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Active Device Usage in Filter Design – An Overview

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ABSTRACT

Usage of Inductors as passive components in filter design poses a number of problems in terms of non-linearity, losses, large physical size , weight and possibility of their integration at very high frequencies only.

Bulky nature of Inductors put a question mark on the foot print of filters designed using them. Microminiaturization of circuits resulted in desire for replacement of Inductors by active elements like Operational Amplifiers which led to the introduction of new class of filters **called as active filters.** Active filter design has evolved over a period of time. Starting with OP AMPs , we have witnessed phenomenal growth of active component usage in filter design and development catering to varying requirements. This has contributed greatly in emergence of circuits with minimal limitations and advantages in terms of wide Bandwidth and High slew rates.

The aim of this paper is to review and compare the functionality of certain novel active blocks . While doing so it will be amply clear that the development of newer active blocks follows a pattern and one combination of blocks leads to a new active element design and the process goes on.

KEYWORDS

OA; CDBA ; OTA;CFA ; CC-II ; FTFN ; CDTA; Trade Off : Signal Linearity ; Bandwidth ;

INTRODUCTION

In the development of microelectronic technologies the demand for electronic circuits with extremely low supply voltages and low power consumption constitute long-term trends [1]. The speed or the accuracy of signal processing are the other requirements which are needed in case of certain specific applications. While fulfilling one requirement another may have to be compromised which leads to non fulfillment of all parameters simultaneously. To overcome this impediment a ***trade-off*** solution is used in practice.

Over a period of time , the evolution of modern applications of analog signal processing has followed the trends of so-called current mode [2], when signals, representing the information being processed, are in the form of electric currents. In contrast to the conventional voltage mode, which utilizes electric voltages, the current mode circuits can exhibit under certain conditions – among other things – *higher bandwidth* and *better signal linearity.* Since they are designed for lower voltage swings, smaller supply voltages can be used. Simultaneously with the development of current-mode applications, the mixed-mode circuits are also analyzed because of the necessity of optimizing the interface between the sub-blocks, which are working in different modes.

The mixed-mode operation and even the comeback to the conventional voltage mode alsohave another justification: it appears that some generally accepted statements about the advantages of the current mode probably have no real basis [3]. However, the criticism of [3] not with standing, the current-mode techniques have given way to a number of important analog signal processing - signal generating circuits as is evident from a vast amount of literature on current-mode circuits and techniques published in the recent past .

Advancements in integrated circuit (IC) technology during the last two decades, have led circuit designers to exploit the potential of current-mode analog techniques for evolving elegant and efficient solutions to several circuit design problems. As a consequence, the current-mode approach to signal processing has often been claimed to provide one or more of the following advantages: higher frequency range of operation, lower power consumption, higher slew rates, improved linearity, and better accuracy.

Besides classical active filters, the target applications of the blocks include advanced fully-integrated input blocks of modern communication circuits. With the exception of DC-precise low-pass filters, the requirements on DC precision of the new blocks are not so relevant in comparison with the requirements on their speed.

In the case of oscillators and other generators, some additional requirements regarding their precision (linearity, offset, etc.) have appeared. For non-linear circuits such as rectifiers of weak signals, precise comparators and Schmitt triggers, shaping networks, etc., the demands for accuracy can be considerable.

The initial set of active elements for analog signal processing is currently proceeding and evolving in following pattern.

The evolution of active blocks is happening by modification of the basic elements such as VFA (Voltage Feedback Amplifier), CFA (Current Feedback Amplifier), OTA (OperationalTrans conductance Amplifier), and particularly current conveyors (CC). The important motivations for such modifications consist in the effort to increase the application potential of the element. Simultaneously, this element should have a simple internal structure in order to retain low power consumption and high-speed operation.

An important urge for new elements is due to electronic control requirements . Evolution of active elements , besides the modification of current ones , is happening by way of emergence of new elements which extend the original VFA-CFA-OTA-CC active set.

Now we will evaluate a few active blocks in brief to drive home the point that the process of evolution has been going on and follows a particular pattern.

