

# SIMPLEST DESIGN OF PI-NETWORKS FOR TUBE OUTPUT STAGES

*IN3IEX – Giorgio Fontana - University of Trento - Italy October 2011*

I describe here a simple method for designing Pi-networks for output stages. The method is quite accurate. A table has been employed to ease the calculation. The method is focused on matching a FULL RANGE of resistive loads to the output tube, reactive loads can be matched but this is not a design parameter.

## Definitions:

$f$ : frequency.

$R_{min}$ : minimum value of the output resistance the network can provide.

$R_{out}$ : output resistance of power tube.

$R_{max}=R_{out}$ : maximum value of the output resistance the network can provide

$C_p$ : plate capacitance of the power tube.

$C_{in}$ : capacitance of the variable capacitor of the Pi-net connected to the plate of the tube.

$C_{out}$ : capacitance of the variable capacitor of the Pi-net connected to the antenna.

$L$ : inductance of the inductor of the Pi-network.

$C_{inMin}$ : minimum capacitance required for  $C_{in}$  (if  $C_p$  is zero)

$C_{inMax}$ : maximum capacitance required for  $C_{in}$  (if  $C_p$  is zero)

$C_{outMin}$ : minimum capacitance required for  $C_{out}$ . This is zero (do not worry about that).

$C_{outMax}$ : maximum capacitance required for  $C_{out}$ .

UNITS are: Hz, Farad, Henry, Ohm.

ALTERNATIVE UNITS (with same formulas): MHz, microFarad, microHenry, Ohm.

Design goal: design a network capable of providing output impedances between  $R_{min}$  and  $R_{max}$ , by varying  $C_{in}$  and  $C_{out}$  within their maximum and minimum values.

## Formulas:

$$C_{inMin} = \sqrt{\frac{R_{out} - R_{min}}{(f \cdot 6.28 \cdot R_{out})^2 \cdot R_{min}}}$$

$$L = C_{inMin} \cdot R_{min} \cdot R_{out}$$

$$C_{inMax} = h \cdot C_{inMin}$$

$$C_{outMax} = k \cdot C_{inMin}$$

Parameters  $h$  and  $k$  can be computed from the ratio ( $R_{out} / R_{min}$ ), see table.

Table of the parameters  $h$  and  $k$  that are employed for the evaluation of  $CinMax$  and  $CoutMax$ .

$Rout/Rmin$	$h$	$k$
2	3.73	4
4	2.54	2.87
6	2.32	2.81
8	2.24	2.90
10	2.19	2.99
14	2.13	3.20
20	2.09	3.48
30	2.06	3.92
40	2.05	4.32
60	2.03	4.97
100	2.00	6.10
200	2.00	8.08
400	2.00	11.17

If your  $Rout/Rmin$  is in between, use the highest values of  $k$  and  $h$  of the two nearest options. If your  $Rout/Rmin$  is outside the proposed values please contact me.

At the end subtract  $Cp$  from  $Cin min$  and  $max$ .

Send comments of your experience to [fontana@science.unitn.it](mailto:fontana@science.unitn.it). I will keep this page updated.

#### EXAMPLE – TABLE OF RESULTS

We have a power tube characterized by 1000 Ohm output resistance, and anode capacitance 20 pF.

We want to design a Pi-network for 7 MHz capable of providing output impedances between 25 and 1000 Ohm. Using the formulas and the table we get:

$$CinMin= 142 \text{ pF}$$

$$L=3.55 \text{ uH}$$

$$CinMax= 291 \text{ pF}$$

$$CoutMax=613 \text{ pF}$$

Taking into account the Plate capacitance:

$$C_{inMin} = 122 \text{ pF}$$

$$L = 3.55 \text{ uH}$$

$$C_{inMax} = 271 \text{ pF}$$

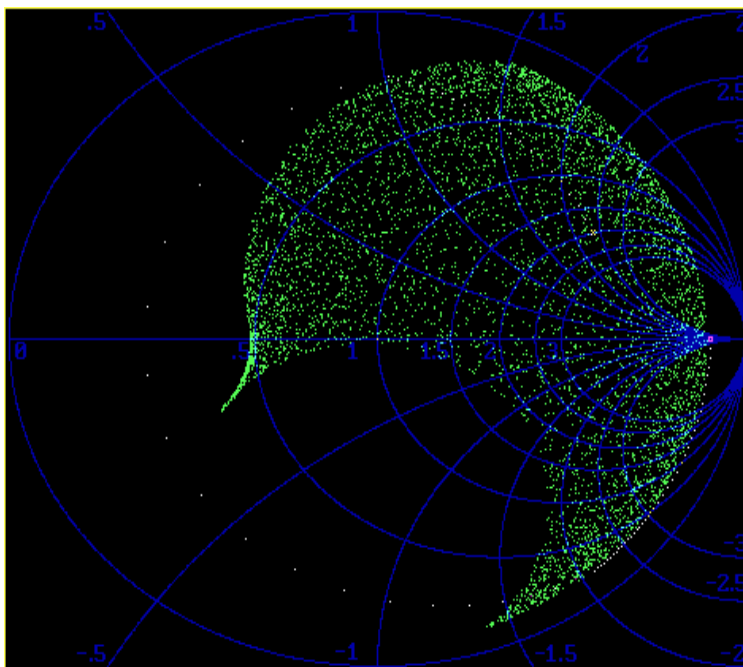
$$C_{outMax} = 613 \text{ pF}$$

Table of required capacitances for the previous problem ( $C_p=0$ ).

$R_{out}$	25	35	50	75	100	150	1000
$C_{in}$	142 pF	161 pF	169 pF	178 pF	186 pF	197 pF	284 pF
$C_{out}$	< 10 pF	576 pF	611 pF	582 pF	547 pF	489 pF	295 pF

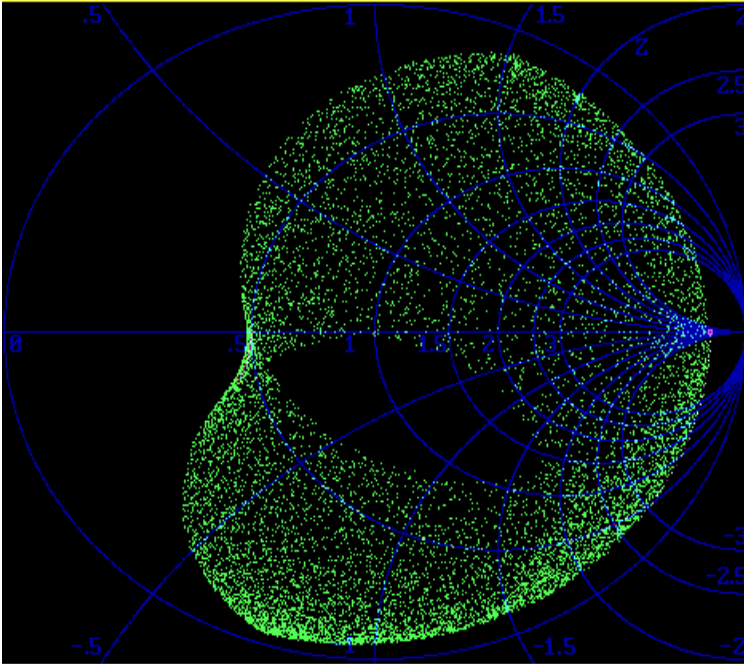
$Q$  is minimum possible at  $R_{out} = 25 \text{ ohm}$ , and maximum at  $R_{out} = 1000 \text{ ohm}$ .

## MONTECARLO SMITH CHART ANALYSIS



All real (pure resistive) impedances between exactly 25 ohm and 1000 ohm (start impedance) are matched to the start impedance (small red square). In fact the horizontal blue segment between .5 ( $R=25 \text{ ohm}$ ) and the red square ( $R=1000 \text{ ohm}$ ) is covered by green dots.

If the input capacitor is allowed to vary from zero to 291 pF we have:



As you can see this Pi-NETWORK cannot match the full range of complex impedances within an area on the complex plane.

For this specific network the best way to “close” the hole is by choosing  $C_{outMax} = 1000$  pF. This is effective but it is necessary to employ this software to find the exact value of  $C_{outMax}$ :

<http://www.science.unitn.it/~fontana/rfmatch.html>.

For ultra-wide range matching the T-NETWORK is to be preferred. See: <http://www.ing.unitn.it/~fontana/antmatch.pdf>