<u>Case Study Mechatronic System Simulation</u>

Task-1: Block oriented and object-oriented simulation of a 2nd order RC low pass filter

Report by

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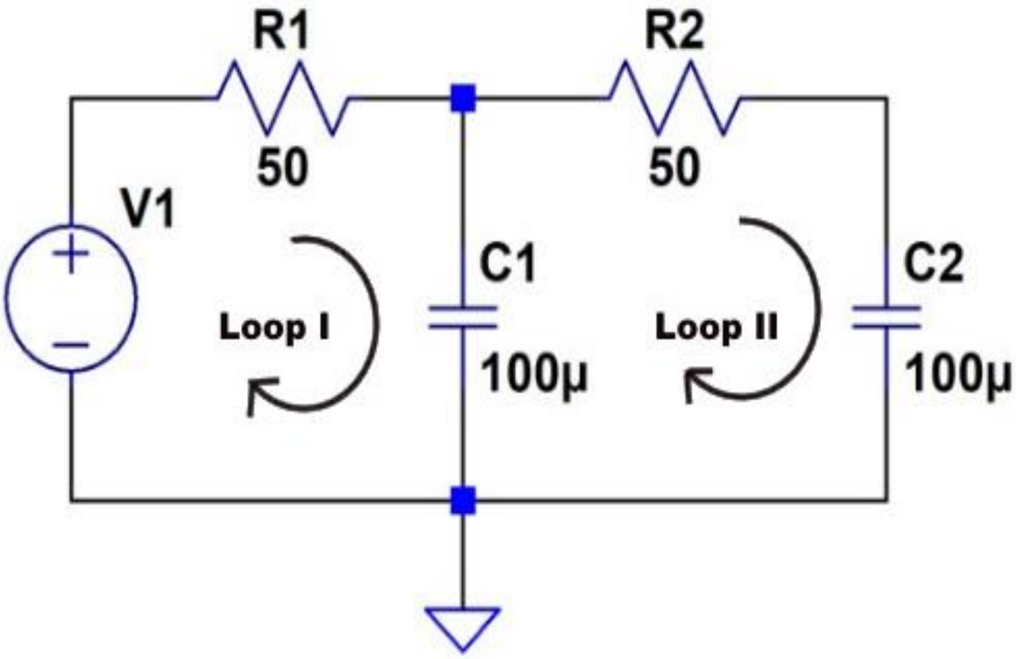

Fig 1: 2nd Order RC Low Pass Filter

a) Determination of the Steady state equations

Given state variables are $U_{c_1}(t)$ and $U_{c_2}(t)$

Lets assume

$$x_1 = U_{c_1}(t) \text{and} x_2 = U_{c_2}(t)$$

And

$$I_1 = c_1 \dot{x}_1 \text{and} I_2 = c_2 \dot{x}_2$$

Applying the Kirchoff's Voltage Law

Loop I

$$V_1 = (I_1 + I_2)R_1 + U_{c_1}(t)$$

$$V_1 = (C_1 \dot{x}_1 + C_2 \dot{x}_2)R_1 + x_1 \longrightarrow \text{(i)}$$

Loop II

$$-X_1 + I_2 R_2 + x_2 = 0$$

$$-x_1 + C_2 \dot{x}_2 R_2 + x_2 = 0$$

$$C_2 \mathring{x}_2 R_2 = x_1 - x_2$$

$$\Rightarrow \dot{x}_2 = \frac{1}{C_2 R_2} x_1 - \frac{1}{C_2 R_2} x_2 \longrightarrow \text{(I)}$$

