

Contents

1	Introduction to Field-Programmable Gate Arrays	1
1.1	FPGA Architectures	1
1.2	Blocks Description	2
1.2.1	Logic Blocks	2
1.2.2	Lookup Tables (LUTs)	5
1.2.3	I/O Blocks	7
1.3	Programming Environments	7
1.3.1	Vivado	7
1.3.2	Quartus II	16
1.3.3	Aldec Active-HDL	21
1.4	Computer Arithmetic	26
1.4.1	Fixed Point Numbers	29
1.4.2	Operations with 2' Complement Numbers	30
1.4.3	Floating-Point Numbers	31
2	VHDL	33
2.1	A Brief History of VHDL	33
2.2	VHDL Structure	33
2.3	Levels of Abstraction	36
2.3.1	Behavioral Description	36
2.3.2	Data Flow Description	39
2.3.3	Structural Description	42
2.4	Modules Description Examples	46
2.4.1	Combinational Circuits	46
2.4.2	Sequential Circuits	51
3	Matlab-Simulink Co-Simulation	61
3.1	Co-Simulation Active-HDL/Matlab-Simulink	61
3.2	Co-Simulation Xilinx System Generator/Matlab-Simulink	67
3.3	Co-Simulation Altera DSP Builder/Matlab-Simulink	72

4	Chaos Generators	77
4.1	On Piecewise-Linear (PWL) Functions	77
4.1.1	Saturated Function Series as PWL Function	77
4.1.2	Chua's Diode as PWL Function	78
4.1.3	Sawtooth as PWL Function	79
4.2	On the Simulation of Chaos Generators for FPGA Implementation	80
4.2.1	One-Step Methods for Simulating the Generation of 2-Scrolls	82
4.3	Symmetric and Nonsymmetric PWL Functions	84
4.3.1	Symmetric PWL Function	85
4.3.2	Nonsymmetric PWL Function	87
4.3.3	VHDL Simulation and Computer Arithmetic Issues	87
4.4	VHDL Code Generation	92
4.5	Bifurcation Diagrams	94
4.6	Multi-scroll Chaotic Attractors with High MLE and Entropy	94
4.6.1	Lyapunov Exponents	103
4.6.2	Evaluation of Entropy	109
4.7	Generating a 50-Scrolls Chaotic Attractor at 66 MHz	111
5	Artificial Neural Networks for Time Series Prediction	117
5.1	Introduction	117
5.2	Generating Chaotic Time Series Using FPGAs	118
5.3	ANN Design Issues	121
5.3.1	ANN Topology Selection	124
5.3.2	ANN Training	126
5.3.3	Weights Updating by Batches and Incremental Methods	129
5.3.4	On the Activation Function in the Last Layer of the ANN	131
5.3.5	Time Series Prediction of Chaotic Signals with Different MLE	132
5.4	FPGA-Based ANN for Time-Series Prediction of Chaotic Signals	133
5.4.1	FPGA Realization of the Hyperbolic Tangent Activation Function	133
5.5	Serial Communication Protocol: PC-FPGA	144
6	Random Number Generators	151
6.1	Generating Pseudorandom Binary Sequences	151
6.2	Numerical Method for Solving a Chaotic Dynamical System	151
6.3	Double-Scroll and Multi-scroll Chaos Generators	152
6.3.1	Chua's Chaotic Oscillator	152
6.3.2	Saturated Function Series-Based Chaotic Oscillator	153

6.4	Measuring the Entropy of a RNG	155
6.5	NIST Measurements	157
6.6	Different RNGs	157
7	Secure Communication System.	173
7.1	Chaotic Secure Communication Systems	173
7.2	Hamiltonian Synchronization Approach	174
7.3	Synchronization of Multi-scroll Chaotic Attractors.	176
7.4	Synchronization of 2D-4-Scroll Chaos Generators	179
7.5	Synchronization of 3D-4-Scroll Chaos Generators	182
7.5.1	Numerical Simulation Results	184
7.6	Image Transmission Through a Chaotic Secure Communication System.	184
7.6.1	Multi-scroll Chaos Generators Based on PWL Functions	185
7.6.2	FPGA Realization	190
7.6.3	Master–Slave Synchronization	191
7.6.4	FPGA Realization	194
8	Challenges in Engineering Applications	205
8.1	On the Length of the Digital Words.	205
8.1.1	Example of a Design with the Lorenz System.	205
8.1.2	Variables Range Determination.	206
8.1.3	Number of Bits in the Integer Part	207
8.1.4	Fixed Point Implementation	208
8.2	Current Challenges	210
	References	215
	Index	221

Engineering Applications of FPGAs

Chaotic Systems, Artificial Neural Networks, Random
Number Generators, and Secure Communication
Systems

Tlelo-Cuautle, E.; Rangel-Magdaleno, J.; de la Fraga, L.G.

2016, XVI, 222 p. 204 illus., 130 illus. in color.,

Hardcover

ISBN: 978-3-319-34113-2