ECE 513 - Lecture 17

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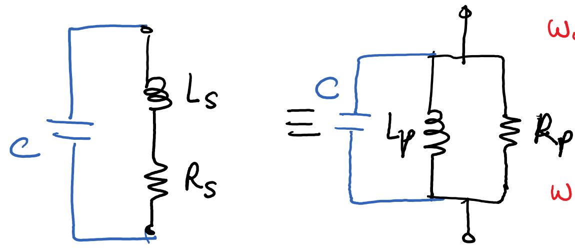
$$R_p = R_s (Q^2+1)$$

$$X_p = X_s \frac{(Q^2+1)}{Q^2}$$

$j\omega_0 L$ or $\frac{1}{j\omega_0 C}$



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

$\omega \simeq \omega_0$

$\Delta\omega = \frac{\omega_0}{Q}$

$$Q = \frac{R_p}{\omega_0 L_p} = \frac{\omega_0 L_s}{R_s}$$

$$Q = \omega_0 R_p C_p = \frac{1}{\omega_0 R_s C_s}$$

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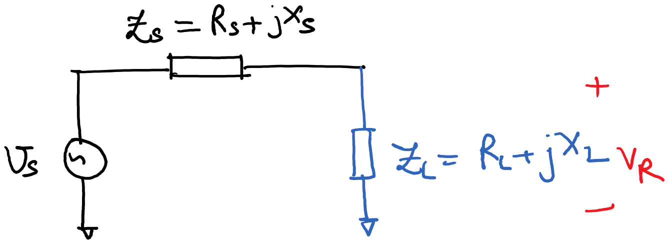


V_R & V_S are the rms voltages across the load & the source

Power delivered to the load

$$\frac{|V_R|^2}{R_L} = \frac{R_L |V_S|^2}{(R_S + R_L)^2 + \cancel{(X_S + X_L)^2}}$$

Maximize

$$(X_S + X_L) = 0 \quad \Rightarrow \quad X_S = -X_L$$

$$\frac{\partial}{\partial R_S}\left[\frac{R_L}{(R_S + R_L)^2}\right] = 0$$

$$R_S = R_L$$

$$Z_L = R_L + jX_L = R_S - jX_S$$

$$Z_L = Z_S^* \quad \text{or} \quad Z_S = Z_L^*$$

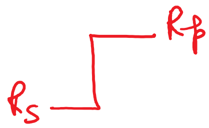
Maximum Power Transfer.

L-match:

$R_p = R_s(Q^2+1)$

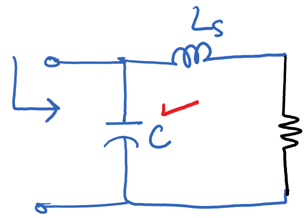
$= 10R_s$ for $Q=3$

$L_p = L_s\left(\frac{Q^2}{Q^2+1}\right)$



for $Q=3$

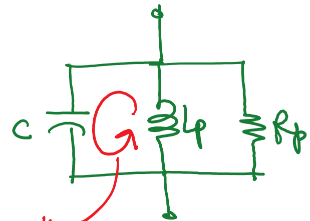
$Z_{in} = R_p$



Upward impedance Transformation

$= 5\Omega$

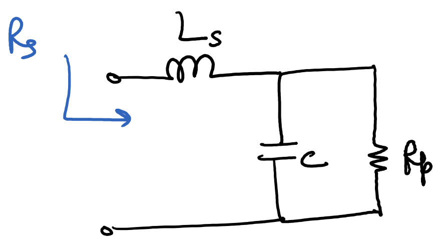
$\equiv$



$\equiv$

LC "resonate" each other

$j\omega_0 C - \frac{j}{\omega_0 L_p} = 0$



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

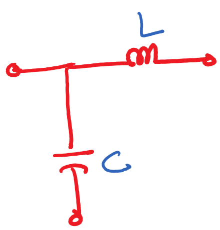
$R_p = R_s(Q^2+1) \longrightarrow$ for large Q,

