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

**Laurent BOUSQUET, Emmanuel SIMEU**
**TIMA Laboratory (CNRS - Grenoble INP – UJF), RMS (Reliable Mixed Signal) Group**

**laurent.bousquet@imag.fr**

## Context

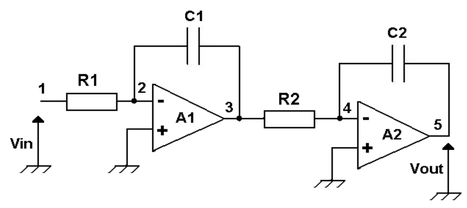
The interest of power consumption high-level modeling is to enrich the behavioral model of a system with the power consumption in order to make the simulations with a SystemC AMS high-level Model of Computation (MoC), leading to save simulation time.

## 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**



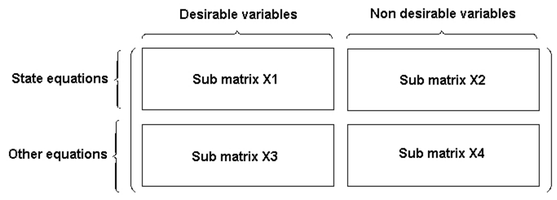

$$\frac{Vout}{Vin} = \frac{1}{R_1 R_2 C_1 C_2 p^2}$$

V1 u23 u45 du23 du45 u00 u10 u20 u30 u40 u50 iR1 iC1 iA1 iR2 iC2 iA2

$$\begin{array}{l}
\text{stateC1} \\ \text{stateC2} \\ \text{topV1} \\ \text{topiR1} \\ \text{topu23} \\ \text{topA1} \\ \text{topiR2} \\ \text{topu45} \\ \text{topA2} \\ \text{gnd} \\ \text{node2} \\ \text{node3} \\ \text{node4} \\ \text{node5}
\end{array}
\begin{pmatrix}
 & & & & & & & & & & & -C1 & & 1 & & & \\
 & & & & & & & & & & & & -C2 & & & & 1 \\
-1 & & & & & -1 & 1 & & & & & & & & & & \\
 & & & & & & 1 & -1 & & & -R1 & & & & & & \\
 & -1 & & & & & & 1 & -1 & & & & & & & & \\
 & & & & & -1 & & 1 & & & & & & & & & \\
 & & & & & & & & 1 & -1 & & & & & -R2 & & \\
 & & -1 & & & & & & & 1 & -1 & & & & & & \\
 & & & & & -1 & & & & 1 & & & & & & & \\
 & & & & & 1 & & & & & & & & & & & \\
 & & & & & & & & & & -1 & 1 & & & & & \\
 & & & & & & & & & & & -1 & -1 & 1 & & & \\
 & & & & & & & & & & & & & -1 & 1 & & \\
 & & & & & & & & & & & & & & & & -1
\end{pmatrix}$$

Rows correspond to equations, columns to variables.

## Circuital Matrix Arrangement & State Space Model




### Relation Matrix

$$\begin{array}{l}
\text{iC1} \\ \text{iR1} \\ \text{u10} \\ \text{iC2} \\ \text{iR2} \\ \text{u30} \\ \text{u20} \\ \text{u50} \\ \text{u40} \\ \text{u00}
\end{array}
\begin{array}{c}
\begin{array}{ccc} \text{V1} & \text{u23} & \text{u45} \end{array} \\
\begin{pmatrix}
1/R1 & & \\ 1/R1 & & \\ 1 & & \\ & -1/R2 & \\ & -1/R2 & \\ & -1 & \\ & & \\ & & \\ & & -1
\end{pmatrix}
\end{array}$$

### Sub-matrix X4

$$\begin{array}{l}
\text{node2} \\ \text{topiR1} \\ \text{topV1} \\ \text{node4} \\ \text{topiR2} \\ \text{topu23} \\ \text{topA1} \\ \text{topu45} \\ \text{topA2} \\ \text{gnd}
\end{array}
\begin{array}{c}
\begin{array}{cccccccccc} \text{iC1} & \text{iR1} & \text{u10} & \text{iC2} & \text{iR2} & \text{u30} & \text{u20} & \text{u50} & \text{u40} & \text{u00} \end{array} \\
\begin{pmatrix}
1 & -1 & & & & & & & & \\
 & -R1 & 1 & & & & -1 & & & \\
 & & 1 & & & & & & & -1 \\
 & & & 1 & -1 & & & & & \\
 & & & & -R2 & 1 & & & -1 & \\
 & & & & & -1 & 1 & & & \\
 & & & & & & 1 & & & -1 \\
 & & & & & & & -1 & 1 & \\
 & & & & & & & & 1 & -1 \\
 & & & & & & & & & 1
\end{pmatrix}
\end{array}$$

