Analog Design
(1MEI104)

Research Project

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Purpose

As stated in the course syllabus, a learning objective for the students is to realize an introductory research project on a practical application of analog electronic circuits and write a technical report.

Research Topic

The proposed research topic is on the implementation of artificial neural networks (ANNs) using off-the-shelf electronic components.

Research work on electronic neural networks within integrated circuits have been extensively reported in the technical literature. The architectures used for integrated circuit implementations are not necessarily suitable for discrete implementations. On the other hand, small size ANNs can be efficiently implemented and built for specific applications with discrete components. The aim of this research project is to address this issue, specially for those applications where the ANN is not required to be programmable on line.

It is recommended that the student follows the research methodology studied at the course *Talleres de Inducción al Posgado*, or any other similar methodology.

Technical Information

The final product of this project consists of designing an analog electronic circuit that implements a 3-layer perceptron with 3 inputs, 3 hidden neurons and 3 outputs, with the following features:

a) The input and output signals can be currents or voltages.
b) The internal weighting factors of the ANN can be either positive or negative.
c) An accurate analytical model for the ANN must be proposed.
d) A single or dual voltage supply is allowed, with maximum magnitudes of 9V.
e) The maximum and minimum values for the input signals can be arbitrary defined by the designer.
f) Maximum power consumption of 500mW.
g) No potentiometers or other adjusting elements are allowed.
h) Any suitable activation function is allowed for the hidden neurons (the output layer should be linear).
i) All the electronic components used must be commercially available parts.

The ANN must be simulated with SPICE using the corresponding component models. The simulation

Introduction (5 points)
The report has a brief introduction
The introduction explains the importance of the subject
The introduction outlines the report's contents

Background (20 points)
Author describes the architecture of a 3LP
Author briefly reviews the main structures and circuits reported for IC ANNs
Author describes some alternative circuits proposed for discrete electronic ANNs

Proposed Implementation (20 points)
The proposed architecture is justified
Author provides detailed analysis of the main structures and circuits proposed
The analyses are technically correct and sufficiently accurate
Author identifies and explains the issues of central interest

Validation (30 points)
SPICE simulation of the proposed ANN is presented
Lab measurements are reported for the electronic ANN proposed
The ANN is simulated and measured for different input combinations, as well as for different weighting factors
A comparison between SPICE results and lab measurements is presented
Results are clear and easy to follow

Conclusions (5 points)
The conclusions are objective
The conclusions summarize and pull together the main points

References (5 points)
The report includes useful references and other resources
The references follow the requested format

Format (15 points)
The report is clean and well organized
The style is concise and clear
The figures and plots are clear and readable
The report is free of grammatical and typographical errors
The report is between 10 and 15 pages long

Exhibit. 1. Grading criteria for the technical report.

results must be compared to those obtained from the analytical model.

The ANN must also be built and characterized from laboratory measurements. The lab measurements must be conducted for at least 3 different combinations of weighting factors in the ANN as well as for 3 different combinations of inputs. The percentage of errors with respect to the analytical model and to the SPICE simulation must be reported.

Grading Criteria for the Research Project

The research project will be evaluated by the instructor based on the technical report. In preparing the report the student should keep in mind the grading criteria shown in Exhibit 1. The two most important elements of this research work are the review on the subject and the electrical performance of the proposed circuit. It is extremely important the reproducibility of the electronic ANN proposed (adjusting

elements should be avoided). It is important that the electronic ANN consumes as less power as possible.

Since this report is intended as a basis for future research work, its accuracy and rigor in format is important. The references must follow the following format:

Journal papers:

J.W. Bandler, M.A. Ismail, J.E. Rayas-Sánchez and Q.J. Zhang, "Neuromodeling of microwave circuits exploiting space mapping technology," *IEEE Trans. Microwave Theory Tech.*, vol. 47, pp. 2417-2427, Dec. 1999.

J.W. Bandler, M.A. Ismail and J.E. Rayas-Sánchez, "Broadband physics-based modeling of microwave passive devices through frequency mapping," *Int. J. RF and Microwave CAE*, vol. 11, pp. 156-170, May 2001.

Conference papers:

M.H. Bakr, J.W. Bandler, K. Madsen, J.E. Rayas-Sánchez and J. Søndergaard, "Space mapping optimization of microwave circuits exploiting surrogate models," in *IEEE MTT-S Int. Microwave Symp. Dig.*, Boston, MA, 2000, pp. 1785-1788.

J.W. Bandler, N. Georgieva, M.A. Ismail, J.E. Rayas-Sánchez and Q.J. Zhang, "A generalized space mapping tableau approach to device modeling," in *29th European Microwave Conf.*, vol. 3, Munich, Germany, 1999, pp. 231-234.

Books:

M. Pozar, *Microwave Engineering*. Amherst, MA: Wiley, 1998, p. 162.