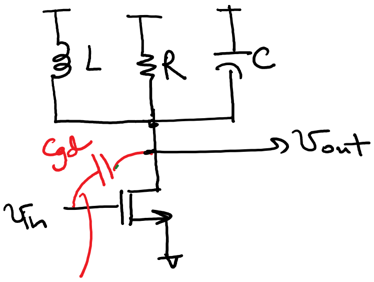
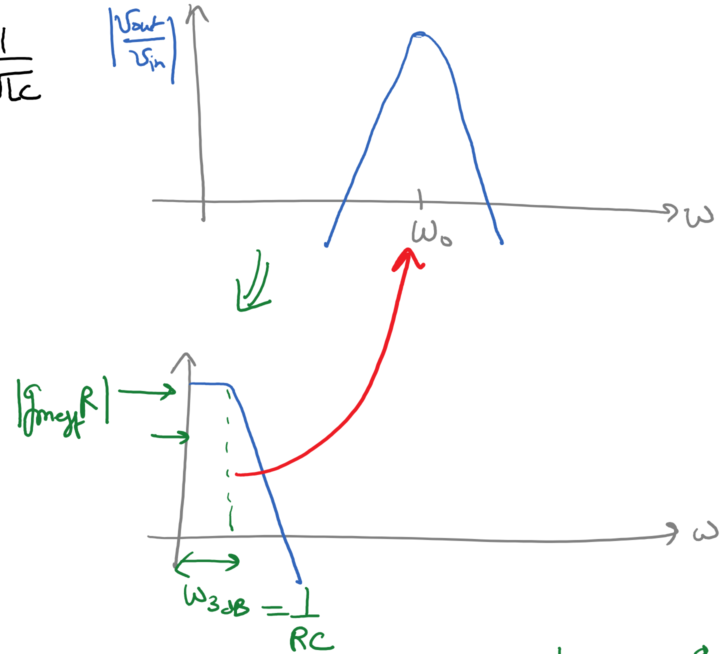
ECE 513 - Lecture 18

Thursday, October 18, 2018 9:30 AM



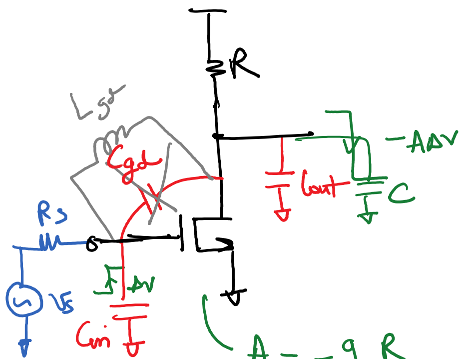
$\omega_0 = \frac{1}{\sqrt{LC}}$



Miller Capacitance
↳ shorts input & output at higher frequencies

$|\text{Gain} \times BW| = g_{m\,eff} R \cdot \frac{1}{RC} = \frac{g_{m\,eff}}{C}$

Miller Effect



$A = -g_m R$

Net charge across C_{gd} = $(1+|A|)\Delta V$

$$\left.\begin{aligned} C_{in} &= C_{gd}(1+|A|) \\ C_{out} &= C_{gd}\left(1+\frac{1}{|A|}\right) \simeq C_{gd} \end{aligned}\right\} \text{approximation}$$

@ higher frequencies, C_{gd} shorts input & output ⇒ zero in the frequency response.

* Can shift the resonance frequency away from ω_0

Use $C \gg C_{gd}$ ⇒ $GBW = \frac{g_m}{C}$ ↓

* R_{in} can have a negative real part at frequencies where the LC tank is inductive ($\omega < \omega_0$)

↳ resistance with negative real part can set oscillations

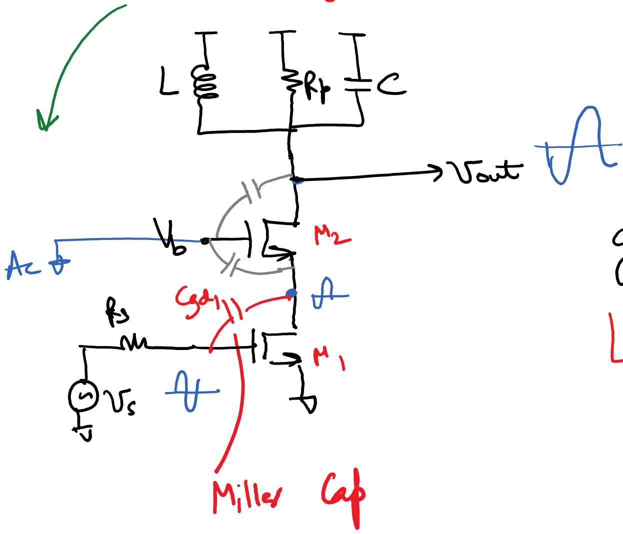
oscillations

* Need to mitigate the deleterious effects of C_{gd}

↳ neutralization → cancel the effect/role of C_{gd} (TH Lee's Book)