Evolution of Current Feedback Amplifier (CFA) from Current Conveyor CC II

Current Feedback Amplifier (CFA) was developed to improve the finite gain-bandwidth product of the conventional voltage - feedback operational amplifier[07]. It can provide not only a constant bandwidth independent of closed loop gain but also a high slew – rate capability[08]. Usage of CFA as a basic building block in active filter design is highly beneficial on account of these factors. The applications and advantages in realizing active filter transfer functions using current feedback amplifiers have received great attention because the amplifier enjoys the features of constant bandwidth independent of closed-loop gain and high slew rate, besides having low output impedance. Thus, it is advantageous to use CFA as a basic building block in the accomplishment of various analog signal processing tasks.

CFA is an operational transimpedance amplifier and is internally a CCII+ followed by a voltage follower [10].

CFA can be represented symbolically as shown in Fig-1

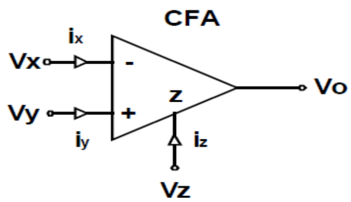
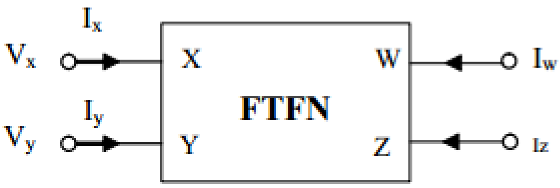


FIG-1 *Symbolic Representation of CFA*

Evolution of Four Terminal Floating Nullor (FTFN) bycascading CFAs

Four Terminal Floating Nullor (FTFN) was introduced after the advent of Current Feedback amplifier .As part of the process of development of continuous-time circuits FTFN [09] was introduced as more flexible and versatile building block than an operational amplifier (OP-AMP) or a second-generation current conveyor (CCII) .The circuit symbol of the FTFN is shown in Figure-2 . The positive FTFN can be implemented by cascading two Current feedback amplifiers (AD844s from analog devices) as shown in Fig-2(b)



(a) Symbol

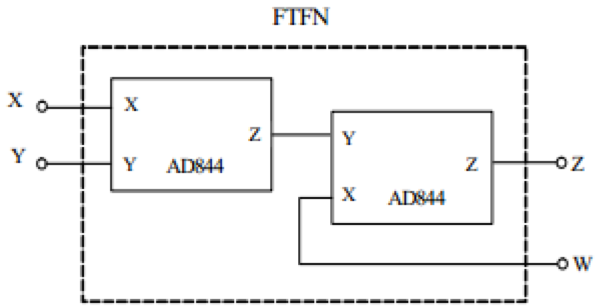


Fig-2 (a) *Symbolic representation of FTFN* (b) *Realization of FTFN using two CFAs*

Further the FTFN functionality is subservient to following port relations;

$$V_x=V_y \quad ; \quad I_x=I_y=0 \quad ; \quad I_w=I_z$$

Evolution of Current Differencing Buffered Amplifier(CDBA) fromCFACascading.

Current Differencing Buffered Amplifier (CDBA), a current-mode component, has beenintroduced by C. Acar and S. Ozoguz in 1999 [6]. It offers advantageous features such as high slew rate, absence of parasitic capacitance, wide bandwidth, and simple implementation .Since the CDBA consists of a unity-gain current differential amplifier and a unity-gain voltage amplifier, this element would be suitable for the implementation of voltage and current-mode signal processing applications. As far as the applications of the CDBA are concerned, various voltage-mode and current-mode filters and oscillators have been reported in literature.

