High-level Modeling of Linear Analog Blocks with Power Consumption Information

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Context

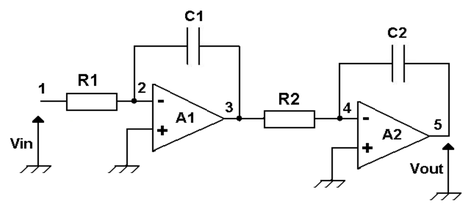
The interest of power consumption high-level modeling is to enrich the behavioral model of a system with the power consumption in order to make the simulations with a SystemC AMS high-level Model of Computation (MoC), leading to save simulation time.

Methodology

Netlist SystemC-AMS ELN MEMS → Circuital Matrix Generation → Circuital Matrix Arrangement → Data Extraction → SystemC-AMS LSF Model Generation

Circuital Matrix Building

V1 1 0 1
R1 1 2 1.6K
C1 2 3 1n
A1 0 2 3 +5 -5
R2 3 4 1.6k
C2 4 5 1n
A2 0 4 +5 -5

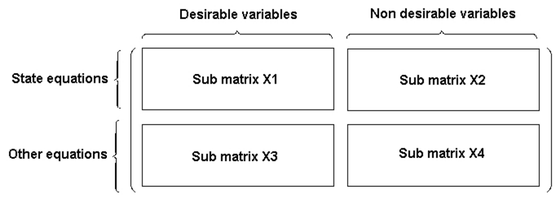


$$\frac{Vout}{Vin} = \frac{1}{R_1 R_2 C_1 C_2 p^2}$$

	V1	u23	u45	du23	du45	u00	u10	u20	u30	u40	u50	iR1	iC1	iA1	iR2	iC2	iA2
stateC1				$-C1$									1				
stateC2					$-C2$											1	
topV1	-1					-1	1										
topiR1							1	-1				$-R1$					
topu23		-1						1	-1								
topA1						-1		1									
topiR2									1	-1					$-R2$		
topu45			-1							1	-1						
topA2						-1				1							
gnd						1											
node2												-1	1				
node3													-1	-1	1		
node4															-1	1	
node5																	-1

Rows correspond to equations, columns to variables.

Circuital Matrix Arrangement & State Space Model



Relation Matrix

	V1	u23	u45
iC1	$1/R1$		
iR1	$1/R1$		
u10	1		
iC2		$-1/R2$	
iR2		$-1/R2$	
u30		-1	
u20			
u50			
u40			
u00			-1

Sub-matrix X4

	iC1	iR1	u10	iC2	iR2	u30	u20	u50	u40	u00
node2	1	-1								
topiR1		$-R1$	1				-1			
topV1			1							-1
node4				1	-1					
topiR2					$-R2$	1			-1	
topu23						-1	1			
topA1							1			-1
topu45								-1	1	
topA2									1	-1
gnd										1

State Space Model

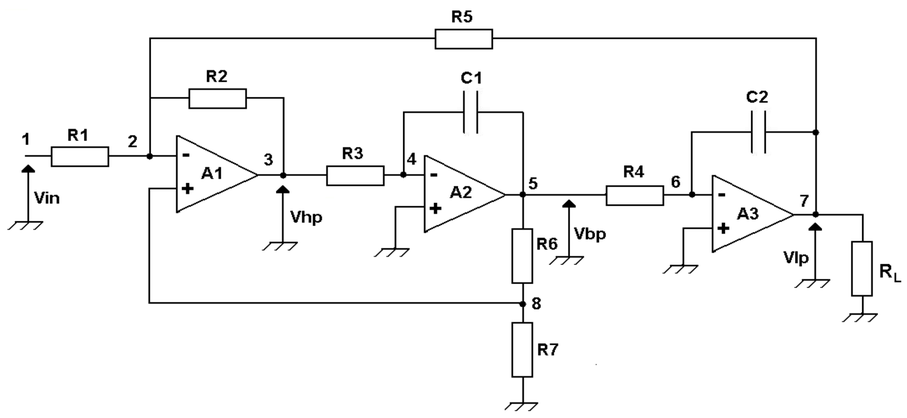
$$\begin{pmatrix} \dot{u}23 \\ \dot{u}45 \end{pmatrix} = \begin{pmatrix} 0 & 0 \\ -6{,}25.10^5 & 0 \end{pmatrix} \begin{pmatrix} u23 \\ u45 \end{pmatrix} + \begin{pmatrix} 6{,}25.10^5 \\ 0 \end{pmatrix} Vin$$

$$u50 = \begin{pmatrix} 0 & -1 \end{pmatrix} \begin{pmatrix} u23 \\ u45 \end{pmatrix}$$

