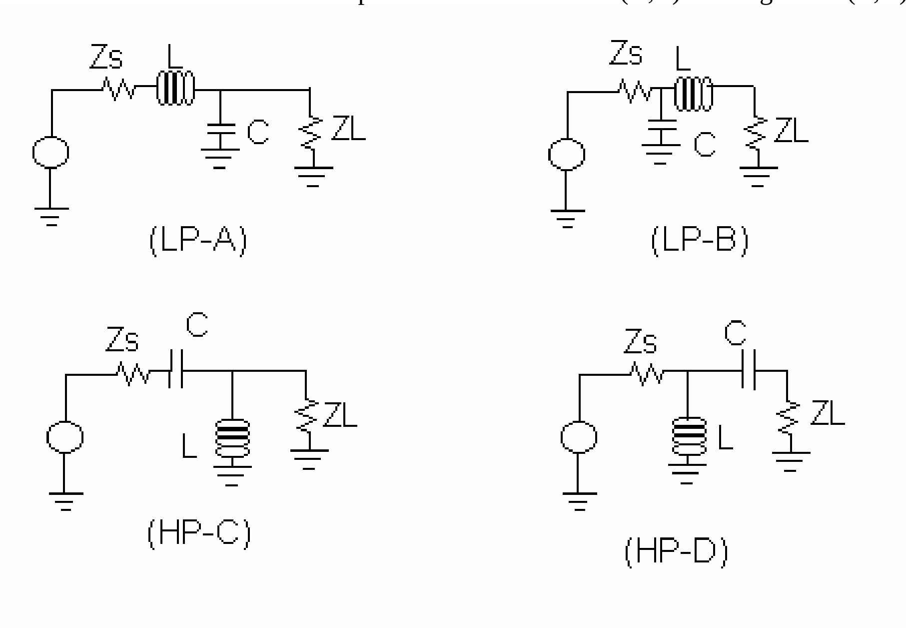
ECE 6130 LUMPED ELEMENT IMPEDANCE MATCHING

Reference: Bowick, RF Circuits, pp. 66-75   (Handout)

Also: Handout sources for SMT caps, inductors

The L-Network:
Four different forms of the L-Shaped Network. LowPass (A,B) and High Pass (C,D):



Purpose of the Elements:

SHUNT Element : Transform large ZL to smaller value with real part equal to the real part of Zs.
SERIES Element: Resonate with (cancel) the imaginary part of the impedance.

Design steps:

$$Q_s = Q_p = \sqrt{\frac{R_p}{R_s} - 1}$$

$$Q_s = X_s / R_s$$

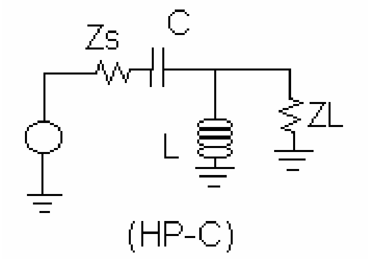
$$Q_p = R_p / X_p$$

Qs = Q of series leg
Qp = Q of parallel leg
Rp = Real part of parallel leg
Rs = Real part of series leg
Xs = Imaginary part of series leg
Xp = Imaginary part of parallel leg
Xs and Xp can be either capacitive or inductive, but must be of opposite type.

Example:
Match a 100-ohm load (Rp) to a 50-ohm line (Rs) at 1 GHz. Do not allow DC power to reach the load.

$$Q_s = Q_p = \sqrt{\frac{100}{50} - 1} = 1$$
$$X_s = Q_s R_s = (1)(50)$$
$$X_p = R_p / Q_p = 100/1$$
$$\omega = 2\pi(1GHz)$$

Since we do not want DC power to reach the circuit, we need one of the high pass configurations such as (C)above. High Pass configuration (D) would work equally well.



Calculate values of L and C:

$$X_s = \frac{1}{\omega C} \rightarrow C = \frac{1}{\omega X_s} = 3.18\,pF$$
$$X_p = \omega L \rightarrow L = X_p / \omega = 15.9\,nH$$

PROBLEMS/LIMITATIONS with this method:

1) Component values can be limited (problem with all discrete element matches)
2) This is either HP or LP, not both (other methods will take care of this)
3) Cannot match impedances less than the line impedance (Q becomes imaginary)
4) Stray capacitances, inductances of the packaging of the elements, solder methods, line lengths (albeit small) may all become significant.