Substituting equation (I) in (i)

$$\Rightarrow V_1 = C_1 R_1 \dot{x}_1 + C_2 \left[\frac{x_1}{C_2 R_2} - \frac{x_2}{C_2 R_2}\right] R_1 + x_1$$

$$V_1 = C_1 x_1^* R_1 + \frac{R_1}{R_2} x_1 - \frac{R_1}{R_2} x_2 + x_1$$

$$C_1 R_1 \dot{x}_1 = -\frac{R_1}{R_2} x_1 + \frac{R_1}{R_2} x_2 - x_1 + V_1$$

$$\dot{x}_1 = -\frac{1}{C_1 R_1} x_1 - \frac{x_1}{C_1 R_2} + \frac{1}{C_1 R_2} x_2 + \frac{V_1}{C_1 R_1}$$

$$\dot{x}_1 = \left[-\frac{1}{C_1 R_2} - \frac{1}{C_1 R_2}\right] x_1 + \frac{1}{C_1 R_2} x_2 + \frac{\mathrm{V}_1}{C_1 R_1} \longrightarrow \text{(II)}$$

The state equations are:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -\frac{1}{C_1 R_1} - \frac{1}{C_1 R_2} & \frac{1}{C_1 R_2} \\ \frac{1}{C_2 R_2} & \frac{-1}{C_2 R_2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} \frac{1}{C_1 R_1} & 0 \end{bmatrix} [V_1]$$

We have,

$V_1 = 10V, R_1 = 50\Omega$

$C_1 = 100\mu F, R_2 = 50\Omega$

$C_2 = 100\mu\mathrm{F}$

Solving for a_{11}, a_{12}, a_{21}anda_{22}

$$a_{11} = \frac{-1}{C_1 R_1} + \frac{-1}{C_2 R_2} = \frac{-1}{100 \times 50 \times 10^{-6}} + \frac{-1}{100 \times 50 \times 10^{-6}} \Rightarrow -400$$

$$a_{12} = \frac{1}{c_1 R_2} = \frac{1}{100 \times 50 \times 10^{-6}} \Rightarrow 200$$

$$a_{21} = \frac{1}{c_2 R_2} = \frac{1}{100 \times 50 \times 10^{-6}} \Rightarrow 200$$

$$a_{22} = -\frac{1}{c_2 R_2} = \frac{-1}{100 \times 50 \times 10^{-6}} \Rightarrow -200$$

$$b_1 = \frac{1}{c_1 R_1} = \frac{1}{100 \times 50 \times 10^{-6}} \Rightarrow 200$$

