R_L C_L$

$$\frac{v_{out}}{v_{in}} \approx \frac{Z_{out}}{Z_{in}}$$ → constant over frequency up to a fraction of

- shunt Peaking Amplifier





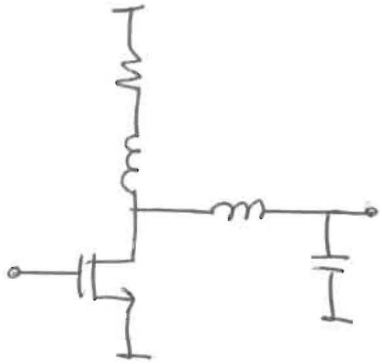
$$Z = (R+Ls) \parallel \frac{1}{Cs} = \frac{R\left[s\left[\frac{L}{R}\right]+1\right]}{s^2 LC + sRC + 1}$$

$$m = \frac{RC}{L/R}, \quad \tau = L/R$$

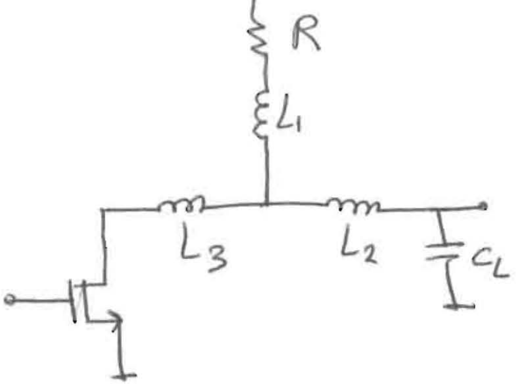
$$\Rightarrow \frac{|Z|}{R} = \sqrt{\frac{1+(\omega\tau)^2}{(1-\omega^2\tau^2 m^2) + (\omega\tau m)^2}},$$

	m	Normalized B.W.	Normalized Peak
Max B.W.	$\sqrt{2}$	1.85	1.19
$\lvert Z\rvert = R$ @ $\omega = 1/RC$	2	1.8	1.03
Maximally flat	$1+\sqrt{2}$	1.72	1
Best group delay	3.1	1.6	1
No shunt Peaking	∞	1	1

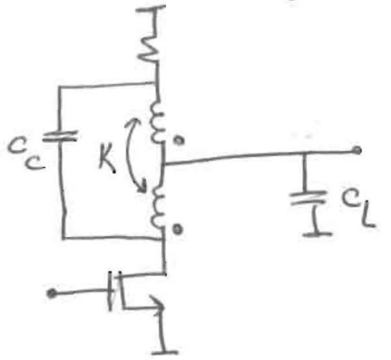
Shunt Peaking cont'd



shunt and series Peaking



shunt- and double series Peaking



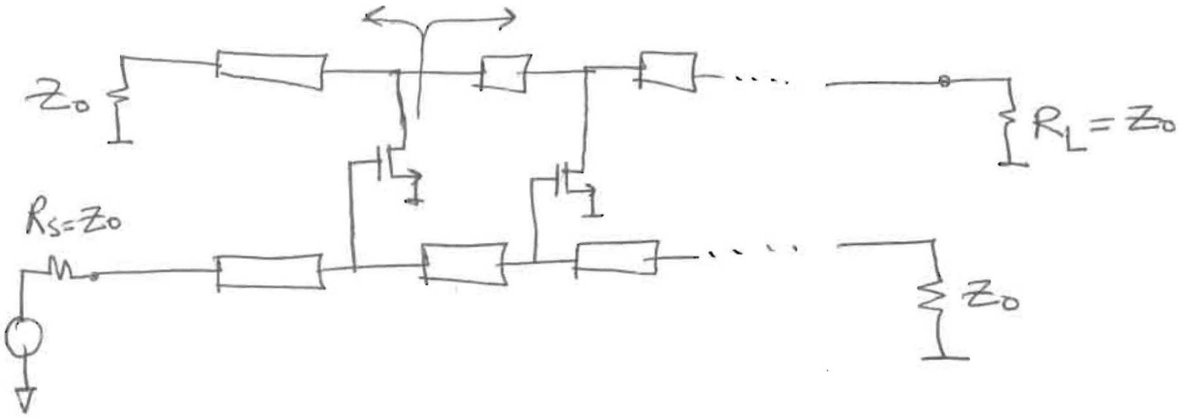
T-coil B.W. enhancement

⇒ basically the order of matching network is increasing and it's resembling a synthesized TL.

