Extended Abstracts of the 1994 International Conference on Solid State Devices and Materials, Yokohama, 1994, pp. 367-369

Different Approaches for Implementing Cellular Neural Networks with Adjustable Template Coefficients

Ari Paasio, Kari Halonen, Veikko Porra
Electronic Circuit Design Laboratory (ECDL)
Helsinki University of Technology Otakaari 5 A, SF-02150 Espoo, Finland
phone +358 0 451 2239 fax +358 0 460 224 e-mail apa@daisy.hut.fi

ABSTRACT-Three different approaches for implementing CNN cell are discussed. The structures are based, one on OTA-amplifiers, one on differential stages and one on current mode operation. Every realization has variable template coefficients. Some results from measurements are also mentioned.

Introduction

Different approaches for implementing cellular neural networks [1] have been reported. In ECDL three different cell structures for CNNs has been investigated. The first CNN version was based on adjustable gain OTA-amplifiers [2]. The second network structure contained differential stages with adjustable bias currents and the third version of a CNN is based on current mode operation [3]. Also this current mode network has adjustable template coefficients. All these cell structures have been implemented with CMOS technology. In the following these structures are first shortly presented and then compared.

OTA based version

In this approach OTA-amplifiers are used as voltage controlled current sources and the output currents are converted to voltage with resistors. In figure 1 there is a variable gain OTA-amplifier without the differential input stage. The gain is varied by controlling the mirroring ratio to the output. This CNN version also had local digital register in every cell. The whole structure of one cell is presented in figure 2.

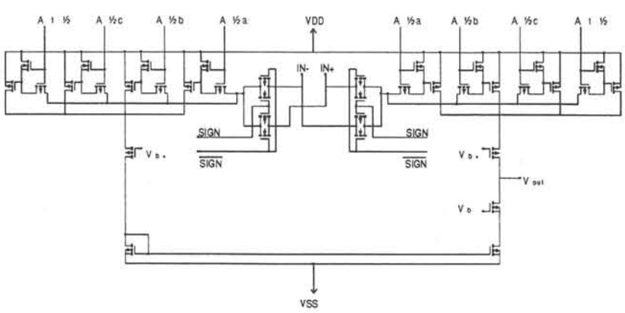

Figure 1 Variable gain OTA

Differential stage approach

The voltage controlled current source used in this implementation [4] is a differential stage amplifier shown in figure 3. The saturation levels of the output current can be varied by varying the bias current to the stage. To be able to have both positive and negative coefficient values four switches has to be added to the differential stage configuration. The whole circuitry for implementing one coefficient is shown in figure 4. The cell structure is designed to be

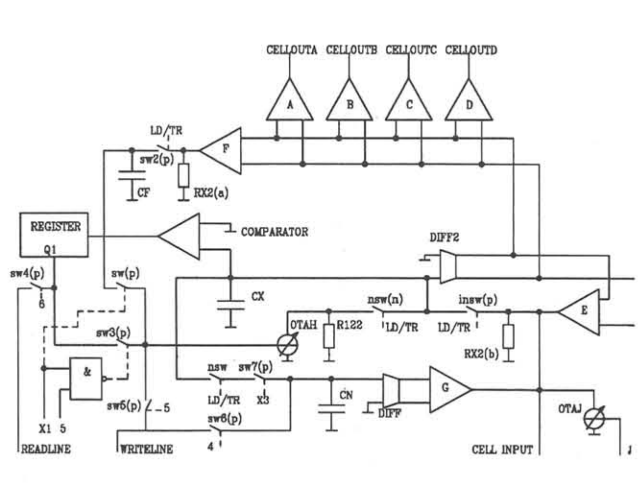

Figure 2 Cell structure

able to be used the same way as in the OTA based version. Also some digital logic is implemented in every cell. The analog part of the cell is shown in figure 5.