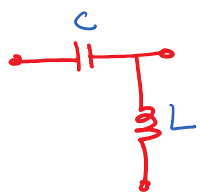
$Q = \sqrt{\frac{R_p}{R_s}}$

$X_p \simeq X_s$

$R_p R_s \simeq \frac{L_s}{C} = Z_0^2$

$Z_0 = \sqrt{L/C}$





2-degrees of freedom

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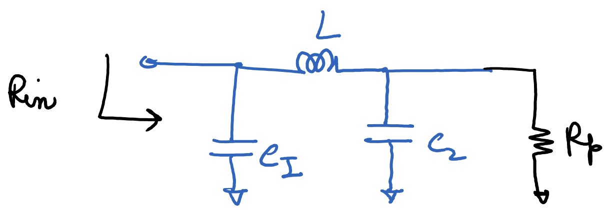
π- Match :

* L-match limitations $\Rightarrow$ we can specify only 2 of the three specifications : ω_0, $\frac{R_p}{R_s}$ or Q

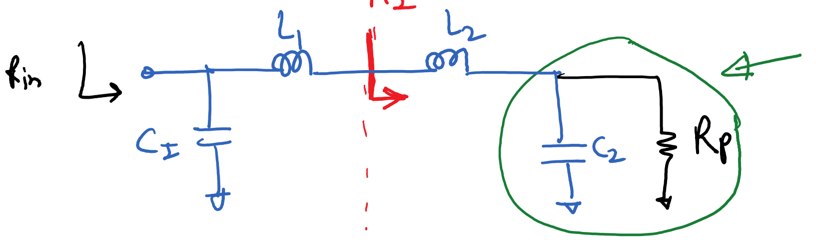
* To get a 3^{rd} degree of freedom, we use a π network

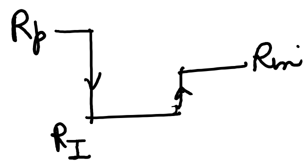


$$Q \sim \sqrt{\frac{R_p}{R_s}}$$

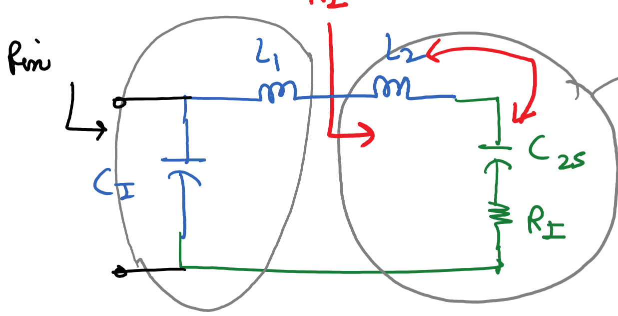
$\Rightarrow$ π- Match $\Rightarrow$ Cascade of two L-matches

$R_I \longrightarrow$ image resistance





Three degrees of freedom $\rightarrow$ C_2, C_I & $L = (L_1 + L_2)$



* Q of the right hand L-section

$$Q_{right} = \frac{\omega_0 L_2}{R_I} = \sqrt{\frac{R_p}{R_I} - 1} \longrightarrow (1)$$

* The left-hand L-section sees a resistance R_I at resonance

$$Q_{left} = \frac{\omega_0 L_1}{R_I} = \sqrt{\frac{R_{in}}{R_I} - 1} \longrightarrow (2)$$

* Overall Q of the network

$$Q = \frac{\omega_0 (L_1 + L_2)}{R} = \sqrt{\frac{R_{in}}{R_I} - 1} + \sqrt{\frac{R_p}{R_I} - 1} \longrightarrow (3)$$

$$Q = \frac{\omega_0 (L_1 + L_2)}{R} = \sqrt{\frac{R_{in}}{R_I} - 1} + \sqrt{\frac{R_p}{R_I} - 1} \longrightarrow (3)$$

* we compute R_I from Eq^n (3) and then we have

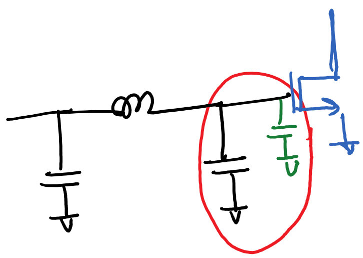
$$\boxed{L_1 + L_2 = \frac{Q R_I}{\omega_0}}$$

$$\boxed{C_1 = \frac{Q_{left}}{\omega_0 R_{in}}}$$

$$\boxed{C_2 = \frac{Q_{right}}{\omega_0 R_p}}$$

Eq^n (3) requires iteration $\Rightarrow$ To simplify it we can assume that Q is large $\Rightarrow$ Then R_I is approximated as

$$\boxed{R_I \simeq \frac{\left(\sqrt{R_{in}} + \sqrt{R_p}\right)^2}{Q^2}} \longrightarrow \text{instead of Eq}^n \text{ (3) for } Q >> 1$$