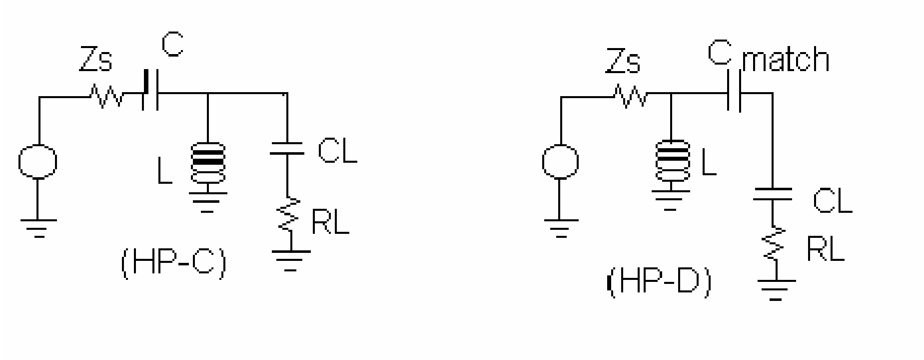
MATCHING COMPLEX IMPEDANCES

Two methods can be used to remove the load reactance:

1) Absorption (using the load reactance as part of the desired matching circuit)
2) Resonance (using an L to cancel a C or a C to cancel an L)

Example:
Same example as above, but let the load have a reactive component:
ZL = 100 -j 25 ohms

Design the matching network ignoring the reactive component, EXACTLY like it was done above.
The XL = -25ohms is equivalent to a capacitor in series with the load resistance RL. The value of CL = 1/(ωXL) = 6.4 pF
This gives either of the two circuits shown below:



ABSORPTION OF CL:

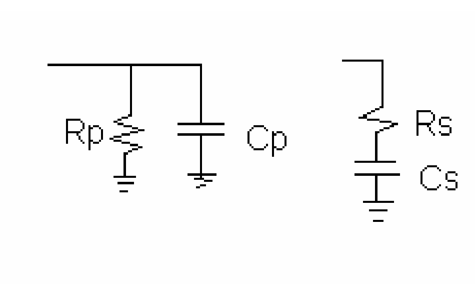
CL can now be "absorbed" in the HP-D configuration.
The combination of Cmatch and CL should equal C from the original matching network design.

That is :
C = Ctotal = 3.18pF = Cmatch in series with CL = Cmatch CL / (CL + Cmatch)
OR:
Cmatch = C CL / (CL - C) = (3.18pF)(6.4pF) / (6.4-3.18pF) = 6.32 pF

LIMITATION:
This only works if CL is greater than Ctotal.

Your book has a similar example where the load is modeled with a parallel C,R configuration.

TO CONVERT FROM SERIES TO PARALLEL LOAD ADMITTANCE:



Write the impedance of the above configurations:
Zp = (Rp) (1/jωCp) / (Rp+1/jωCp) = Rp / (1+ jωCp Rp)
Zs = Rs + 1/ jωCs

Equate: Zs = Zp
This gives two equations and two unknowns.
The unknowns are either Rs,Cs (if you have Rp,Cp) OR Rp,Cp (if you have Rs,Cs)

Solving gives

$$Rs = Xp^2 Rp \,/\, (Xp^2 + Rp^2)$$

$$Xs = RpRs \,/\, Xp$$

$$where$$

$$X = \frac{-1}{\omega C}\ OR\ \omega L$$

OR

$$Rp = (Rs^2 + Xs^2)/Rs$$

$$Xp = RpRs/Xs$$

For our case where Rs=100 and Xs = -25 ohms, we get Rp=106.25 ohms and Xp = -425 ohms.
This is a shunt capacitance $Xp = -1/(\omega C)$ where C = 0.374 pF

RESONANCE of CL:
If you cannot absorb CL, you may be able to resonate its effect away. This is done by canceling it out with an inductance. This is easier when the C and L are in parallel.
Then $Lp = 1/(\omega^2 Cp)$=67.72H
The input impedance that needs to be matched is now ZL = Rp (which is different than the original RL).
Proceed with normal matching as in the first example. See also EXAMPLE 4.3 in the handout.