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Araştırma Makalesi/Research Article

The Modeling of Semiconductor Circuit Elements by Using Artificial Neural Networks

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ABSTRACT: In this study, the modeling of semiconductor circuit elements very frequently used in electronic circuits are carried out by using an Artificial Neural Networks (ANN). The modeling of electronic circuit elements is very important both in respect of engineering, and in respect of practical mathematics. The FNN modeling methods are especially suited for applications where physically justified analytical circuit element models lack the required accuracy. The main aim of these modeling systems is to shorten the simulation time and to examine the real physical system applications in computer environment easily by using the model elements instead of using the ones used in real applications. This for, a PNP bipolar transistor is used as the example application. The structure of the ANN which will be used for modeling of the PNP bipolar transistor is improved and trained in MATLAB toolbox. A hybrid learning algorithm consists of back-propagation and least-squares estimation is used for training the ANN network. The PNP bipolar transistor element is modeled successfully with the obtained ANN model. Results of obtained show that the ANN modeling technique can be simply used in software tools for modeling of the PNP bipolar transistor element and the other electronic circuit elements.

Key words: System modeling, Artificial neural networks, Bipolar transistor.

Yapay Sinir Ağları Kullanarak Yarıiletken Devre Elemanlarının Modellenmesi

ÖZET: Bu çalışmada, elektronik devrelerde çok sık kullanılan yarıiletken devre elemanlarının Yapay Sinir Ağları (YSA) tarafından modellenmesi gerçekleştirilmiştir. Elektronik devre elemanlarının modellenmesi hem mühendislik hem de pratik matematik açısından çok önemlidir. YSA modelleme yöntemleri, özellikle fiziksel gerçekleştirmenin zor olduğu hassas uygulamalar için uygundur. Bu modelleme sistemlerinin temel amacı simülasyon zamanını kısaltmak ve gerçek uygulamalarda kullanılan elemanların yerine modelini kullanarak bilgisayar ortamında gerçek fiziksel sistem uygulamalarını incelemektir. Bunun için, bir PNP bipolar transistor, örnek olarak kullanılmaktadır. PNP bipolar transistörün modellemesi için kullanılacak YSA yapısı geliştirilmiş ve MATLAB araç kutusunda eğitilmiştir. YSA ağının eğitimi için bir hibrit öğrenme algoritması olan geriye yayılım algoritması ve en küçük kareler yöntemi kullanılmaktadır. Elde edilen YSA modeli ile PNP bipolar transistör elemanı başarılı bir şekilde modellenmiştir. Elde edilen sonuçlar göstermiştir ki YSA modelleme tekniği hem PNP bipolar transistör elemanı hem de diğer elektronik devre elemanlarının modellenmesi için basit bir yazılım aracı olarak kullanılabilir.

Introduction

ANN is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information (Lu et al., 2006). ANNs are mathematical systems consisting weighted interconnected, adaptive simple many processing nodes or neuron. The neurons are interconnected via feed-forward considered links. ANNs are being used increasingly to model the non-linear input–output characteristics for the devices (Norgaord et al., 2002). Neural networks have become very important vehicle pattern recognition, classification (Jui, 2011), identification systems (Antari et al., 2007) and ANNs have been utilized for circuit modelling, simulation and analysis (Litovski et al., 1992), (Tuntas et al., 2008). The purpose in system modeling is to make computer simulation studies more practical, easy and understandable by using models in place of physical systems used in real life applications (Krishnaiah et al., 2006), (Srivastava et al. 2005), (Pei et al., 2005). The most important point here which has to be taken into consideration is to select the most suitable model which can reveal the modeling ability in a learning module while selecting techniques for modeling of systems in a correct way.