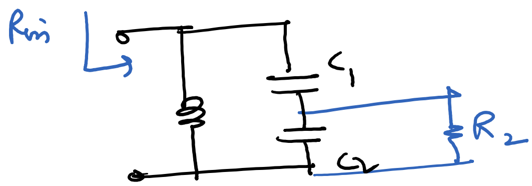


parasitic capacitance can be absorbed in the network design.

T- Match:

"See uploaded chapter"

Tapped Capacitor or Inductor



Transmission Line Match:

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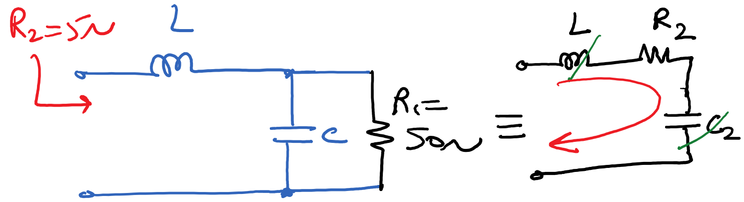
$$R_s = \frac{R_p}{Q^2+1}$$

Ex:

$f_0 = 1\,\text{GHz}$

$R_1 = 50\Omega$ to $R_2 = 5\Omega$

$BW = 25\,\text{MHz}$



$$Q = \sqrt{\frac{R_p}{R_s} - 1} = \sqrt{10-1} = \boxed{3}$$

But we desire $BW = 25\,\text{MHz} \Longrightarrow Q = \frac{f_0}{BW} = \frac{10^9}{25\times10^6} = 40$

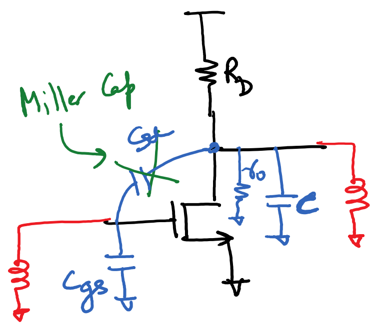
$$Q = \frac{\omega_0 L_s}{R_s} = \cancel{\frac{R_p}{\omega_0 L_p}} = \frac{\omega_0 L}{R_2} \Rightarrow L = \frac{Q R_2}{\omega_0} \simeq \boxed{2.39\ \text{nH}}$$

$$Q = \omega_0 R_p C_p = \cancel{\frac{1}{\omega_0 R_s C_s}} = \omega_0 R_1 C$$

$$\hookrightarrow C = \frac{Q}{\omega_0 R_1} = \boxed{9.55\ \text{pF}}$$

See π-match Example from T.H. Lee's Chapter

Tuned Circuit Topologies and Analysis:



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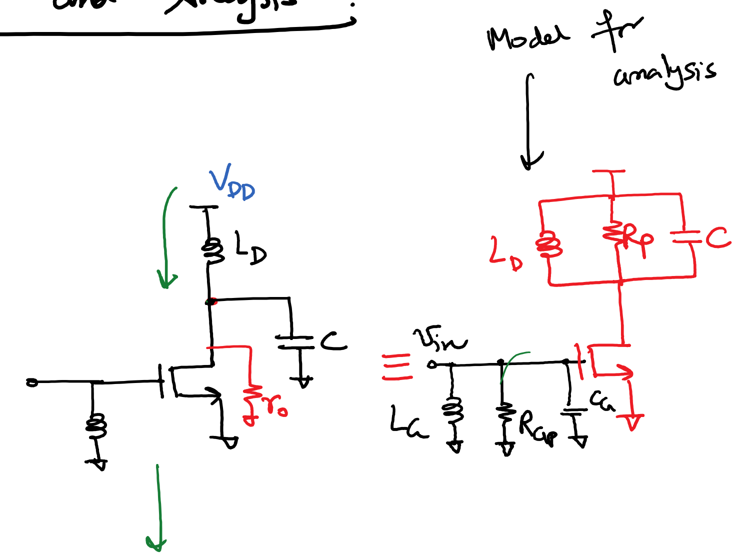
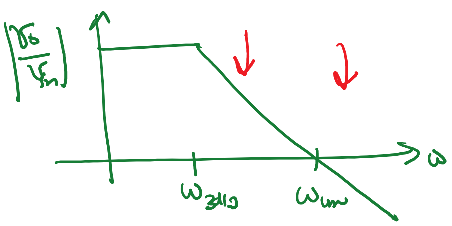


