An Open Source Collaborative Matlab Toolbox for the Design and Simulation of Continuous-Time Sigma Delta modulators

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Simulating Continuous Time (CT) Sigma Delta Modulators (SDM) is commonly done using block level systems such as Simulink which is a highly time consuming task even at system level. Therefore, the existing design tools for SDM are either discrete time oriented (Schreier toolbox) or proprietary (Ulm toolbox).

In this work, we propose a new Matlab/C toolbox for the design of CT SDM. Simulation is based on state space representation thereby allowing to support most of the existing SDM architectures. Moreover, the main non-idealities of the main blocks are modeled (opamp DC gain, finite GBW, DACs mismatch, ISI and quantizer offset). Besides, thanks to the modular and open source approach for this toolbox, every user can easily implement additional features and include it.

One of the main feature of this toolbox is to provide self-explanatory Matlab codes and equivalent C-based codes so that peers can easily use fast and optimized codes and contribute to the project without having to write elaborate documentation. Matlab codes excerpts in Fig. 1 illustrates a self-explanatory Matlab code implementing the computation of the state variables (Fig. 1a) and a testbench showing the equivalence between Matlab and C-based codes (Fig. 1b). Fig. 2 shows a simulation result obtained using the toolbox functions. Matching with the theoretical formula demonstrates the accuracy of the simulation tool.

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(a) simulateSIM, DCTSS Matlab function

```matlab
for i=0:N-2
% Compute states of the modulator
dsmStates(:,i+1) = AbbS*dsmStates(:,i+1) + BOvS*[u(i+1,:);dsmOut(i+1,:)];
end
```

(b) Testbench calling both Matlab and C-based functions

```matlab
% ... code omitted ...

% Simulate both implementations for comparison
% Matlab version
% % Compute states of the modulator
dsmStates = simulateDSM_DCTSS_blas(input_sig, A, B, C, D, OOSR, nlev);
% C-based version
% % Compute states of the modulator
dsmStates = simulateSIM_DCTSS(input_sig, A, B, C, D, OOSR, nlev);
% ... code omitted ...
```

Figure 1: Codes excerpts

Designs and simulations for various architectures of CT SDM are performed during the forum to demonstrate the accuracy and efficiency of the proposed toolbox.

In this toolbox, collaborative work is enabled by a distributed version control system (Git). This collaborative tool allows to develop features in a world-wide distributed fashion and easily integrate it to the project. Fig. 3 shows the web interface of the used version control system. The collaborative development workflow will be demonstrated with attendees.

![Figure 2: STF of a CT lowpass 4th CIFB modulator (Fs = 640MHz, BW = 10MHz)](image)

![Figure 3: Preview of the Git-based collaborative version control system web interface](image)