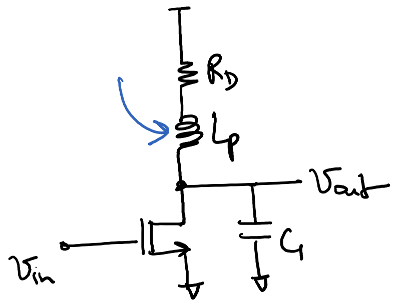
ECE 513 - Lecture 22

Thursday, November 1, 2018 9:30 AM

Shunt Peaking:



$$A_v(s) = A_o \cdot \frac{1 + s/\omega_z}{1 + \frac{s}{Q\omega_o} + \frac{s^2}{\omega_o^2}}$$

zero

$\leftarrow$ 2nd-order system denominator

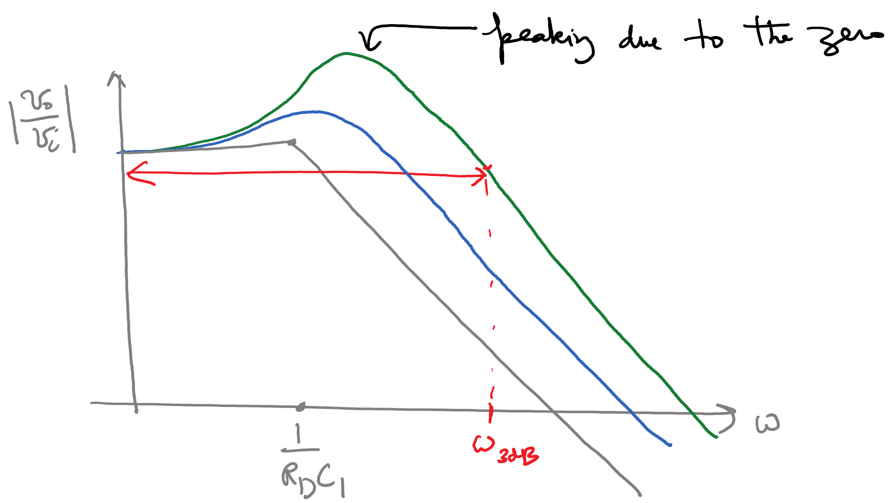
$Q \Rightarrow$ quality factor

$$A_o = -g_m R_D$$

$$\omega_o = \frac{1}{\sqrt{L_p C_1}}$$

$$\omega_z = \frac{R_D}{L_p} = \frac{\omega_o}{Q}$$

$$Q = \frac{1}{R_D}\sqrt{\frac{L_p}{C_1}}$$



$Q < 1$

* for maximally flat response $\Rightarrow$ $Q = 0.63$

$\hookrightarrow$ $L_p = Q^2 R_D^2 C_1 = 0.4\, R_D^2 C_1$

$\hookrightarrow$ Results in 70% increase in bandwidth (BW) compared to the case when $L_p = 0$.

* for a maximally flat group delay response even smaller Q is needed

$\hookrightarrow$ $L_p = 0.32\, R_D^2\, C_1$

$\hookrightarrow$ BW extension is 60%

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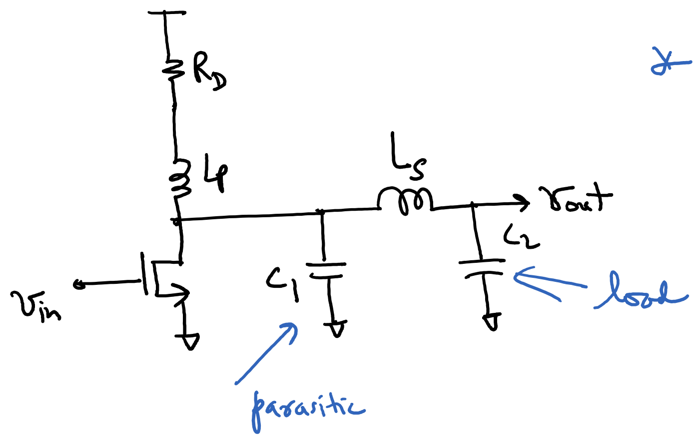
Shunt - Series peaking:

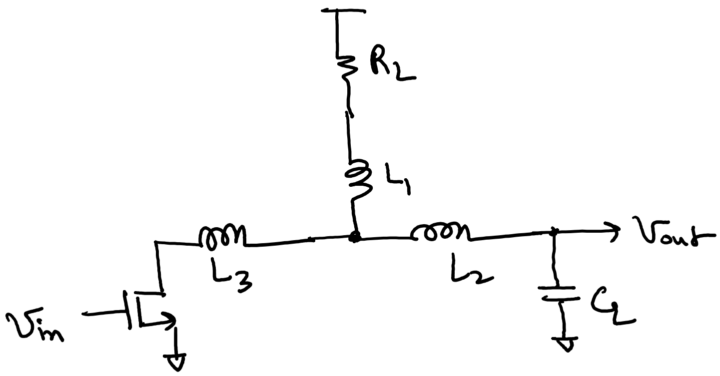


Tom Lee's Book:

* Employing two inductors results in 2X BW compared to the original amplifier

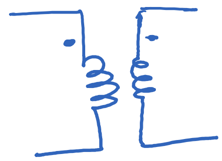
↳ 100% improvement

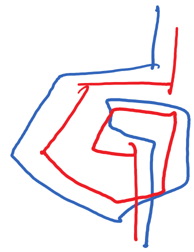
Shunt and Double Series peaking:

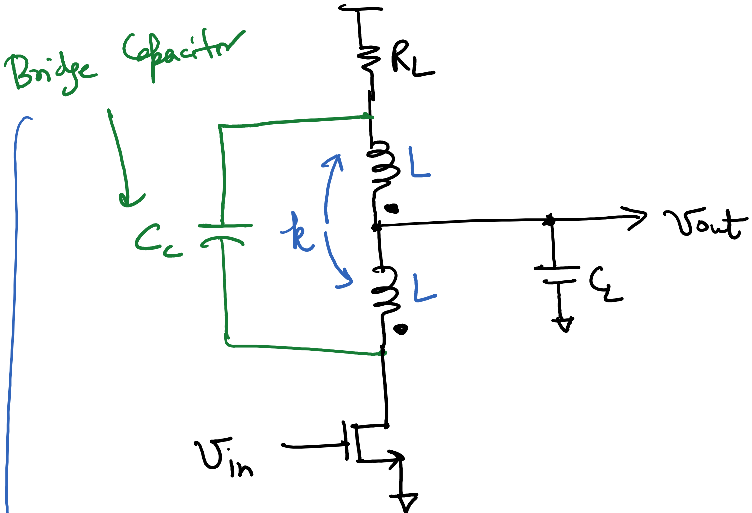


* $2\sqrt{2}\,X$ bandwidth improvement
↳ 183 %

* To save die area, the combination of three inductors is realized using a pair of magnetically coupled inductors (i.e. a transformer)
↳ A T-Coil







Design Equations:

$$L_1 = L_2 = \frac{R_L^2 C_L}{2(k+1)}$$

& $$C_c = \frac{C_L}{4}\left[\frac{1-k}{1+k}\right]$$

→ Creates a parallel resonance with L's

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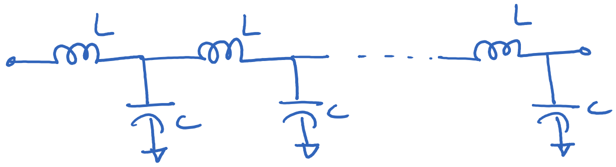
Distributed Amplifiers:

* Invented in 1936 by Percival

Lossless Tline

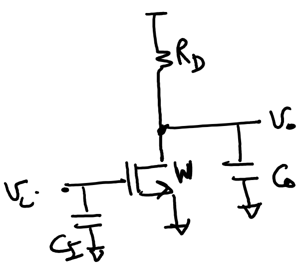


Characteristic impedance

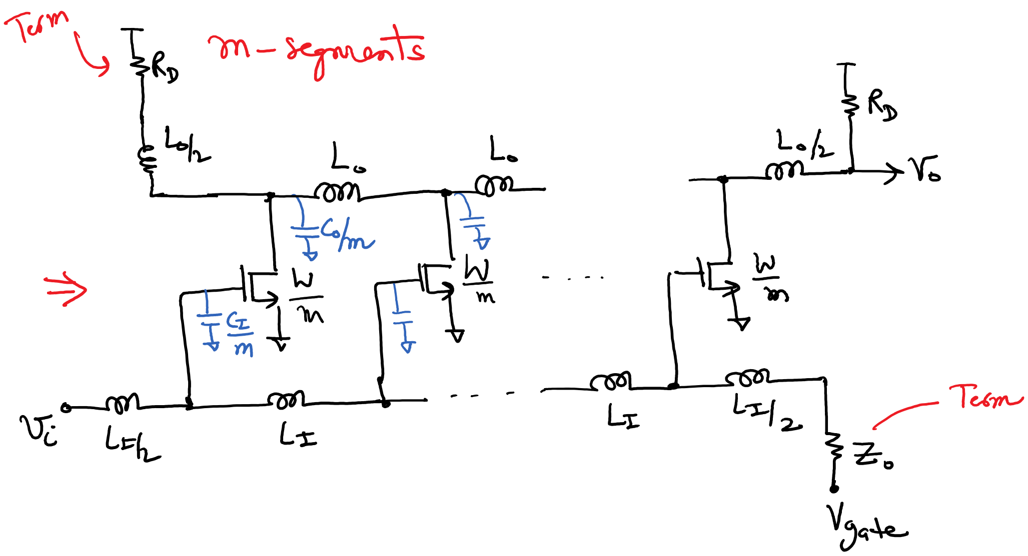
$$Z_0 = \sqrt{\frac{L}{C}}$$

$$BW_{3dB} = \frac{1}{\pi\sqrt{LC}}$$

Lumped amplifier



$\Rightarrow$



$$\omega_p = \frac{1}{R_D C_o}$$

$$\omega_{un} = \frac{g_m}{C_o}$$

$$L_I = Z_o^2 \cdot \frac{C_I}{m} \quad \text{and} \quad L_o = R_D^2 \cdot \frac{C_o}{m} \qquad \text{①}$$

$$Z_o = \sqrt{\frac{L}{C}}$$

$$A_v = -m\left(\frac{g_{meff}}{m}\right)\frac{R_D}{2} = -g_{meff}\frac{R_D}{2}$$

$\because$ at very low frequencies the two R_D come in parallel.

* The bandwidth is given by

$$BW_{3dB} = \min\left\{\frac{1}{\pi\sqrt{L_I \frac{C_I}{m}}}, \frac{1}{\pi\sqrt{L_o\frac{C_o}{m}}}\right\} \qquad \text{②}$$

* Usually $C_i = C_o \Rightarrow$ if not equal, add extra capacitance in parallel

Parallel

* If we set $R_D = Z_o$ then

$$BW_{3dB} = \min\left\{ \frac{n}{\pi R_D C_I}, \frac{n}{\pi R_D C_o} \right\}$$

① is substituted here in ②

$n \to \infty$, $BW_{3dB} \to \infty$ (ideally)

↳ ultimately limited by parasitics

↳ by f_{MAX} of the transistor

* f_T doubler
* Cherry-Hooper stage

Book 4 T.H. Lee Book.