$f \to f_T$

Inductor bias the drain

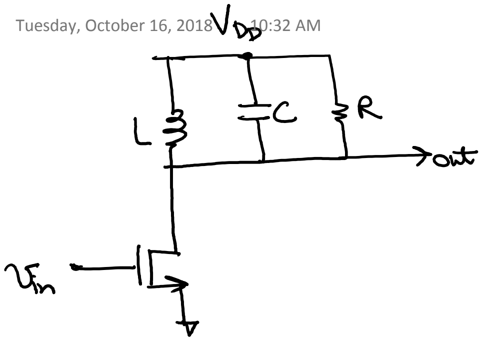
$V_{DS} = V_{DD}$ ← biased at V_{DD}

↓ drain can swing above V_{DD}.



* In general its common to cascade a large number of tuned amplifier stages.

* Tuned amplifiers are used extensively to provide selective amplification and a degree of filtering of unwanted signals.
  ↳ power requirements to obtain narrowband gain are considerably less.



$\Rightarrow$ Single-tank tuned CS amplifier

$R \Rightarrow$ transistor's output impedance

$C \Rightarrow$ transistors drain parasitics + load

$C_{gd} \Rightarrow$ Ignored

$$Z_L = sL \,||\, R \,||\, \frac{1}{sC}$$

$$\frac{1}{Z_L} = \frac{1}{sL} + \frac{1}{R} + sC$$

$$= \frac{R + sL + s^2LCR}{sLR}$$

$$\Rightarrow Z_L = \frac{1}{C} \cdot \left[\frac{s}{s^2 + s\left(\frac{1}{RC}\right) + \frac{1}{LC}} \right]$$

2^{nd}-order transfer F^n

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

$$A_v(s) = -g_{meff} Z_L(s)$$

$$= -\frac{g_{meff}}{C} \cdot \frac{s}{s^2 + s\left(\frac{1}{RC}\right) + \frac{1}{LC}}$$

$$\Rightarrow A_v(j\omega_0) = -\frac{g_{meff}}{C} \cdot \frac{\cancel{j\omega_0}}{-\cancel{\frac{1}{LC}} + \frac{\cancel{j\omega_0}}{RC} + \cancel{\frac{1}{LC}}}$$

$$= -g_{meff} \cdot R$$

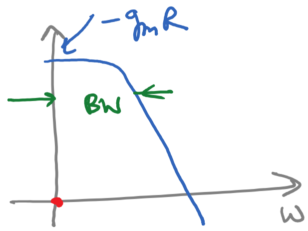
$$\omega_0 = \frac{1}{\sqrt{LC}}$$

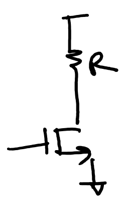
$$Q = \omega_0 RC = \cancel{\frac{\omega_0 L}{R}} \quad \boxed{R/\omega_0 L}$$

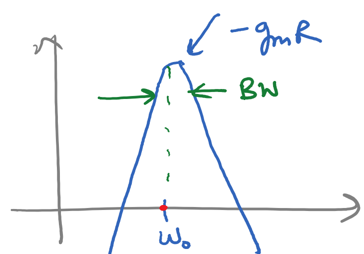
$$BW = \frac{1}{RC}$$

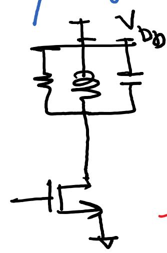
$$\text{Gain} \times BW = g_{meff} R \cdot \frac{1}{RC}$$

$$= \frac{g_{meff}}{C}$$









f_{max} sets the ultimate limit on $\omega_0 = 2\pi f_0$