ECE 513 – Lecture 20

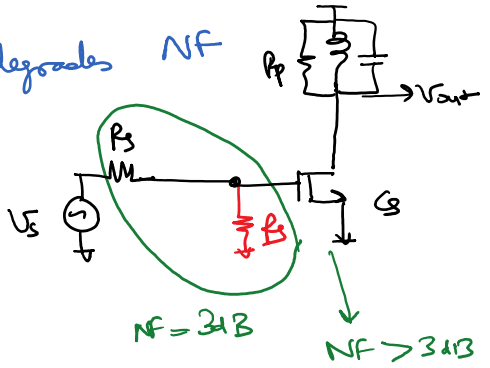
Tuesday, October 23, 2018 1:59 PM

Part I: Active Device Matching

optimized $W = W_f \cdot N_f$ to obtain a noise match i.e. $Re\{Z_{SOPT}\} = Z_0 = 50\Omega$

Part II: Passive Component Matching

* Adding resistive component for matching degrades NF
* Purely reactive components do not add noise
  - ↳ Ideal inductors, transformers, Transmission Lines (TL), and/or Capacitors.
  - ↳ These elements have loss resistance ⇒ finite Q
  - ↳ Inductors occupy large area on-chip
  - ↳ In an LNA, inductors are more force dominant.



$$Q_L = \frac{\omega_0 L_S}{R_S}$$

Tuesday, October 23, 2018 2:10 PM

Design philosophy for Impedance Match:

* Select LNA topology with the lowest number of transistors
  - ↳ avoid active loads or active inductors → degrade NF & linearity

* Bias the transistors at J_{OPT} of the topology ← $NF = NF_{min}$
  - ↳ choose the optimal finger width W_f for least NF_{min}

* Calculate the transistor size (n_f) that corresponds to $R_{S,OPT} = Z_0$

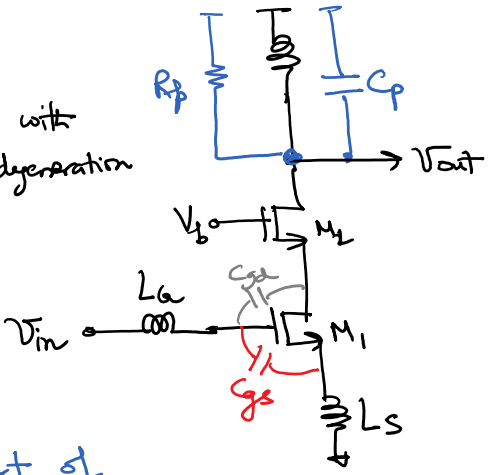
↓ New part

* Add reactive (lossless) feedback to transform the real part of the input resistance ($R_{in} = Re(Z_{in})$) to the desired value, i.e. Z_0

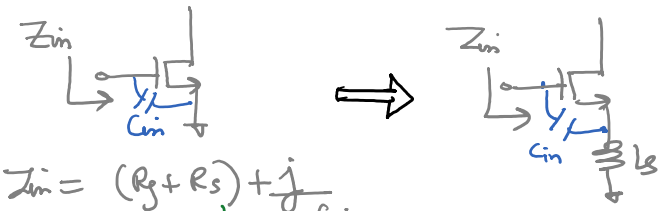
* Add reactive matching to "tune out" the imaginary parts of the optimum noise impedance ($Z_{S,OPT}$) as well as the input impedance (Z_{in})

LNAs with Inductive Degeneration

* most widely used topology → Cascode with inductive degeneration



* lossless inductor L_S is a series-series feedback
  - ↳ Doesn't alter the real part of transistor's Z_{sopt} & overall N_{Fmin} (Analyzed in chapter 5) Series_Series feedback



use Cascode f_T not CS f_T

$$Z_{in} = (R_g + R_s + \omega_T L_s) + j\left(\omega_0 L_s - \frac{1}{\omega_0 C_{in}} + \omega_0 L_G\right)$$