↳ unilaterization ~ $|S_{12}| \simeq 0$

Cascode CS Amplifier



Gain seen across M_1 is small $\simeq -1$

↳ Effect of Miller cap is mitigated as the gain across $C_{gd} \simeq -1$ (Miller Killer)

Tuned CS Amplifier Analysis :

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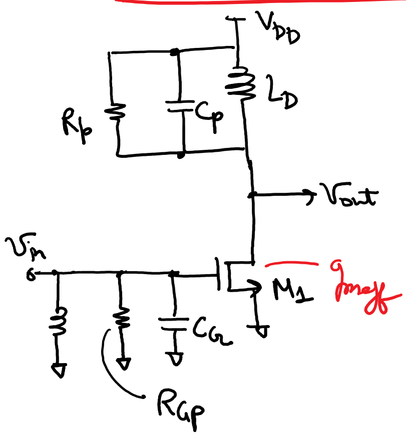
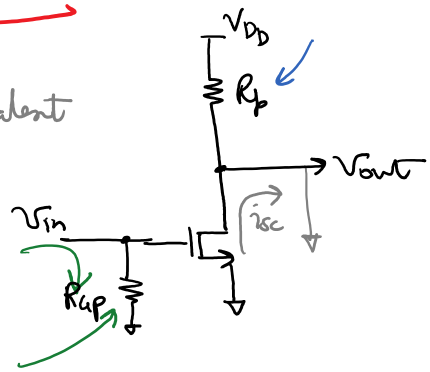


Baseband Equivalent $\Rightarrow$



$$g_{meff} = \frac{g_m}{1+g_m R_s}$$

Theorem (see Razavi Analog Book)

$A_v = -G_m R_{out}$ ← o/p resistance

G_m → short circuit g_m

* $R_{out}(\omega_o) = R_p$

* $R_{in}(\omega_o) = R_{Gp}$

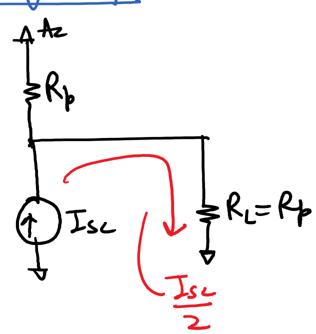
Output short circuit current

* $I_{sc}(\omega_o) = -g_{meff} V_{in}$

* Voltage gain: $A_v(\omega_o) = -G_m \cdot R_{out} = -\frac{I_{sc}}{V_{in}} \cdot R_{out} = -g_{meff} \cdot R_p$

$\boxed{\text{Power Gain}}$ $\quad I_{sc} = -g_{meff} V_{in}$

"Assume the input & output ports are conjugate matched"



$I_{load} = \frac{I_{sc}}{2} = -\frac{g_{meff} V_{in}}{2}$ ⟶ ①

$V_{out} = \frac{I_{sc}}{2} \cdot R_p = -\frac{g_{meff} V_{in}}{2} \cdot R_p$ ⟶ ②

Power delivered to the "matched" load

$P_{load} = V_{out} \times I_{load} = \frac{g_{meff} R_p}{4} \cdot V_{in}^2$ ⟶ ③

Power delivered from the signal source

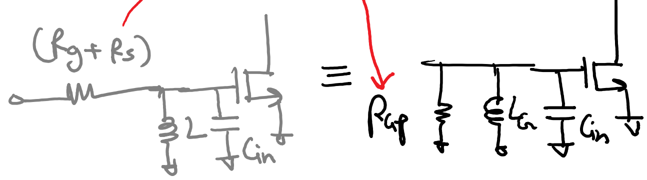
$P_{in} = V_{in} \times i_{in} = V_{in} \cdot \left(\frac{V_{in}}{R_{Gp}}\right) = \frac{V_{in}^2}{R_{Gp}}$ ⟶ ④

power gain $\quad g = \dfrac{P_{load}}{P_{in}} = \boxed{\dfrac{g_{m,eff}^2 \cdot R_p \cdot R_{ap}}{4}}$

Now, assuming that we have ideal inductors (infinite Q) for tuning the input and output. $R_p = r_{o,eff} \leftarrow$ effective output resistance of the NMOSFET

* At the input side

series to parallel transformation



$$R_{ap} \simeq (R_g + R_s)\, Q^2$$

$$= \frac{(R_g + R_s)}{\omega_o^2 (R_g + R_s)^2 C_{in}^2} = \frac{1}{(R_g + R_s)\,\omega_o^2\, C_{in}^2}$$

