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An intelligent technique for generating equivalent gyrator circuits using Genetic Algorithm

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ABSTRACT

Genetic algorithm (GA) applications in analog design circuits play an important role with promising results. This algorithm is utilized to generate equivalent circuits for the well-known gyrator circuit which is the most commonly used active circuit for the realization of a grounded inductor. The conventional gyrator circuit is realized by the op-amp which has the drawback of frequency limitations. This paper introduces the gyrator-GA Technique. It is an intelligent technique for generating equivalent gyrator circuits utilizing Second Generation Current Conveyor (CCII) as well as Transconductance Amplifier (TA) circuits. The proposed algorithm is based on the pathological representation of the active blocks. As illustrations to demonstrate the systematic realization of gyrator-GA, a fifth-order Butterworth lowpass filter is designed and simulated using PSPICE.

1. Introduction

The symbolic analysis is a powerful tool to analyze electronic circuits, where all parts of the circuit elements are considered symbols. The nullor is quite useful for the analysis, synthesis, and design procedures, as it facilitates modeling the behavior of any active device disregarding the particular realization of the active blocks [1–6]. It is well known that the nullator-norator combinations cannot realize the CCII+, ICCII+ and ICCII− unless additional resistors are used as demonstrated in [1,2]. The pathological voltage mirror (VM) and the pathological current mirror (CM) introduced in [3,4] provided means of representing the four single-output CCII and ICCII members without any need to use resistors [3]. The systematic synthesis of active circuits developed in [5,6] is based on using the nullor elements, the basic ideas were extended in [7,8] to accommodate the pathological mirror elements allowing ideal representations of active circuits. The Nullor and Mirror elements symbols are given in [1,4]. Also, the CCII family and TA, represented using nullor and mirror elements, are shown in [7–9] and [10–13], respectively.

The Genetic Algorithm (GA) is such an optimization technique which operates on the principle of "survival of the fittest". GA has the capability to generate new design solutions from a population of existing solutions, and discarding the solutions which have an inferior performance or fitness [14]. The GA starts from high-level descriptions to automatically synthesize analog circuits. However, the automatic synthesis of analog circuits from high-level specifications is recognized yet as a challenging problem [14–17]. It is worth noting that the genetic algorithm with nullator-based descriptions was applied to generate Voltage Followers (VFs) circuits as in [16]. This method described how an automatic system can deal with huge search spaces to design practical VFs by performing evolutionary operations from nullator-based descriptions. Also, generation of Voltage Mirrors circuits (VMs) based on the genetic algorithm was presented in [17]. Moreover [14], introduced a new genetic algorithm to synthesis the negative type CCII-blocks by superimposing VFs and current followers (CF).

One of the most useful building blocks of active network synthesis is gyrator which is also known as the type 1 LC mutator [24] were introduced in [25]. It is used to realize grounded and floating inductors. The realization of op amp gyrators by means of nullors and resistors has been presented in [18–20]. As a current-mode active device, the current conveyor (CC) provides several advantages, such as greater linearity and wider bandwidth, over voltage-mode active devices such as op-amps [9,21]. The realization of active gyrators using CCs is given in [9,22,23]. Also, the three port gyrator and its realizations using TA and CCII was given in [26,27].

This paper introduces a new methodology based on nullor and pathological elements to generate equivalent CCII and TA gyrator circuits. Another method to obtain equivalent gyrator circuits, based on NAM expansion, was proposed in [10,28]. But the advantage of the proposed GA methodology is that it can generate all possible circuits programmatically and also, it can be applied to any op-amp circuit other than gyrator to get CCII or TA equivalent circuits.

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The paper is organized as follows; the proposed methodology is described in Section 2. In Section 3, the methodology is applied to the gyrator-GA circuit to get CCII equivalent circuits. GA is also applied to get TA-gyrator equivalent circuits in Section 4. In Section 5, the fifth-order Butterworth lowpass filter is designed using CCII-gyrator-GA and TA-gyrator-GA and simulated. The simulation results are compared to the ideal RLC filter. Finally, Section 6 concludes the work.

2. Methodology

The flowchart of the proposed algorithm is shown in Fig. 1. Firstly, the nodal equation for the circuit is to be written in the form $[Y][V]=0$ so that element count can be extracted. The number of diagonal elements represents the number of grounded elements, and the reminder elements are thus the floating ones. Secondly, each element is represented by Gen in the form: $R \cdot C \cdot S$, where R is the row number, C is the column number, and S is a sign bit. Third, if $R=C$ and $S=1$ so, this is a positive diagonal element and it is transferred to the output file and it is represented for simplicity by Gen: $R \cdot 0$ otherwise an expansion subroutine for the element is applied.