CDBA can be represented symbolically as shown in Fig-3

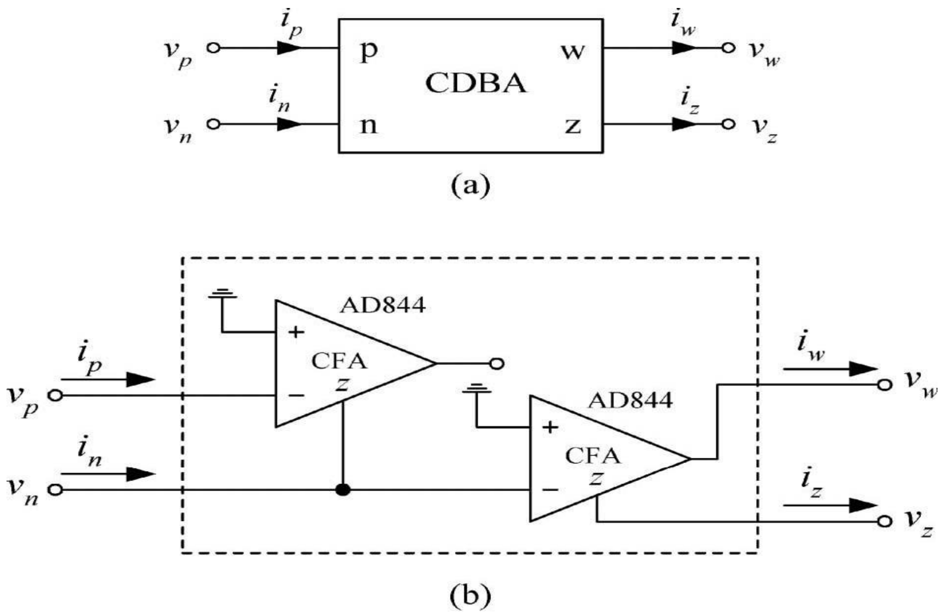


Fig-3 (a) *Symbolic representation of CDBA* (b) *Cascading of CFAs to build CDBA*

Evolution of Current Difference Transconductance Amplifier (CDTA) by adding two Current Conveyors CC II & OTA

Current Difference Transconductance Amplifier being analogous to the CDBA, has difference currentinputs *p* and *n*. The difference of these currents flows from terminal *z* into an outside load. The voltageacross the *z* terminal is transferred by a transconductance*g* to a current that is taken out as a current pair to the *x* terminals. This last element part is the familiar transconductance operational amplifier (OTA). In general, the transconductance is controllable electronically through an auxiliary port .The pair of output currents from the *x* terminals, shown in Fig. 4, may have three combinations of directions:

1. Both currents can flow out.
2. The currents have different directions.
3. Both currents flow inside the CDTA element.

This leads us tothe CDTA configurations of CDTA++, CDTA+-, and CDTA-- elements. It is suitable to mark the current directions in the circuit symbol by the signs + (outside) and – (inside) as shown in Fig. 4.

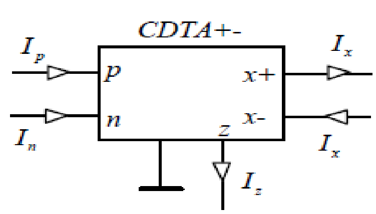


Fig- 4 *Symbolic representation of CDTA*

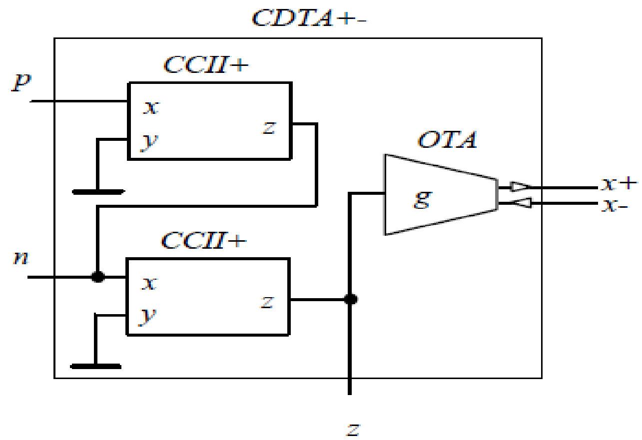


Fig-5 *Realization of CDTA with CC II & OTA.*

The effort is going on to evolve new buiding blocks to address the problem of higher acceptability of a circuit element. Universality of a circuit element without making it complex is a big challenge for circuit developers. Removal of parasitic effects , better analog or digital control of parameters and decreasing the footprint by way of usage of lesser number of components are some of the new challenges that designers will face in future.