In above structures Parasitic caps are charged and discharge[d] serially so the current available to charge a cap is more and hence the rise time is shorter at the expense of delay

⇒ the ultimate case : A distributed amplifier

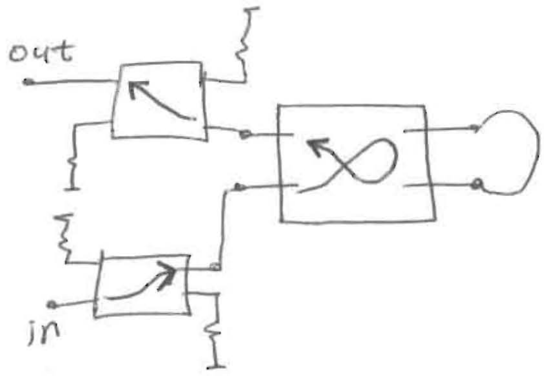
7- Distributed Amplifier



$$A_V = n g_m \left(\frac{Z_0}{2}\right) e^{-t_d w}$$

Additive gain, very high B.W. up to $\frac{f_T}{2}$

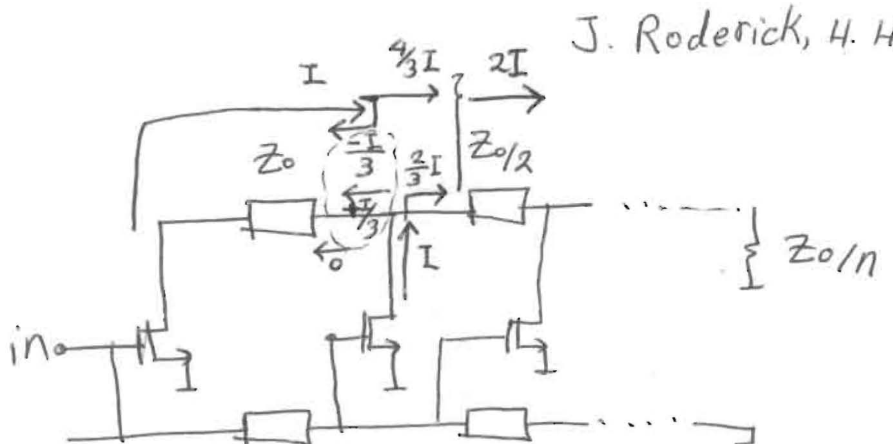
- to reuse the signal going into the isolated termination



A. Arbabian, A.M. Niknejad (ISSCC 2008)

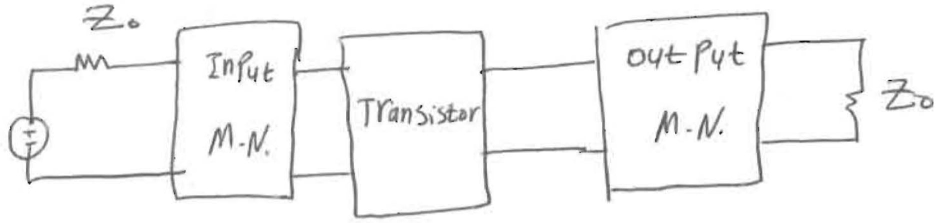
or

J. Roderick, H. Hashemi (ISSCC 2009)



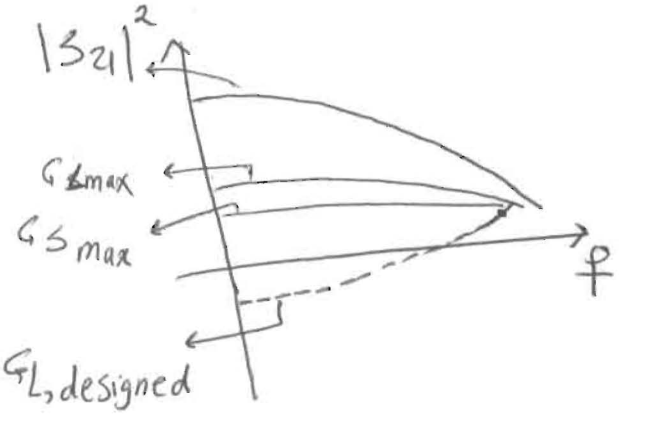
8 - Wide band Amplifiers

- Increasing the B.W. through Matching Network:

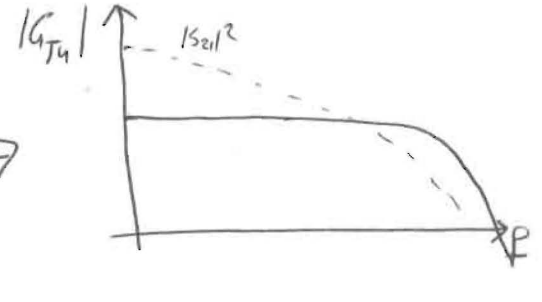


$$G_{TU,max} = \frac{1}{1-|S_{11}|^2} \, |S_{21}|^2 \, \frac{1}{1-|S_{22}|^2}$$

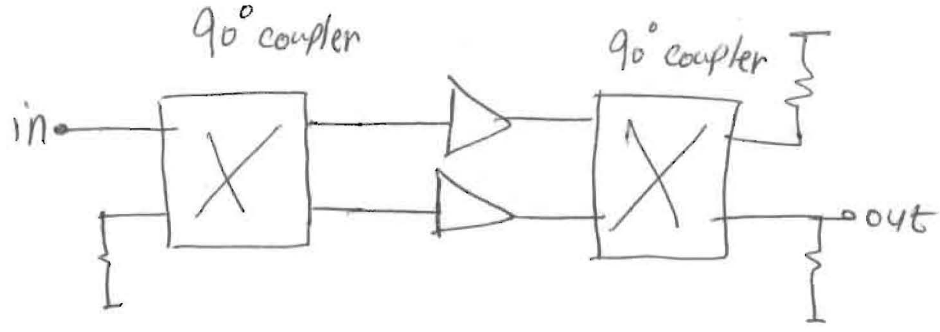
$$G_{S max} = \frac{1}{1-|S_{11}|^2} \qquad G_{L max} = \frac{1}{1-|S_{22}|^2}$$



$\Rightarrow$

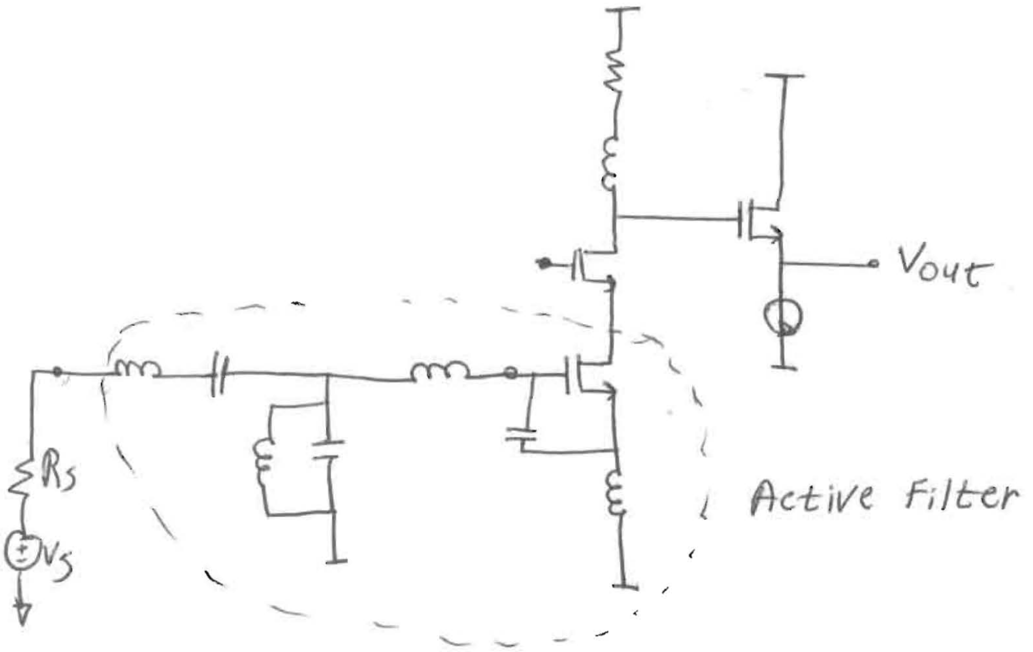


$\Rightarrow$ To fix the mismatch (Balanced Amplifiers)