$(R_g + R_s + \omega_T L_s) \Rightarrow Z_0$

$\Rightarrow 0$ at $\omega = \omega_0$

$$L_s = \frac{Z_0 - R_g - R_s}{2\pi f_T}$$

Impedance match $Re\{Z_{in}\} = Z_0$

$$L_G \simeq \frac{\omega_T}{\omega^2 g_{meff}} - L_s$$

Cancel imaginary part of Z_{in}

$\therefore \omega_T = \frac{g_{meff}}{C_{in}}$

$Im\{Z_{in}\} = 0$

$Re\{Z_{sopt}\} = Z_0$

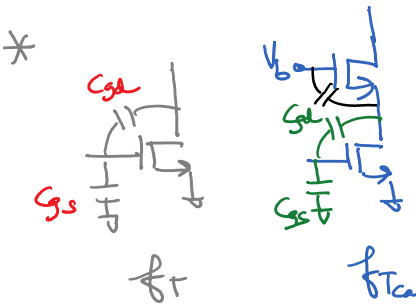
$Re\{Z_{in}\} = Z_0$

$Im\{Z_{sopt}\} = 0$??

$Im\{Z_{in}\} = 0$

within 20% margin of error

Imaginary part of noise impedance Z_{sopt} is within 20% of $Im\{Z_{in}\}$



f_T $\qquad$ $f_{T_{casc}}$

* Cascode device f_T < CS device f_T

$Z_o \simeq \omega_T L_s$ ← Cascode f_T

$$\omega_T \simeq \frac{g_m}{C_{gs}+C_{gd}} \qquad \omega_{T_{casc}} \simeq \frac{g_m}{C_{gs}+2C_{gd}}$$

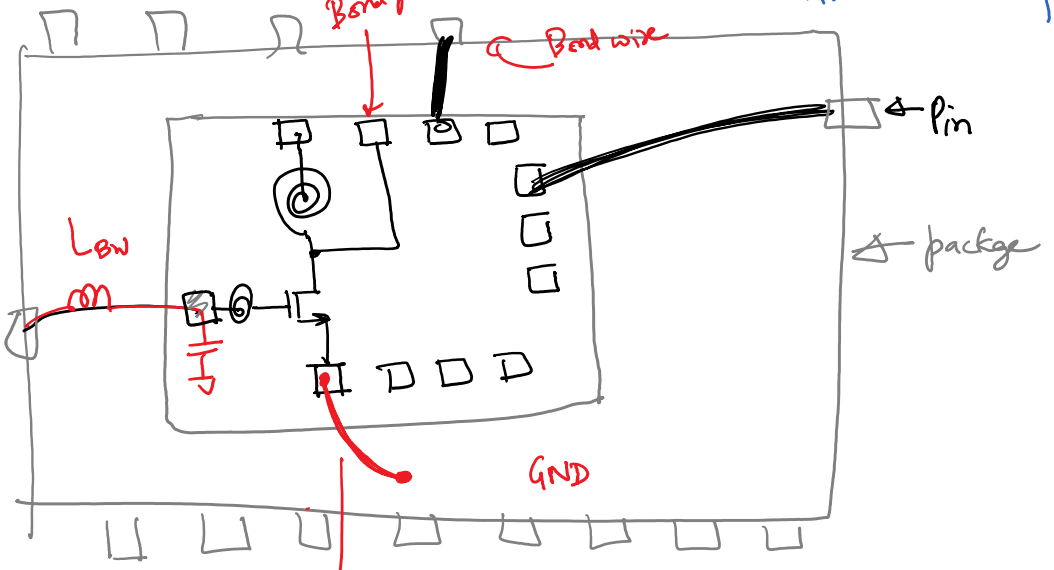
$$\omega_T L_s = Z_o \Rightarrow L_s = \frac{Z_o}{\omega_T}$$

In 65nm CMOS, f_T = 160 GHz

$$= \frac{50\Omega}{2\pi \times 160\,GHz} = 50pH$$

↑ only depends on technology

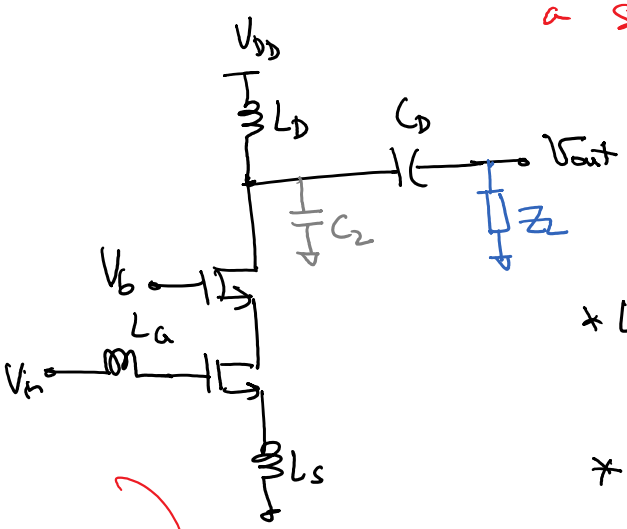
Not frequency of operation (ω_o)