Feed Forward Multilayered Neural Networks

In this study, for modeling of semiconductor circuit elements, a modeling method has been obtained by using Feed Forward Artificial Neural Networks (FNNs). Ideal weightiness was obtained via training Levenberg Marquardt algorithm which has faster combination character than back propagation method (Tuntas et al., 2004) by using the following equations.

$$\gamma_p^q = \sum_m w_{pm} x_m^q \qquad (1)$$

$$v1_p^q = \tanh(\gamma_p^q) = \tanh(\sum_m w_{pm} x_m^q) \qquad (2)$$

Here w_{pm} show that weightiness among p-input unit in first layer and m-hidden unit. Outputs are obtained by same procedure in the latter layer, also.

$$y_k^q = \sum_n w_{kn} \{ \tanh[\sum_p w_{np} \tanh(\sum_m w_{pm} x_m^q)]\} \qquad (3)$$

The weights and biases are updated according to Levenberg–Marquardt optimization, which minimizes a combination of squared errors and weights to produce a well generalized network. The new weight value can produce by the following:

$$w_{jk}(n+1) = w_{jk}(n) + \Delta w_{jk}(n) \qquad (4)$$

Where the Δw_{jk} is the weight between the hidden and output layer. Process is repeated until the convergence condition is conformed. The weights of the trained network are stored in the vector space created by the weights and biases, and can be used later for predicting outputs given a different set of inputs.

System Modeling with ANN

In this study, the training block scheme of the FNN model in Figure 1 was used, which is trained to behave as PNP bipolar transistor. The system which is trained as desired gives an output corresponding to the desired input value, and utilizing the error between the own output of the model network and the system output, recognition of the system by the model network is ensured (Yildiz, 2012).

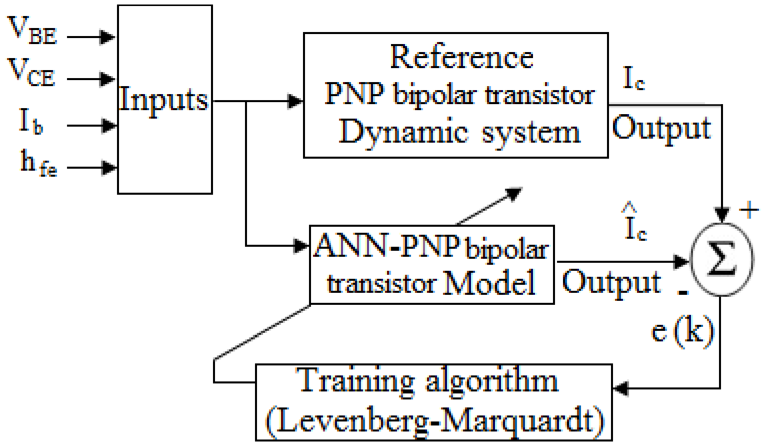

Figure 1. Training of the FNN model of PNP bipolar transistor

Results and Discussion

A feed-forward ANN architecture is used for identification of the PNP bipolar transistor. The topology of the ANN was as follows: 4 inputs, one hidden layers consisting of 8 neurons, and 1 outputs. The inputs were: collector-emitter voltage (V_{CE}), base-emitter voltage (V_{BE}), base current (I_b) and forward current transfer ratio (h_{fe}). The outputs were: collector current (I_c). The 2500 input–output data sets for ANN model training and testing are obtained based on the characteristic values of the MATLAB simulink model of the PNP bipolar transistor circuit, which shown in Figure 2. The 2000 of these 2500 signals are used for training phase and others 500 signals are used for testing phase of the ANN system modelling. A hyperbolic tangent (tanh) function was used as the transfer function in the ANN model. Model networks have been trained with Levenberg Marquardt algorithm, and have been modeled with 10e-8 error with 1200 iteration. For different parameter values, the comparisons between the ANN model with simulink model output signals of PNP bipolar transistor is shown in Figure 3.