### State Space Model

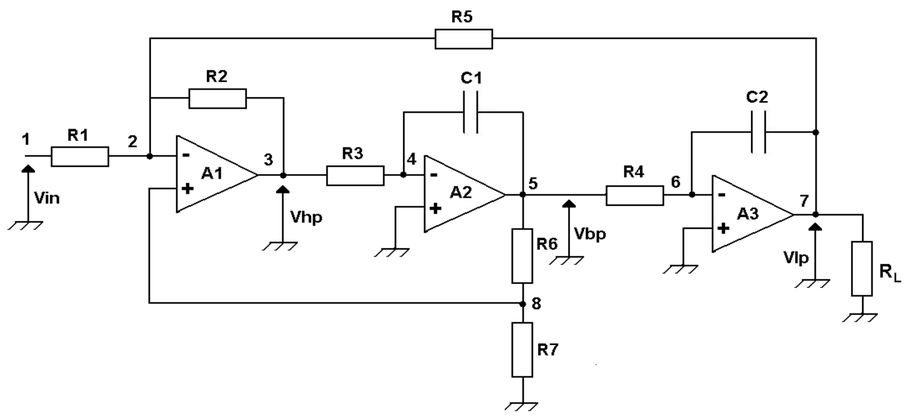
$$\begin{pmatrix} \dot{u23} \\ \dot{u45} \end{pmatrix} = \begin{pmatrix} 0 & 0 \\ -6{,}25.10^5 & 0 \end{pmatrix} \begin{pmatrix} u23 \\ u45 \end{pmatrix} + \begin{pmatrix} 6{,}25.10^5 \\ 0 \end{pmatrix} Vin$$

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

## 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**




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

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

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

### Power Consumption Information Extraction

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

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

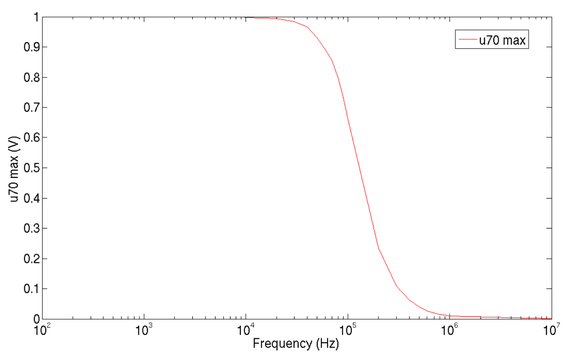
$$P_{DYNAMIC} = (i_{R7} + i_{R8}) * (V_{DD} - V_{SS})$$

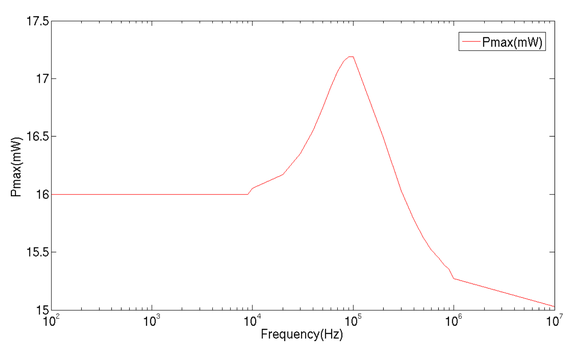
$$\begin{pmatrix} \dot{u45} \\ \dot{u67} \end{pmatrix} = \begin{pmatrix} -9{,}37.10^5 & 6{,}25.105 \\ -6{,}25.10^5 & 0 \end{pmatrix} \begin{pmatrix} u45 \\ u67 \end{pmatrix} + \begin{pmatrix} 6{,}25.10^5 \\ 0 \end{pmatrix} Vin$$

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

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

## 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.