MODELLING, ANALYSIS AND DESIGN OF BIOELECTRONIC CIRCUITS IN VLSI

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ABSTRACT

Biological phenomena at the molecular level are being imitated by electronic circuits. The immense effectiveness and versatility of bioelectronic circuits have yielded multiple benefits to both the electronic, and the biological worlds. Advancement in technology is being made towards the design and implementation of these systems due to their extreme proficiency and extraordinary capabilities. Development of bioelectronic circuits is assisting researchers to gain deep insights into complex processes of life. These systems are classified into different categories depending on the various kinds and nature of the biological processes. Cytomorphic and neuromorphic circuits are two major classifications of the bioelectronic systems.

Cytomorphic circuits mimic the biological processes taking place inside a living cell. Activities involved in DNA-protein interactions play a vital role for the survival of living organisms. This thesis illustrates modelling and the design of the cytomorphic circuits in VLSI representing the DNA-protein interactions at the molecular level. Electronic circuits imitating neural activities are classified as neuromorphic circuits. The significance of these bioelectronic circuits cannot be denied. Hence, an effort is made in this research to model neuron-to-neuron communication process through electronic circuit components in VLSI. For an electronic representation of these phenomena, biological to electrical analogies are determined, analysed, and modelled. Circuit design validation is accomplished by comparing the circuit results with experimentally reported biological data.

The cytomorphic circuit is capable of analysing the cellular behaviour of living organisms, while the neuromorphic circuit is competent to mimic the neurological processes that are dependent on neuron-to-neuron combination such as neural DNA transcription initiation. Biological experimentation on bacteria *Escherichia coli* is carried out that validates that the cytomorphic VLSI circuit design is capable of predicting gene behaviour of living organisms. The neuromorphic circuit is fabricated using 0.13µm IBM CMOS technology and fabrication results are illustrated in the thesis. Electronic gene oscillators and neural DNA transcription initiation circuits are illustrated as applications of the proposed VLSI bioelectronic circuit designs.

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LIST OF ABBREVIATIONS

Acetyl CoA	Acetyl Coenzyme A
ACh	Acetylcholine
BiCMOS	Bipolar-CMOS
BJT	Bipolar Junction Transistor
Ca^{+2}	Calcium ion
CaMKIV	Ca^{+2}/calModulin-dependent protein Kinase IV
CAT	Choline AcetylTransferase
CMOS	Complementary Metal Oxide Semiconductor
CREB	cAMP-Responsive Element Binding Protein
DNA	Deoxyribonucleic acid
E.coli	Escherichia coli
EPC	End Plate Current
EPSP	Excitatory Postsynaptic Potential
IC	Integrated Circuit
Lac	Lactose
MATLAB	MATrix LABoratory
Memristor	Memory Resistor
miRNA	Micro Ribonucleic Acid
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
mRNA	Messenger Ribonucleic Acid
NMOS	n-channel MOSFET
ONPG	*o*-nitrophenyl-β-galactoside
OpAmp	Operational Amplifier
pCREB	Phosphorylated CREB
PMOS	p-channel MOSFET
Pre-miRNA	Precursor Micro Ribonucleic Acid
Pri-miRNA	Primary Micro Ribonucleic Acid
RNA	Ribonucleic Acid
TiO_2	Titanium dioxide
VLSI	Very Large Scale Integration

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