To get an equivalent circuit for the gyrator-GA using CCII family and TA, That active elements are encoded in genes as shown in Tables 1–3.The current conveyors types considered in this work are CCII+, CCII-, ICCII+, and ICCII- which are presented in [6–7,9]. Also, TA based on nullor elements and pathological mirror elements was employed to provide pathological realizations of different types of TA which are presented in [10–13]. The Balanced Output TA (BO-TA) and the Single Output TA (SO-TA) are the two different types of the TAs. In this work, BO-TA and Single-Input-Single-Output SISO-TA will be considered. There are four configurations for SISO-TA and two for BO-TA. To facilitate dealing with them in the proposed algorithm, each one can be codified in genes as shown in Table 3. The gene codification of positive resistances can be obtained using the first and the second configurations

Table 1
Gene codification of the nullor and mirror elements.

Nullor and mirror elements	Genetic representation
Nullator	**O**
Norator	**P**
Voltage mirror	**V**
Current mirror	**I**

Table 2
Gene codification of the CCII family.

CCII name	Genetic representation
CCII+	Z.X.I.X.Y.O
CCII-	Z.X.P.X.Y.O
ICCII+	Z.X.I.X.Y.V
ICCII-	Z.X.P.X.Y.V

Table 3
Gene codification of the TA family.

TA name	Genetic representation
TAI-	Gen| = U.S.P.S.M.O Gen| = U.S.I.S.M.V
TAO-	Gen| = U.S.P.S.N.O Gen| = U.S.I.S.N.V
TAI+	Gen| = U.S.I.S.M.O Gen| = U.S.P.S.M.V
TAO+	Gen| = U.S.I.S.N.O Gen| = U.S.P.S.N.V
BO-TA+	Gen| = U.S1.P.S1.M.O.S1.S2.G.S2.W.P.S2.N.O Gen| = U.S1.I.S1.M.V.S1.S2.G.S2.W.I.S2.N.V
BO-TA−	Gen| = W.S1.I.S1.M.O.S1.S2.G.S2.U.I.S2.N.O Gen| = W.S1.P.S1.M.V.S1.S2.G.S2.U.P.S2.N.V

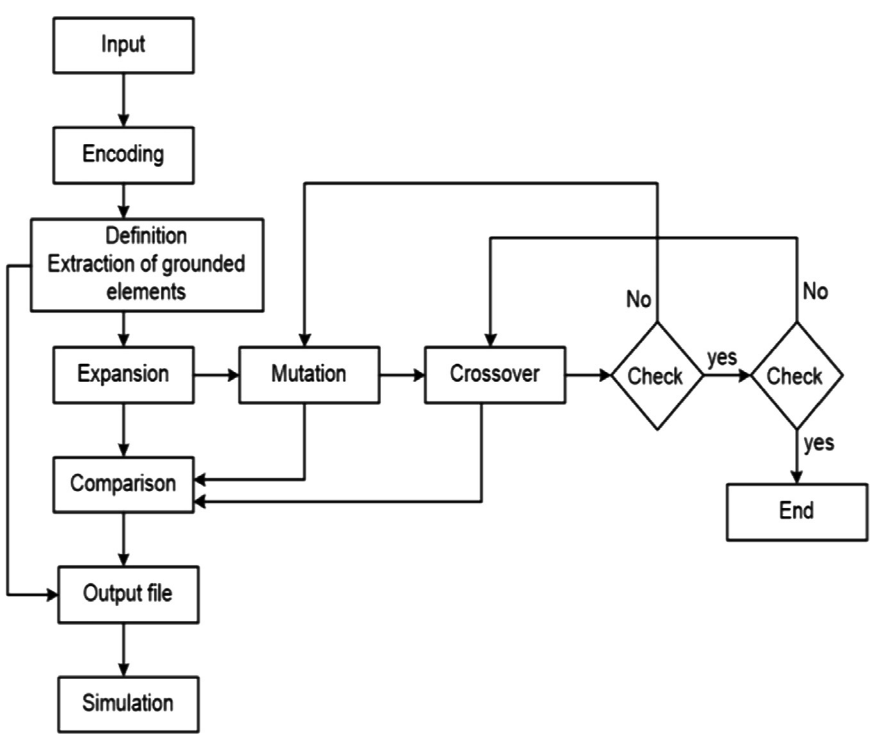

Fig. 1. Flow chart for the proposed algorithm.