b) Block Structure for Simulation in Scilab/Xcos

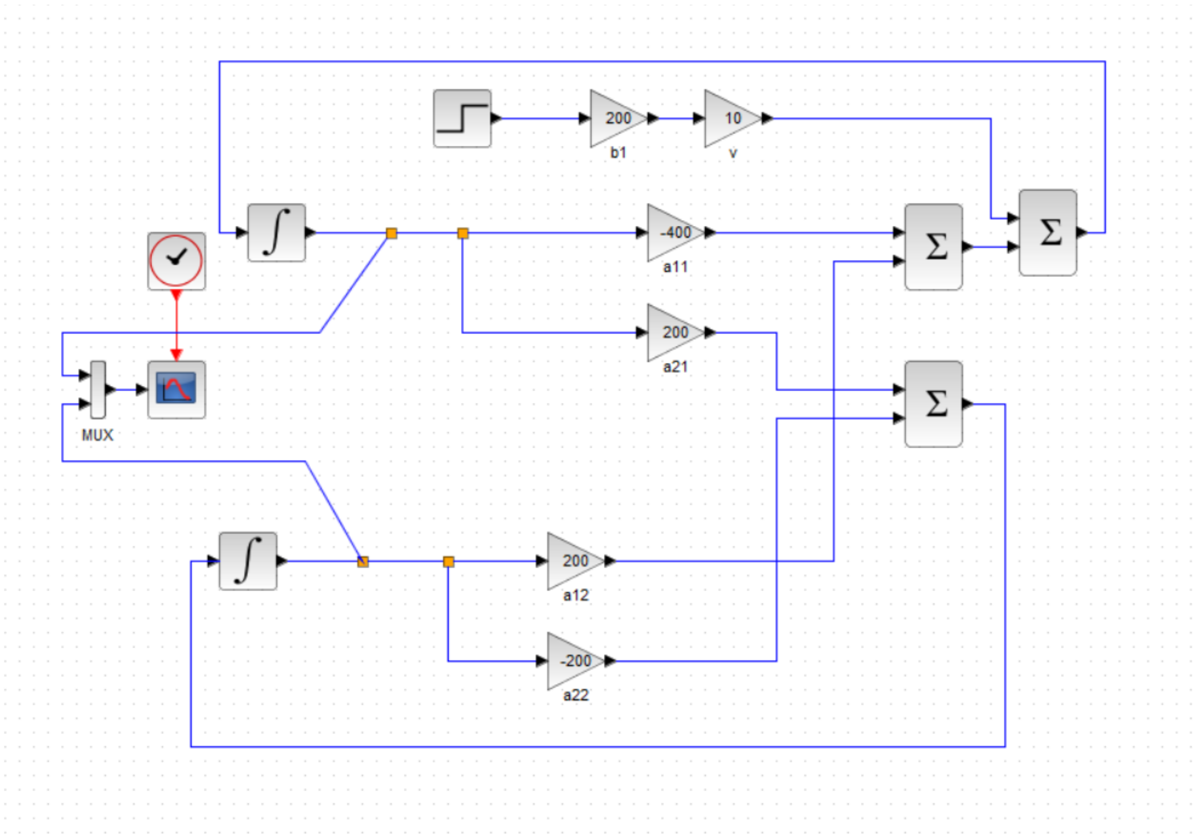

Fig 2: Block diagram

c) Simulation in Scilab/Xcos the frequency response of UC1(t) of the filter

report1.1

```
R1=50;
R2=50;
C1=0.0001;
C2=0.0001;
a11=-1/(C1*R1)-1/(C1*R2);
a12=1/(C1*R2);
a21=1/(C2*R2);
a22=-1/(C2*R2);
b1=1/(C1*R1);
A=[a11 a12;a21 a22];
B=[b1;0];
F=syslin('c',A,B,[0 1]);
bode(F,1,100);
```

