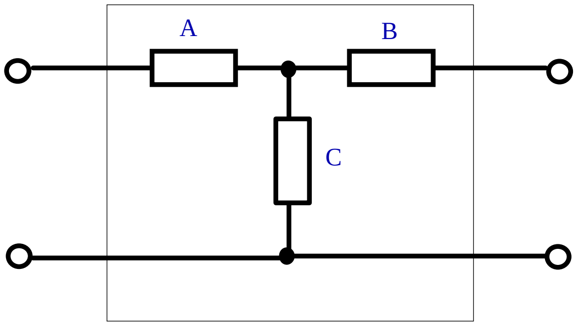
3.3.3.3: TESTING S-PARAMETERS FOR TYPICAL PASSIVE CIRCUITS

This chapter is divided into a first section, interpreting measured S-parameters against either a TEE *or* a PI structure, and a second section, where the data is tested against a *cascade* of a PI and a TEE structure. The lumped components are inductors, resistors and capacitors.

RLC_TEE OR RLC_PI CIRCUITS

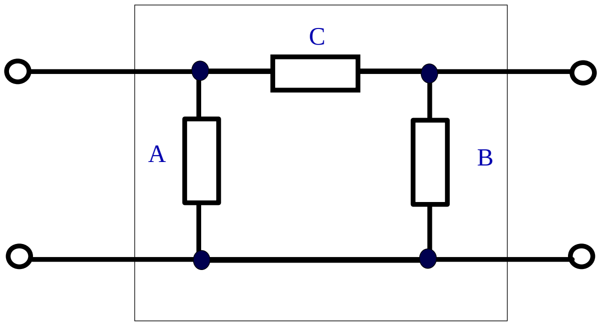
IC_CAP file: pass_RLC_TEE_or_PI.mdl

This chapter is intended to present some matrix manipulations for the interpretation of S-parameters of typical passive LRC networks. This is done by transforming the S-parameters to Y or Z-parameters. For these types of matrices exist simple interpretation capabilities, provided their underlaying circuits have a structure like in figures 1 and 2.



$$Z_{TEE} = \begin{pmatrix} A+C & C \\ C & B+C \end{pmatrix}$$

Fig.1: a TEE circuit interpreted as a Z matrix.



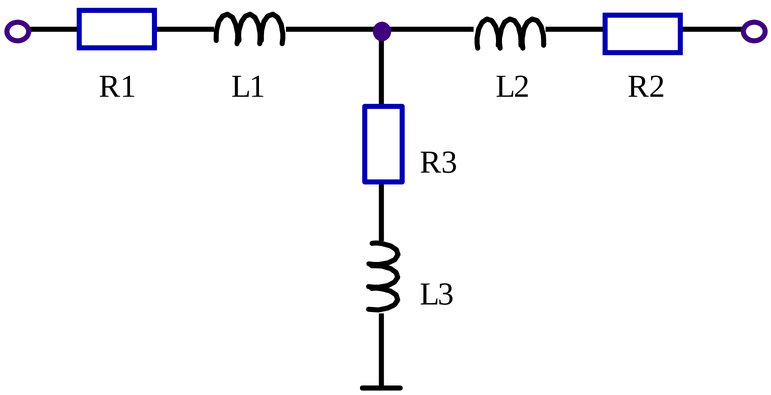
$$Y_{PI} = \begin{pmatrix} A+C & -C \\ -C & B+C \end{pmatrix}$$

watch the signs! .

Fig.2: a PI circuit interpreted as a Y matrix.

The following examples cover modeling algorithms for typical passive LRC networks.

Circuit 1:



This circuit has a TEE structure and therefore we have to interprete it following fig.1. That's why we transform the S parameters to Z and calculate the auxiliary variable

Zxy = (Z12 + Z21) / 2

Then, we obtain for the circuit elements from fig.1:

A = Z11 - Zxy
B = Z22 - Zxy
C = Zxy

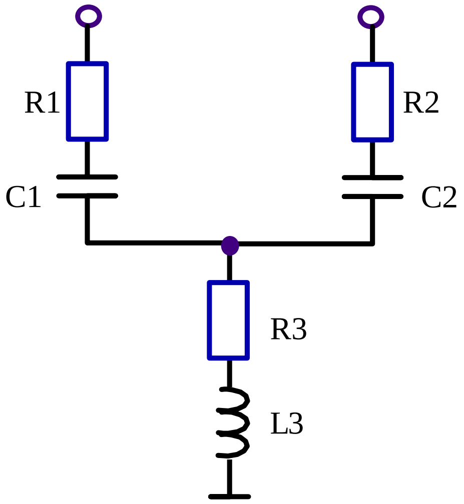
Out of that, we can now calculate the parameter values of the elements of our circuit:

$$R1 = REAL(A) \qquad L1 = \frac{IMAG(A)}{2 * PI * freq}$$

$$R2 = REAL(B) \qquad L2 = \frac{IMAG(B)}{2 * PI * freq}$$

$$R3 = REAL(C) \qquad L3 = \frac{IMAG(C)}{2 * PI * freq}$$

Circuit 2:



This circuit which is a typical one for an OPEN dummy on a silicon wafer has a TEE structure. So, again, we interprete it following fig.1. To do so, we have to transform the S parameters to Z, calculate

Zxy = (Z12 + Z21) / 2

and obtain for the circuit elements of fig.1:

A = Z11 - Zxy
B = Z22 - Zxy
C = Zxy

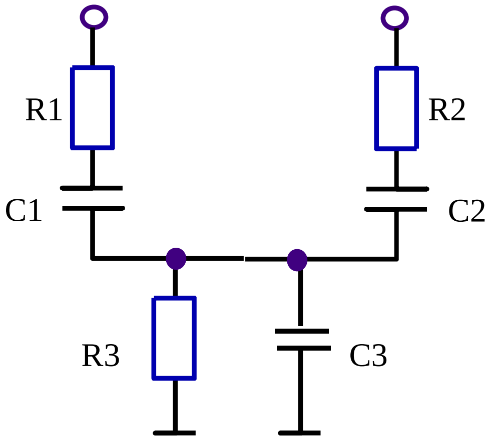
Back to our actual circuit, we get for its parameter values:

$$R1 = REAL(A) \qquad C1 = \frac{-1}{2 * PI * freq * IMAG(A)}$$

$$R2 = REAL(B) \qquad C2 = \frac{-1}{2 * PI * freq * IMAG(B)}$$

$$R3 = REAL(C) \qquad L3 = \frac{IMAG(C)}{2 * PI * freq}$$

Circuit 3:



This circuit is a variation of the circuit 2. Again, we interprete it following fig.1, i.e. we have to transform the S parameters to Z, calculate

Zxy = (Z12 + Z21) / 2

and obtain for the circuit elements of fig.1:

A = Z11 - Zxy
B = Z22 - Zxy
C = Zxy

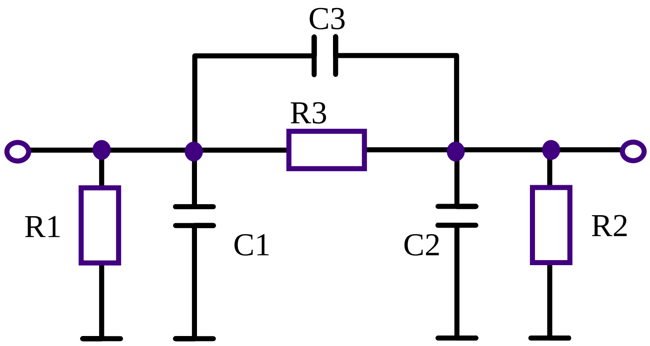
Back to our actual circuit, we get for its parameter values:

$$R1 = REAL(A) \qquad C1 = \frac{-1}{2*PI*freq*IMAG(A)}$$

$$R2 = REAL(B) \qquad C2 = \frac{-1}{2*PI*freq*IMAG(B)}$$

$$R3 = \frac{1}{REAL\left(\frac{1}{C}\right)} \qquad C3 = \frac{IMAG\left(\frac{1}{C}\right)}{2*PI*freq}$$

Circuit 4:



In this case, the circuit behaves like a PI structure and so we have to interprete it after fig.2. Transforming the S parameters to Y and calculating

Yxy = (Y12 + Y21) / 2

we get for the circuit elements of fig.2:

A = Y11 + Yxy
B = Y22 + Yxy
C = -Yxy

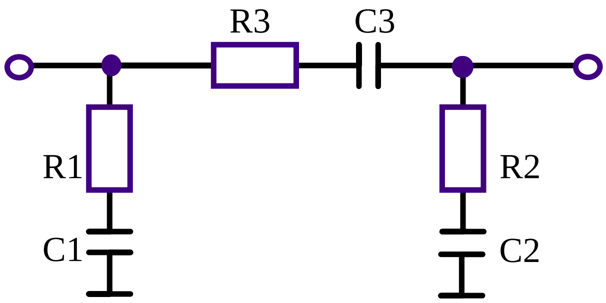
Finally, the parameter values of our actual circuits are:

$$R1 = \frac{1}{REAL(A)} \qquad C1 = \frac{IMAG(A)}{2 * PI * freq}$$

$$R2 = \frac{1}{REAL(B)} \qquad C2 = \frac{IMAG(B)}{2 * PI * freq}$$

$$R3 = \frac{1}{REAL(C)} \qquad C3 = \frac{IMAG(C)}{2 * PI * freq}$$

Circuit 5:



Transforming the S parameters to Y and interpreting them as a PI structure (fig.2), we get using

Yxy = (Y12 + Y21) / 2

the circuit elements

A = Y11 + Yxy
B = Y22 + Yxy
C = -Yxy

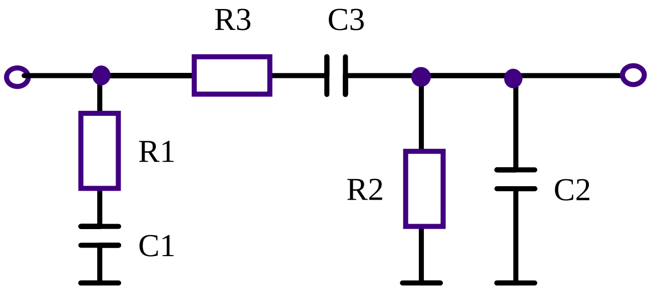
Out of them, we can calculate the parameter values of the actual circuit to

$$R1 = REAL\left(\frac{1}{A}\right) \qquad C1 = \frac{-1}{2 * PI * freq * IMAG\left(\frac{1}{A}\right)}$$

$$R2 = REAL\left(\frac{1}{B}\right) \qquad C2 = \frac{-1}{2 * PI * freq * IMAG\left(\frac{1}{B}\right)}$$

$$R3 = REAL\left(\frac{1}{C}\right) \qquad C3 = \frac{-1}{2 * PI * freq * IMAG\left(\frac{1}{C}\right)}$$

Circuit 6:



This example also looks like a PI structure and therefore we transform again the S parameters to Y and obtain for the circuit elements of fig.2 using:

Yxy = (Y12 + Y21) / 2

A = Y11 + Yxy
B = Y22 + Yxy
C = -Yxy

This leads to the parameters of our actual example.
We get for R1 and C1:

$$R1 = REAL\left(\frac{1}{A}\right) \qquad C1 = \frac{-1}{2 * PI * freq * IMAG\left(\frac{1}{A}\right)}$$

and for R2 and C2:

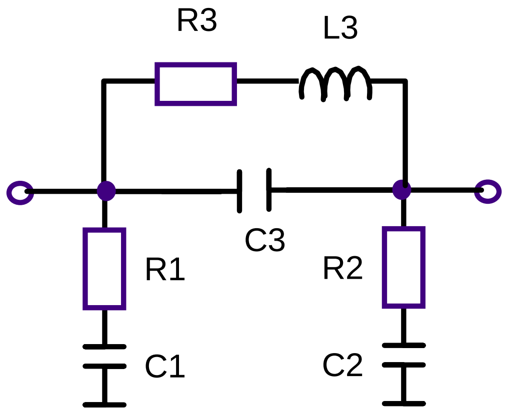
$$R2 = \frac{1}{REAL(B)} \qquad C2 = \frac{IMAG(B)}{2 * PI * freq}$$

as well as for R3 and C3:

$$R3 = REAL\left(\frac{1}{C}\right) \qquad C3 = \frac{-1}{2 * PI * freq * IMAG\left(\frac{1}{C}\right)}$$

The implementation of these formulas into IC-CAP is very simple using PEL and can be looked at in the model file.

Circuit 7:



This example is another PI structure and therefore we transform again the S parameters to Y and obtain for the circuit elements of fig.2 using:

Yxy = (Y12 + Y21) / 2

A = Y11 + Yxy
B = Y22 + Yxy
C = -Yxy

We get for R1 and C1:

$$R1 = REAL\left(\frac{1}{A}\right) \qquad C1 = \frac{-1}{2 * PI * freq * IMAG\left(\frac{1}{A}\right)}$$

and for R2 and C2:

$$R1 = REAL\left(\frac{1}{B}\right) \qquad C2 = \frac{-1}{2 * PI * freq * IMAG\left(\frac{1}{B}\right)}$$

as well as for R3, C3 and L3:

$$R3 = REAL\left(\frac{1}{C}\right)$$

extract from data before resonance, at low frequencies

$$L3 = \frac{-1}{2 * PI * freq * IMAG(C)}$$

extract from data before resonance, at low frequencies

$$C3 = \frac{-1}{2 * PI * freq * IMAG\left(\frac{1}{C}\right)}$$

extract from data after resonance, at high frequencies

APPLICATION: modeling of spiral inductors

CASCADED RLC_TEE AND RLC_PI CIRCUITS

IC_CAP file: pass_RLC_TEE_and_PI.mdl

This chapter is currently under development.