Case Study

State Variable Filter

V1 1 0 1
R1 1 2 1.6K
R2 2 3 1.6K
R3 3 4 1.6K
R4 5 6 1.6K
R5 7 2 1.6K
R6 5 8 1.6K
R7 8 0 1.6K
R8 7 0 10K
C1 4 5 1n
C2 6 7 1n
A1 8 2 3 +5 -5
A2 0 4 5 +5 -5
A3 0 6 7 +5 -5



$$\frac{V_{LP}}{V_{IN}} = \frac{-1}{p^2 + \frac{3}{2RC}p + \frac{1}{R^2C^2}}$$

$$\begin{pmatrix} \dot{u}45 \\ \dot{u}67 \end{pmatrix} = \begin{pmatrix} -9{,}37.10^5 & 6{,}25.105 \\ -6{,}25.10^5 & 0 \end{pmatrix} \begin{pmatrix} u45 \\ u67 \end{pmatrix} + \begin{pmatrix} 6{,}25.10^5 \\ 0 \end{pmatrix} Vin$$

$$u70 = \begin{pmatrix} 0 & -1 \end{pmatrix} \begin{pmatrix} u45 \\ u67 \end{pmatrix}$$

Power Consumption Information Extraction

$$P_C = P_{STATIC} + P_{DYNAMIC}$$

$$P_{STATIC} = I_{QUIESCENT} * (V_{DD} - V_{SS})$$

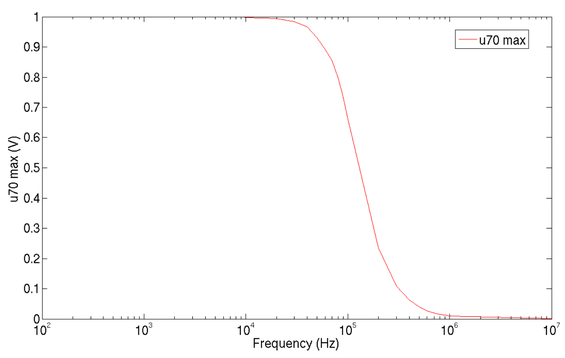
$$P_{DYNAMIC} = (i_{R7} + i_{R8}) * (V_{DD} - V_{SS})$$

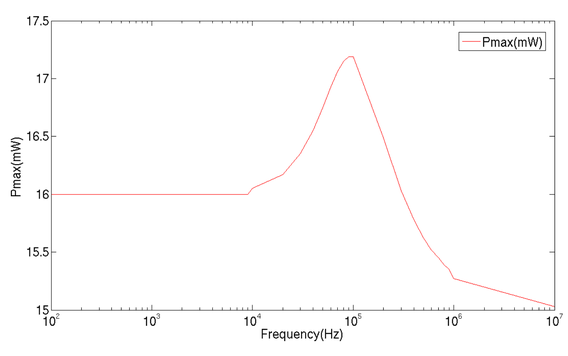
$$\begin{pmatrix} \dot{u}45 \\ \dot{u}67 \end{pmatrix} = \begin{pmatrix} -9{,}37.10^5 & 6{,}25.105 \\ -6{,}25.10^5 & 0 \end{pmatrix} \begin{pmatrix} u45 \\ u67 \end{pmatrix} + \begin{pmatrix} 6{,}25.10^5 \\ 0 \end{pmatrix} Vin$$

$$\begin{pmatrix} u70 \\ iR7 \\ iR8 \end{pmatrix} = \begin{pmatrix} 0 & -1 \\ -3{,}13.10^{-4} & 0 \\ 0 & -1.10^{-5} \end{pmatrix} \begin{pmatrix} u45 \\ u67 \end{pmatrix}$$

$$P_C = (V_{DD} - V_{SS})\left((i_{R7} + i_{R8}) + 3 * I_{QUIESCENT}\right)$$

Simulation Results





Conclusion and Perspectives

- This method allows to generate automatically the power consumption of an analog circuit at high level of abstraction using the state space model.
- The next step will consist on extend the method in order to model MEMS, using the electromechanical analogies and the electrical equivalent circuit.