9- Highe order Matching Networks

A. Bevilacqua, A.M. Niknejad (ISSCC 2004)

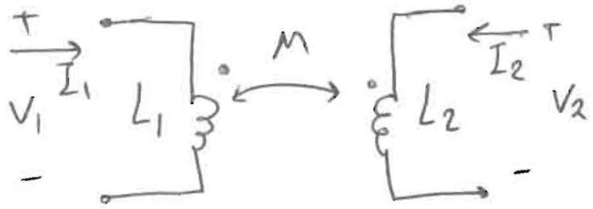


- mitigating the effect of C_{gd}

→ unilateralization (cascode, ~~cross~~ source-coupled Pair)

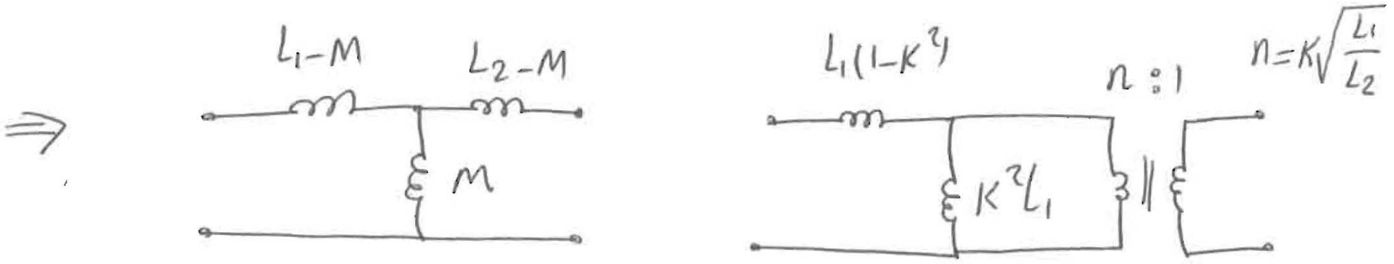
→ Neutralization

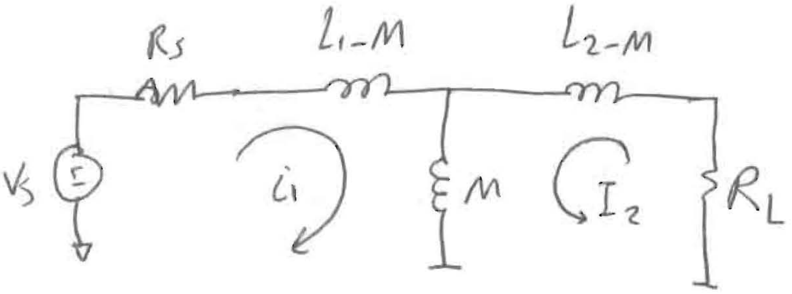
10- Transformer Matching



$$\begin{cases} V_1 = L_1 s I_1 + M s I_2 \\ V_2 = M s I_1 + L_2 s I_2 \end{cases}$$

$\Rightarrow$



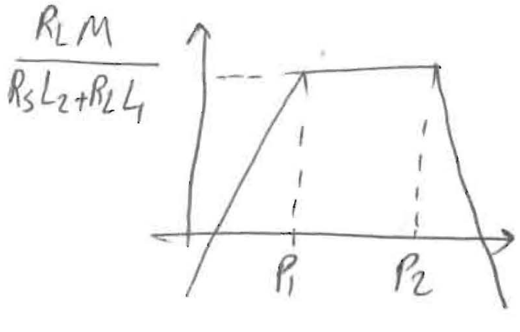


Mesh Analysis $\longrightarrow$ $$\frac{V_{out}}{V_S} = \frac{R_L M s}{s^2(L_1L_2 - M^2) + s(R_S L_2 + R_L L_1) + R_S R_L}$$

$$\frac{V_{out}}{V_1} = \frac{R_L M}{L_1 L_2 - M^2}\,\frac{s}{(s-P_1)(s-P_2)}$$

if $P_2 \gg P_1 \Rightarrow P_1 = -\dfrac{R_S R_L}{R_S L_2 + R_L L_1}$

$$P_2 \approx P_1 + P_2 = -\frac{R_S L_2 + R_L L_1}{L_1 L_2 - M^2}$$



mid_band $\dfrac{V_{out}}{V_S} = \dfrac{R_L M}{R_S L_2 + R_L L_1}$

$R_S \to 0$
$R_L \to \infty \Rightarrow A = K\sqrt{\frac{L_2}{L_1}} = K\left(\frac{N_2}{N_1}\right)$