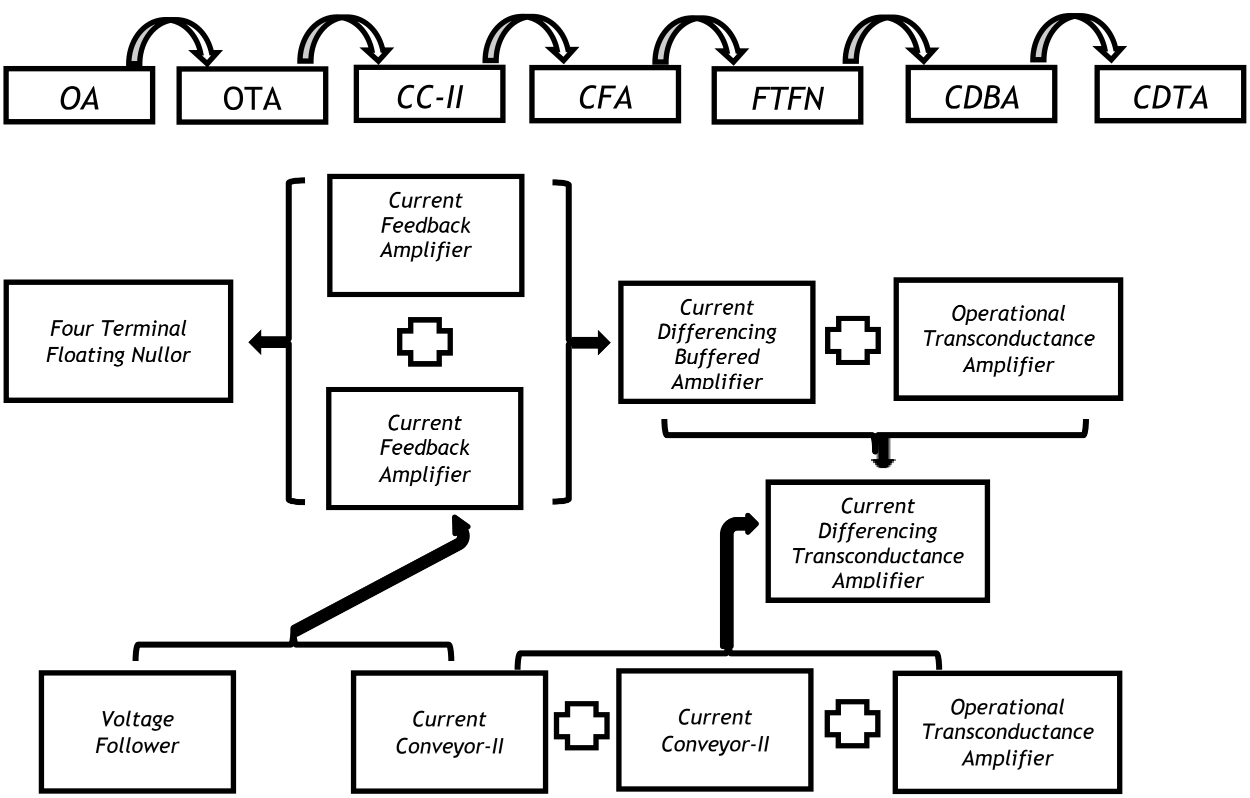


Fig-6 :*Evolution of active devices by suitable modifications of basic active blocks.*