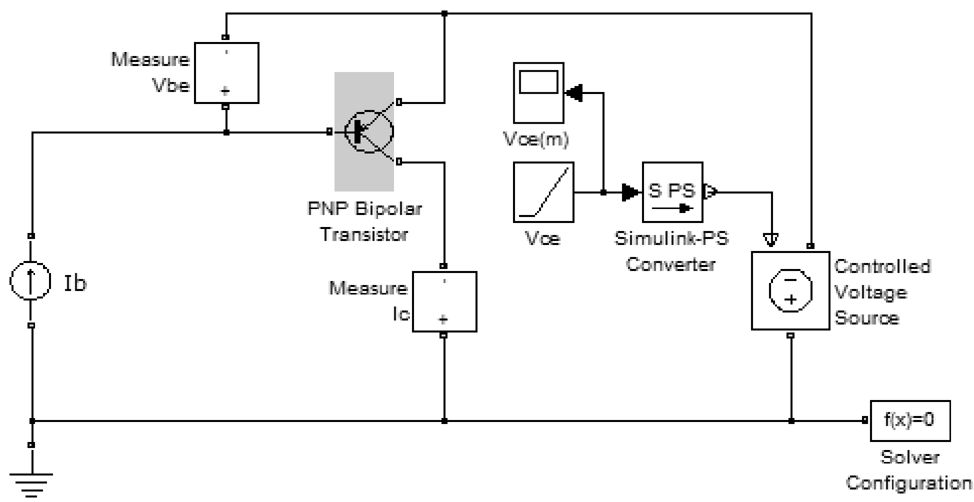

Figure 2. The simulink model of the PNP bipolar transistor circuit

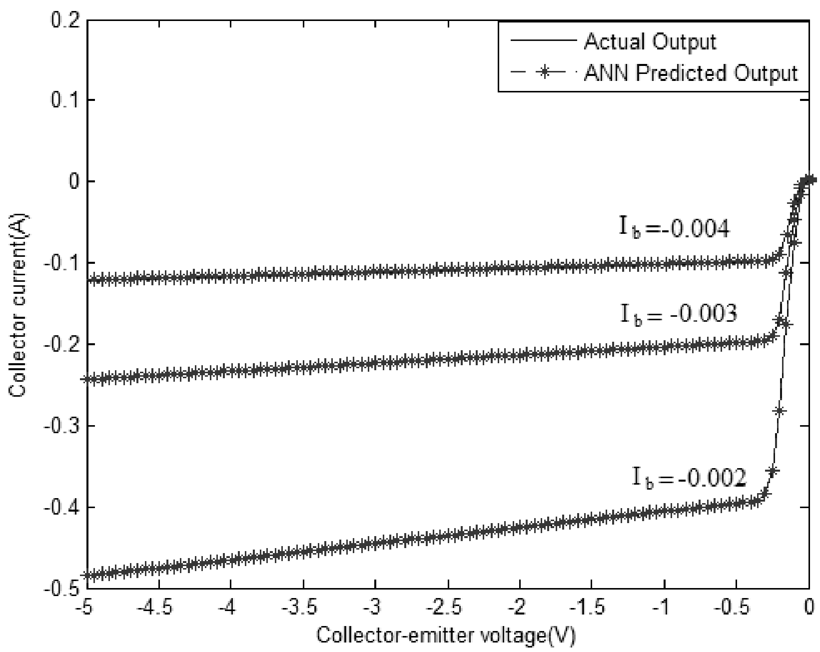

Figure 3. The comparisons between the ANN model with simulink model output signals

As shown in the results obtained, there is a good agreement between simulink model and ANN- PNP bipolar transistor model. The statistical value of the correlation coefficient r is obtained between 96% and 98%, which is very satisfactory. These results show the effectiveness of the implemented ANN-PNP bipolar transistor model.

Conclusions

The FNN models of semiconductor circuit elements were handled in this work. The FNN models developed for device modeling are independent of the device structure and technology. It has been established that the FNN models based models can represent the complete non-linear behavior of novel semiconductor device structures. The system analyze was obtained successfully as seen in figure 3 and, by modeling with FNNs the every system station with developed a simulating programmed. Excellent agreement was obtained between the modeled results and the simulink model. The FNN modeling methods are especially suited for applications where physically justified analytical device models lack the required accuracy. The models are found to describe the device characteristics over the entire operating range very accurately. These models can be used for the accurate and fast analysis in circuit design as well as for parameter extraction. Thus, the FNN based models serve as cost-effective solution to the problem of a suitable interface between nonlinear behavioral models of semiconductor devices and practical circuit simulators.

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