Fig 3: Scilab Notes code for RC filter

d) Circuit diagram of the RC filter with the help of LTspice

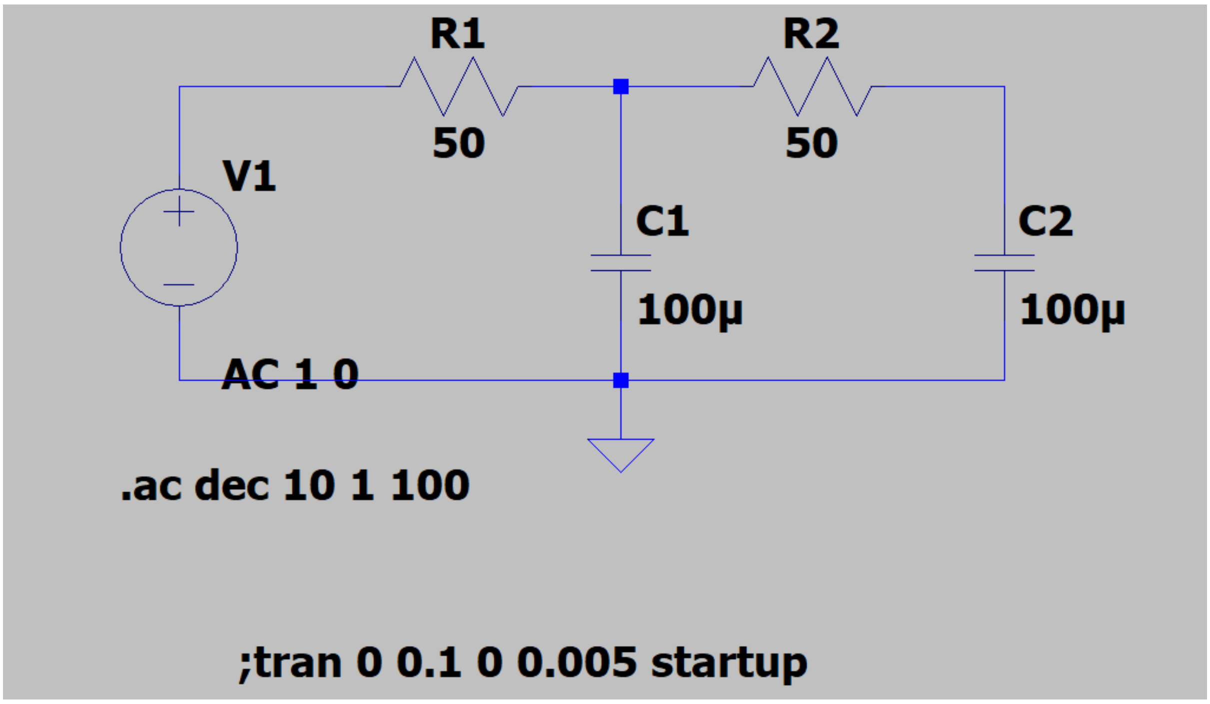

Fig 4: Circuit Diagram in LTspace

e) Comparing the results from Scilab and LTspace

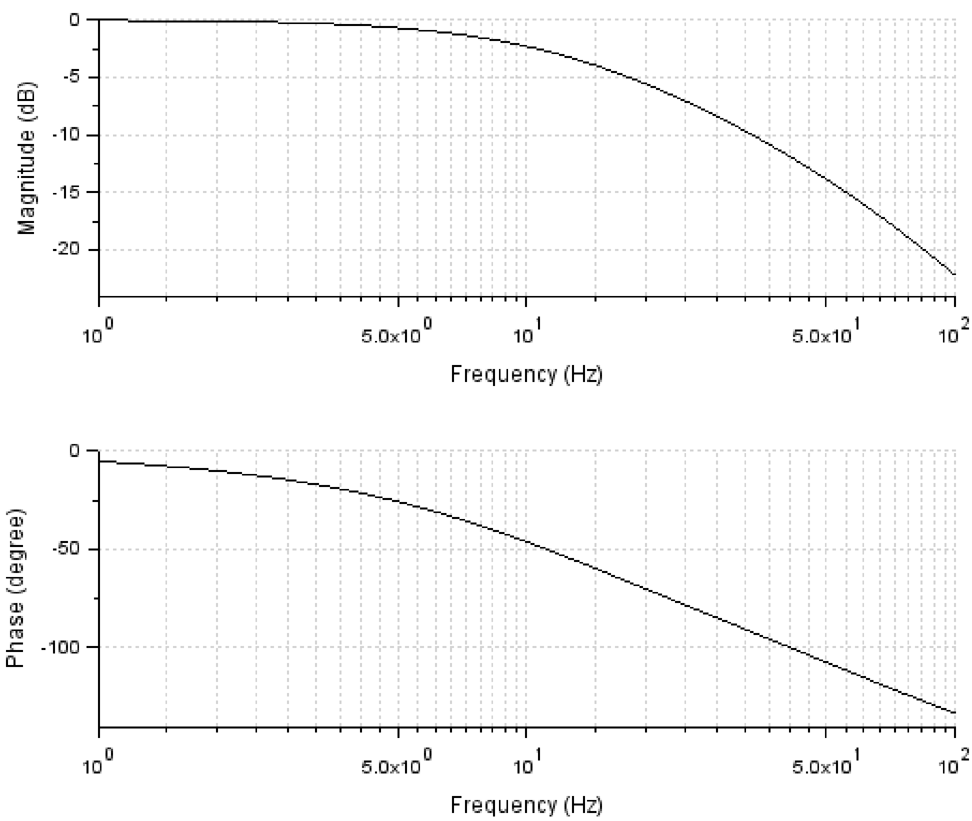

Fig 5: Bode plot of RC filter in Scilab

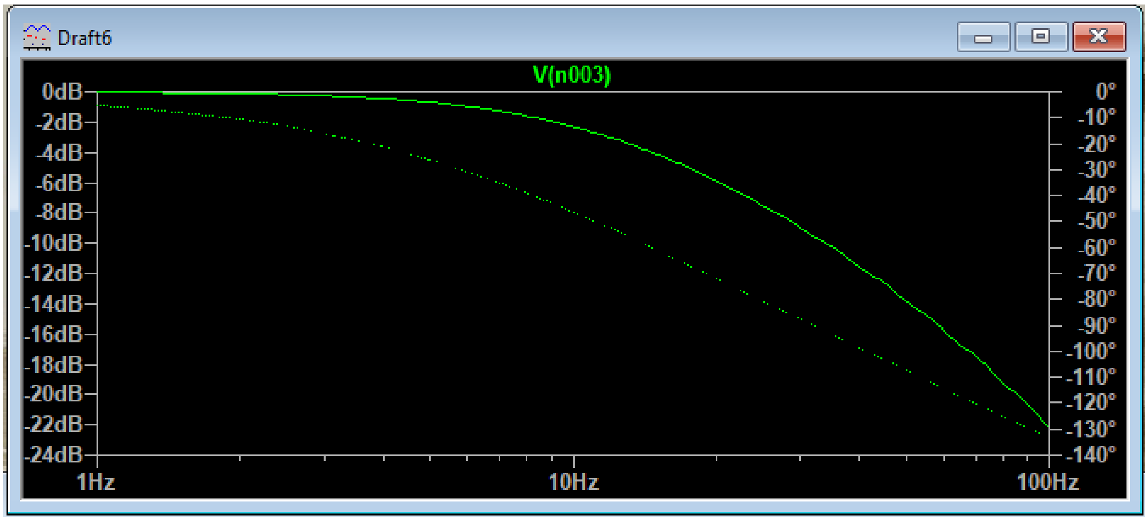

Fig 6: AC Analysis Using LTspace

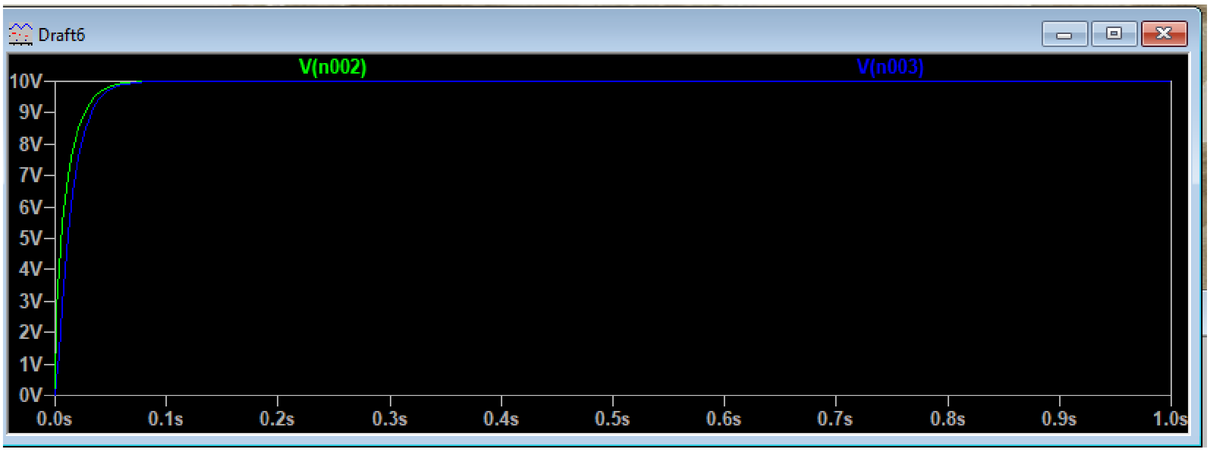

Fig 7: Transient Analysis Using LTspace

COMMENTS:

- For block-oriented simulation, it describes the simulation steps including the mathematical calculations (summation, integration, differentiation. Etc) during the simulation itself. While object-oriented simulation describes the functional structure of the system only.
- In block-oriented simulation, there is fixed order of computation. While object-oriented simulation has variable order of computation.
- The re-usability of object-oriented simulation is depending on the components (R1, R2, C1, C2, V1), While re-usability in block-oriented simulation depends on very low level of mathematical operations.
- Block-oriented programming requires the derivation of state space equations and the calculation of coefficients whereas object-oriented programming does not require any calculations.
- Object-oriented method can be easily interpreted but block-oriented needs some time and skill.
- Any change in the circuit can be easily modified in object-oriented than in block-oriented.