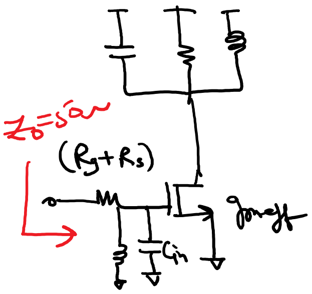
$$g(f) = \frac{g_m^2 r_o}{4\omega^2 C_{in}^2 (R_g + R_s)} \simeq \frac{f_T^2}{4f^2} \cdot \frac{r_o}{R_g + R_s} = \boxed{\frac{f_{MAX}^2}{f^2}}$$

where $f_{MAX} = \dfrac{f_T}{2}\sqrt{\dfrac{R_{out}}{R_{in}}}$

available power gain $\propto \dfrac{1}{f^2}$

No power gain beyond $f = f_{MAX}$

$f_{MAX} > f_T$

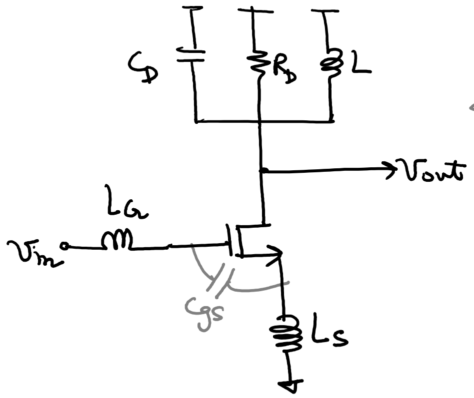


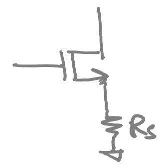
$R_{in} = R_g + R_s$ with input tank tuning

$\Rightarrow \frac{1}{j\omega C_{gs}} + (R_g+R_s)$ ↑ ↑ R_g & R_s ↓ for f_{MAX} ↑

Need 'Real' impedance at the input without degrading NF or BW.

CS with Inductive Degeneration

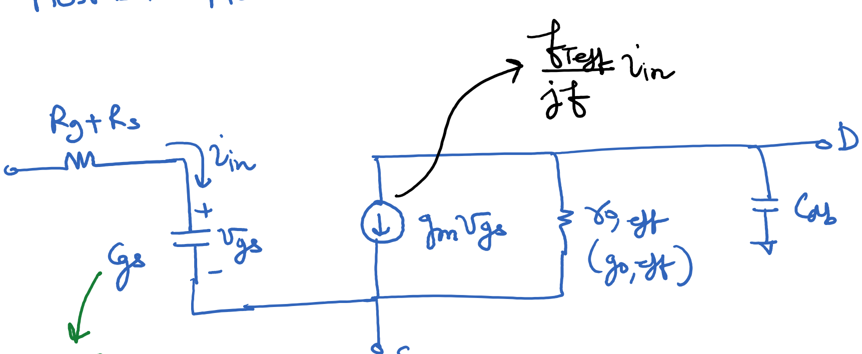




Source degeneration

$\omega_{Teff} = \frac{g_{meff}}{2\pi C_{gs}}$

HF MOSFET Model

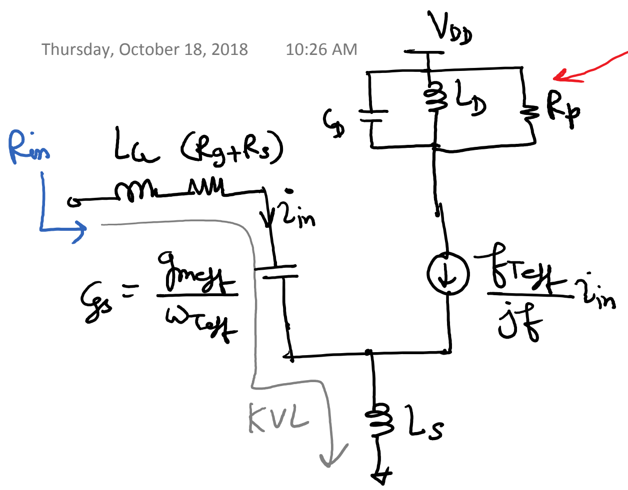


$C_{gs} = \frac{g_{meff}}{\omega_{Teff}}$

Experimental/Simulation based values for g_{meff}, ω_{Teff}

↳ These include the impact of C_{gd}

↳ ±15% error at 100 GHz



g_{oeff} (or r_{oeff}) is lumped into R_p

Step1: Calculate R_{in} (KVL)

$$v_{in} = i_{in}\left(j\omega L_G + R_g + R_s + \frac{\omega_{Teff}}{j\omega\, g_{meff}} + j\omega L_s\right) + j\omega L_s \cdot \frac{\omega_{Teff}}{j\omega} i_{in}$$

$$\Rightarrow Z_{in} = \frac{v_{in}}{i_{in}} = \underbrace{R_g + R_s + \omega_{Teff} L_s}_{Re} + \underbrace{j\left[\omega(L_G + L_s) - \frac{\omega_{Teff}}{\omega\, g_{meff}}\right]}_{Im} \longrightarrow ①$$