Downbond ⇒ 50pH → 50Ω at the input

Output Matching to Maximize Gain:

* In an IC, the load of the LNA is provided by another gain stage, phase shifter (mmWave Beamforming Receiver), or by a mixer.
* output of the LNA is capacitive
* A simple narrowband matching network is realized using an L-section
  - ↳ shunt inductor L_D connected to V_{DD} followed by a series capacitor



$Z_L =$ $R_L = 50\Omega$ or $\frac{1}{j\omega C_{off}}$

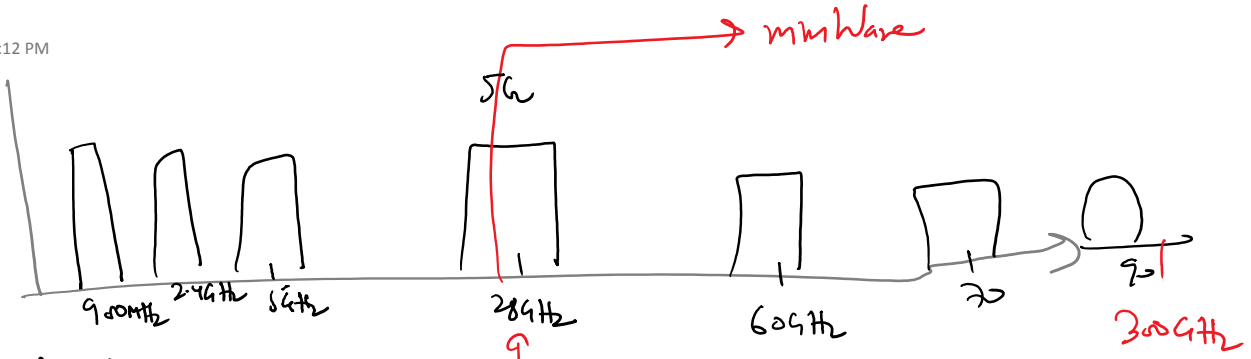
* L_D forms a parallel resonant circuit with the output capacitances
* Inductive load (L_D) allow the output, V_{out}, to swing above the supply voltage (V_{DD})
  - ↳ improves linearity compared to the case with resistive load.
* Broadband o/p match ⇒ π-match or other matching networks

$$R_L = \frac{R_p}{Q^2+1}$$

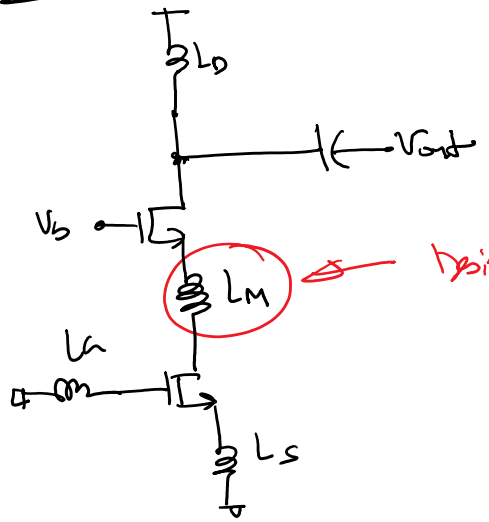
$$\Rightarrow Q = \frac{R_p}{\omega_0 L_D}$$

- At resonance, the input and outputs are matched to 50Ω and Z_L respectively.

Power gain, $G \leq \frac{1}{4}\left(\frac{f_T}{f_0}\right)^2 \frac{R_L}{Z_0}$


mmWave
5G
900MHz
2.4GHz
5GHz
28GHz
60GHz
70
90
300GHz
30GHz

mmWave LNAs:


LD
Vout
Vb
LM
Design procedure
LG
LS