Emulation of biological cells

Jerry Jacob, Nitish Patel, Sucheta Sehgal

The University of Auckland
Auckland, New Zealand

Aim: The Fourier Series methodology (FSM) has shown promise in emulation of action potential (AP) of biological cells. We aim to establish a suitable implementation technique for hardware platforms - specifically FPGAs without floating point units. The Direct Digital Synthesis (DDS) and Resonant Model (RM) techniques are reported.

Method: The accuracy of the FSM is reliant on the selection of harmonics. However, a trade-off between accuracy and usage of silicon real-estate is necessary. The AP waveshape is a significant factor and hence this study considers 4 different APs from various cell models. The comparative metrics are based on a Cyclone V FPGA as well as an 'atomic' NAND gate count. Specifically, we obtain the parameters of the FSM with 8 harmonics from MATLAB and implement the FSM on an FPGA using integer/fixed-point operations. Typical performance metrics have been obtained and tabulated.

Table 1: NAND gate utilization of DDS and RM

Resource	DDS	RM
Look-Up Table	65536	0
Adder/Subtractor	5712	9792
Multipliers	11872	0
8x1 Multiplexer with counter	225	0
1x8 Demultiplexer	336	0
Total NAND gates	**83681**	**9792**
Logic Utilization on Cyclone V	**3409**	**401**

Results: The AP waveshapes of the cell models (FitzHugh Nagumo, Beeler Reuter, Luo Rudy I and Fenton Karma model) were used as reference. The reconstruction of these AP waveshapes with DDS and RM captures 95% to 98% of the trend. However, the silicon usage varies. The synthesis of the DDS and RM design gives the NAND gate utilization summary for 32-bit inputs. Table 1 shows the number of NAND gates used by various components of the DDS and RM. It has been seen that the silicon utilized by RM implementation is almost 8.5 times lesser than the DDS approach. This comparison is also justified by the estimation of logic utilization using Cyclone V SoC in Quartus Prime 20.1 Lite.

Conclusion: The RM offers a much lower hardware footprint when compared to the DDS. Hence, RM can emulate a large number of cells with fewer resources.