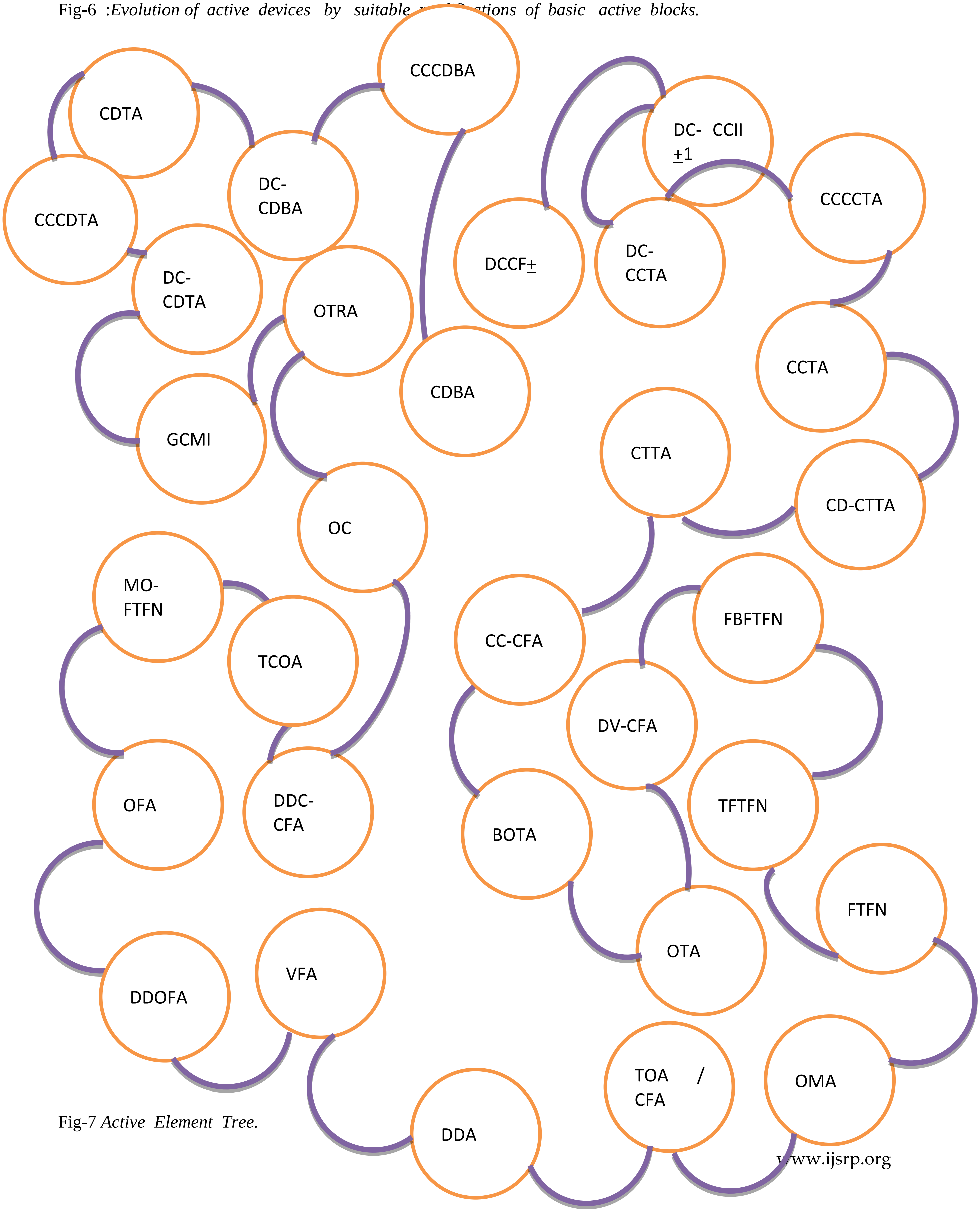


Fig-7 *Active Element Tree.*

(Not in an order)

CONCLUSION

The tree of active building blocks is growing and the present family of active blocks as shown by Fig-7 will have additions as we address the issues of Universality , Smaller Footprint , Digital Control and decreased component density .

The development of new circuit elements over the last ten years, Viz; CDBA, CDTA, ICCII, FDCCII, MCCIII, CCOA, DDOFA, FBFTFN, CFA-OTA, CC-CFA, CCTA, CCCDTA,CCCCTA, CTTA, CCCDBA, DC-CDBA, CMI, DCCF, etc. shows that the procedure of finding new circuit elements is going at a very good pace and we will continue to evolve in right direction with respect to design of better active elements.

Further as is depicted in Fig-6 , the development and evolution of Active elements used as gain devices in Filter design is following a pattern and the combination of building blocks gives birth to new elements with better acceptability , smaller size with less component usage and better control.

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