Step2: Output short circuit current

$$I_{sc} = -\frac{f_{Teff}}{jf} i_{in} = j\frac{f_{Teff}}{f} i_{in} \longrightarrow ②$$

Step3: To match the input to a signal source with real impedance Z_0

↳ The imaginary part of Z_{in} is cancelled by a proper choice of L_G

$$L_G = \frac{\omega_{Teff}}{\omega^2 g_{meff}} - L_s$$

↳ Z_{in} is made equal to the source impedance Z_0 by choosing appropriate value for L_s

$$L_s = \frac{Z_0 - (R_g + R_s)}{\omega_{Teff}}$$

Step4: Power gain

$$V_{out} = \frac{I_{sc}}{2} \times R_p = \frac{\cancel{j} f_{T_{eff}} \cdot R_p}{\cancel{j} f} i_{in}$$

$$I_{load} = \frac{I_{sc}}{2} = \frac{j f_{T_{eff}}}{2f} i_{in}$$

$$P_{load} = V_{out} \cdot I_{load}^* = \frac{f_{T_{eff}}^2 R_p}{4f^2} |i_{in}|^2 \longrightarrow ③$$

$$P_{in} = V_{in} \cdot i_{in}^* = i_{in} \cdot R_{in} \cdot i_{in}^* = R_{in} |i_{in}|^2 \longrightarrow ④$$

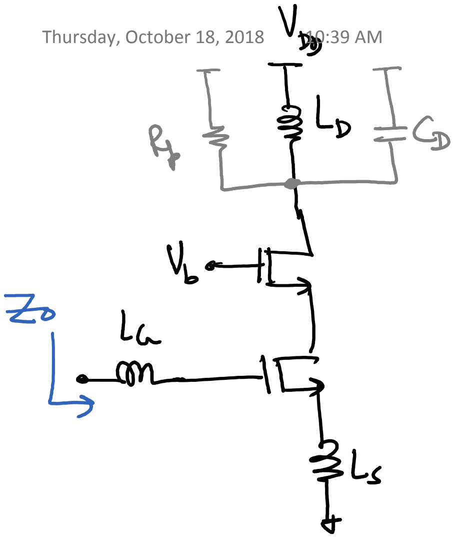
$$G = \frac{P_{load}}{P_{in}} = \frac{f_{T_{eff}}^2}{4f^2} \cdot \frac{R_p}{R_{in}}$$

Normally $R_p = R_{in} = Z_o$ (matched to Z_o)

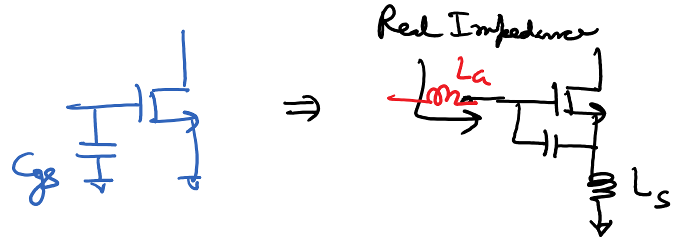
$$\Rightarrow G \simeq \frac{f_{T_{eff}}^2}{4f^2}$$

Power Match vs Noise Match

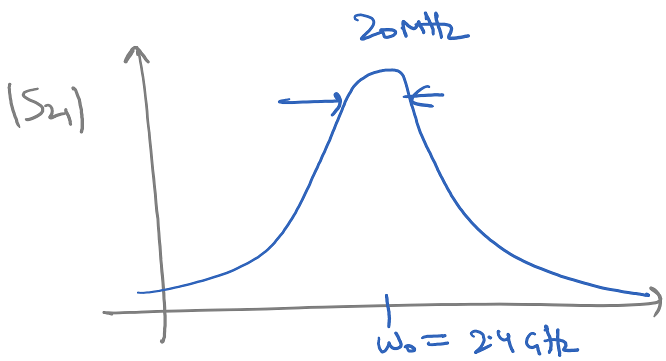
$Z_s = Z_{s,opt}$



LNA



Tuned Amplifiers



Broadband Amplifier