Design of mm Wave LNAs :

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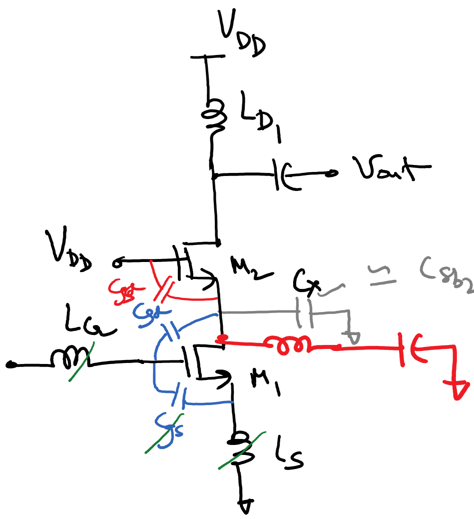


$C_x \simeq C_{sb_2} + C_{db_1} + C_{gs_2} + C_{gd_1}$

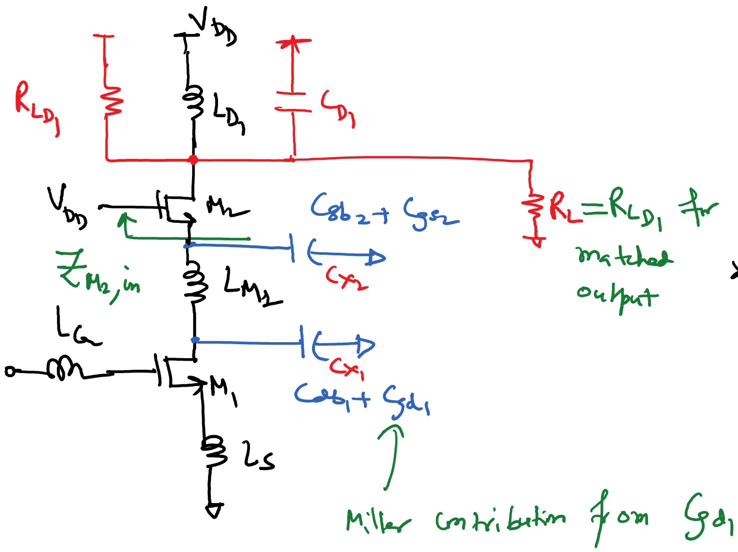
MOSFET

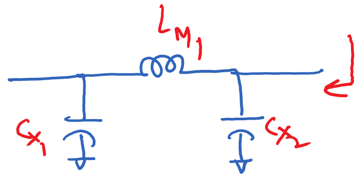
$C_{gd} \simeq 50\%$ of C_{gs}

↳ reduces the f_T of the transistor in Cascode config by 33%

① Use shunt inductor to AC ground to tune-out C_x

↳ this resonance is narrowband





* The characteristic impedance of this artificial TLine can be expressed as

$$Z_{0_1} = \sqrt{\frac{L_{M_1}}{C_{gs_2} + C_{sb_2}}} \qquad \because Z_0 = \sqrt{\frac{L}{C}}$$

* The 3dB BW when matched at both the ends becomes

$$f_{3dB} = \frac{1}{\pi\sqrt{L_{M_1}(C_{sb_2} + C_{gs_2})}}$$

Razavi's Analog Book

* ECE 410 / 515 Course

$$Z_{M_2,in} = \frac{1}{g_{m_2}} + \frac{R_{Drain}}{g_{m_2} r_{o_2} + 1}$$

$$= \frac{1}{g_{m_2}} + \frac{R_{LD_1} \| R_L}{g_{m_2} r_{o_2} + 1}$$

$$= \frac{1}{g_{m_2}} + \frac{1}{2} \cdot \frac{R_{LD_1}}{g_{m_2} r_{o_2} + 1}$$

$$\because Q = \frac{R_p}{\omega_0 L_p}$$

$$\rightarrow R_p = \omega_0 Q L_p$$

$$\boxed{Z_{M_2,in} = \frac{1}{g_{m_2}} + \frac{1}{2} \cdot \frac{\omega_0 Q L_{D_1}}{g_{m_2} r_{o_2} + 1}}$$

Set $$Z_{0_1} = \sqrt{\frac{L_{M_1}}{C_{gs_2} + C_{sb_2}}} = Z_{M_2,in}$$

$\hookrightarrow$ gives value for L_M.