Artificial Neural Networks (ANNs), having a highly parallel architecture, have emerged as a new paradigm for solving computationally intensive tasks, using collective computation in a network of neurons. They can be considered as analog computers relying on simplified models of neurons.

Recurrent neural networks, which are essentially ANNs employing feedback interconnections between the neurons, were extensively explored after the concept of Lyapunov (or ‘energy’) functions, as a means of understanding the complex dynamics of such networks, was introduced by Hopfield and Tank. Their architecture, called the Hopfield Network, was implementable in hardware, and although it became very popular, many limitations like convergence to infeasible solutions and the requirement of a large number of neurons and interconnection weights were revealed when attempts were made to apply it to practical applications. These drawbacks warranted the exploration of alternative neural network architectures which are amenable to hardware realizations. The Nonlinear Synapse Neural Network (NOSYNN) has been proposed as one such alternative which alleviates the problems that plagued the Hopfield Network.

In the present thesis, the NOSYNN architecture has been chosen as the starting point of the exploration for better hardware implementations of ANNs. Thereafter, the work progresses in two dimensions. Firstly, the voltage-mode NOSYNN has been reconfigured
and applied to a new problem \textit{viz.} the solution of linear equations. The proposed network has an associated energy function which contains transcendental terms as opposed to the quadratic terms in the energy functions for the Hopfield network and its variants. It is shown that the network has only a unique minimum in the energy landscape, and moreover, the global minimum coincides exactly with the solution point of the system of linear equations. Thereafter, it has been shown that two other important problems of mathematical programming: linear programming problem (LPP) and quadratic programming problem (QPP) could also be solved by incorporating small modifications in the voltage-mode network proposed for the solution of linear equations.

Secondly, new implementations for the NOSYNN have been proposed. These include a ‘mixed’-mode (MM) and a current-mode (CM) implementation of the non-linear feedback neural networks presented for the solution of linear equations, LPP and QPP. In the so called ‘mixed’-mode hardware realization, neuron states are represented as voltages whereas the synaptic interconnections convey information in the form of currents. It has been shown that the proposed mixed-mode implementation of the NOSYNN leads to reduction in the overall circuit complexity, as compared to the existing voltage-mode realization, by eliminating the resistors employed as synaptic weights. Further, current-mode circuit realizations for NOSYNN based hardware are proposed. It is demonstrated that the proposed CM circuits indeed enjoy resistor-less realizations for the application discussed, thereby ensuring ease of monolithic integration as well as reduced hardware complexity.