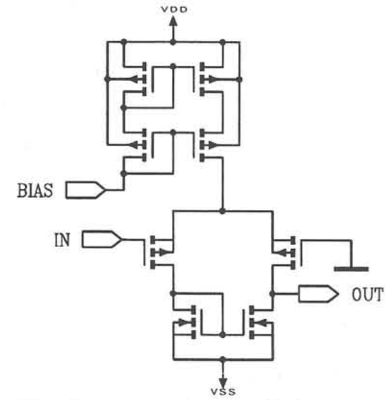

Figure 3 Floating n-well type differential stage

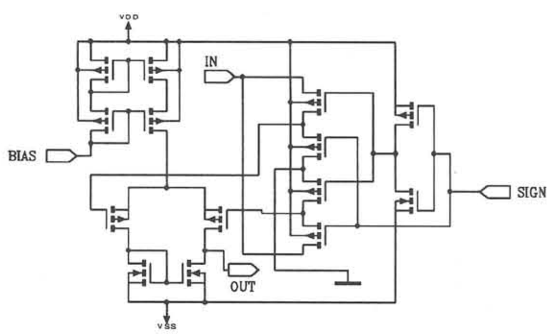

Figure 4 Realization of the template coefficients

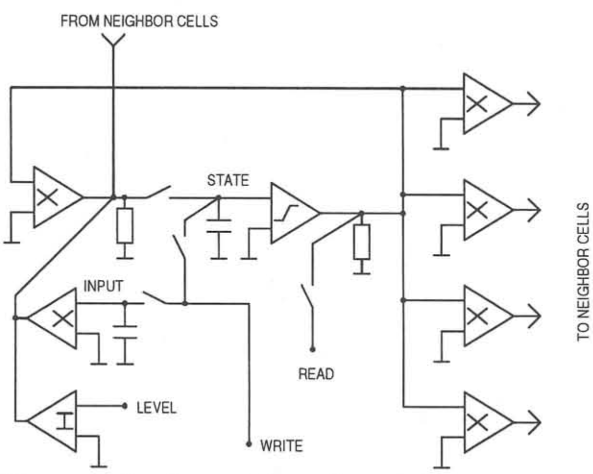

Figure 5 Implementation of one cell

Current mode network

The latest version implemented is based on current mode operation first reported in [3]. The sigmoid is produced using two level shifted current mirrors in series. This configuration is shown in figure 6. The coefficient magnitude is determined by the mirroring ratio k in the second current mirror in fig. 6. In our circuit the current mirror in figure 7 was used for both implementing the current mirrors as well as the current sources. The output current of this type of current mirror can be set to be either input current or zero current by applying proper voltages to the bias node V_{b2}. To be able to have currents which correspond to the negative coefficients current inverters have been used. The cell structure is shown in figure 8.

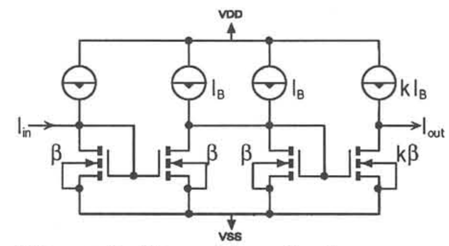

Figure 6 Sigmoid realization

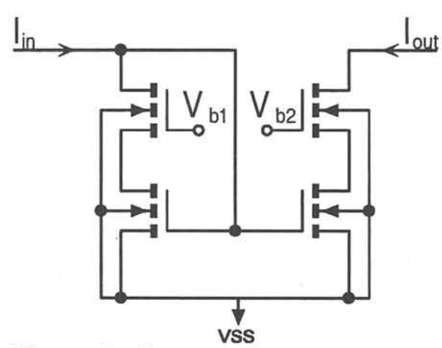

Figure 7 Current mirror

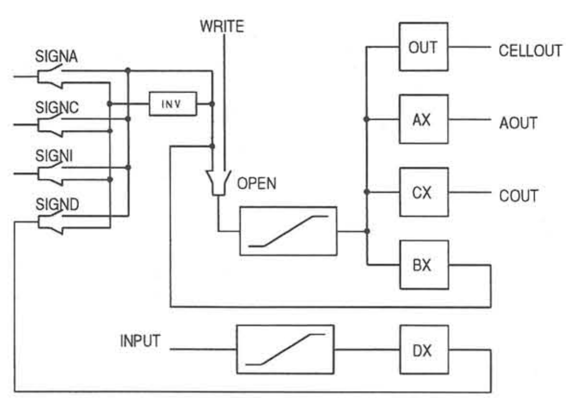

Figure 8 Current mode cell

Comparison of the structures

In table 1 the three structures described above and their realization are compared. The accuracy of the coefficients in OTA-based and in current mode realizations is four bits when the accuracy in the continuously adjustable coefficients is one per cent from

	OTA-based	differential stage	current mode
size of the net	4x4	1x3 2x2	1x5
variable templates	±3, ±2, ±1, ±½, 0	continuous betw. ±8	±3½,±3,±2½,±2,1½,±1, ±½,0
digital local register	yes	yes	no
implementation technology	2μ CMOS 1.2μ CMOS	1.2μ CMOS	1.2μ CMOS
cell size μm²	1360 x 1400 910 x 980	430 x 350	330 x 350

Table 1 Comparison between different structures

the desired value. Because the coefficients are current controlled in the differential stage version the inaccuracies increase as the currents have to be copied with current mirrors when distributed to the whole network. The unit voltage of the OTA-version is 250mV and the unit voltage in the differential stage realization is 50mV. The unit current in the third structure is 2μA. Transient measurements showed that every structure works as desired. The current mode CNN was the fastest. The time constant in the other two voltage mode realizations were almost the same. A constant input offset of 30mV was observed in the sigmoids realized with the differential stages, but that can be compensated with level shifting coefficient.

Conclusion

Three different structures have been realized. All these realizations have been measured and they have shown correct behavior, although some adjustments had to be made to the template coefficients in order to achieve the desired action. The OTA-based version is large, but it can be reduced because now one third of the area is taken by digital register. Also the area of the current mode cell can be reduced by optimizing the layout.

REFERENCES

[1] L. O. Chua and L. Yang, "Cellular neural networks: theory", IEEE Trans. Circuits and Systems, CAS-35, 1257-1272.

[2] K. Halonen, V. Porra, T. Roska, L. O. Chua, "VLSI implementation of a reconfigurable cellular neural network containing local logic", Proc. IEEE CNN'90 Conf., Budapest, Dec 1990, IEEE, New York, 1991, 206-215

[3] S.Espejo, R.Dominguez-Castro and A.Rodriguez-Vazquez, "Design and Testing Issues in Current-Mode Cellular Neural Networks," Proc. 2nd IEEE Int. Workshop on CNNs and Their Appl. (CNNA-92), pp. 169-174, 1992, Munich

[4] A.Paasio, K.Halonen, V.Porra, "CMOS Implementation of Associative Memory Using Cellular Neural Network Having Adjustable Template Coefficients," Proc. ISCAS'94 Conf., London, May-Jun 1994, IEEE, Vol.6. 487-490