iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: IV Month of publication: April 2018

DOI: http://doi.org/10.22214/ijraset.2018.4181

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Survey of Chuas Oscillator Using CCTA

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Abstract: The purpose of this paper is to propose a detailed analysis of the literature survey done during the design of a high frequency Chua's oscillator/chaotic oscillator using the block current conveyor trans conductance amplifier (CCTA). In literature survey, we have thoroughly studied total eight papers, that have the relevant data required for our design along with many other papers to understand the fundamental points and design parameters in order to understand the working of the circuit and noted the various methodologies and components used along with their drawbacks. In our design, we have tried to remove all the drawbacks mentioned in this paper.
Keywords: Chua's oscillator, CCTA, VDCC, DVCCTA, OTRA, CFOA, Operational amplifier, Transconductance, High frequency.

I. INTRODUCTION

The concept of an unstable state is familiar in science. It is not possible in practice to balance a ball on the peak of a mountain, even though the configuration of the ball, perfectly balanced on the peak is a steady state. The problem is that the trajectory of any initial position of the ball near, but not exactly, at the steady state, will evolve away from the steady state. What eventually happens to the ball placed near the peak? It moves away from the peak and settles in a valley at a lower altitude. The valley represents a stable steady state. A chaotic circuit continues to experience forever the unstable behaviour that an orbit exhibits near a source that is not itself fixed or periodic. It never manages to find a sink to be attracted to. At any point of such an orbit, there are points arbitrarily near that will move away from the point during further iteration. This sustained irregularity is quantified by Lyapunov numbers and Lyapunov exponents [Wolf, 1986]. Chaos is defined by a Lyapunov exponent greater than zero.

Eventhough chaos was experimentally observed by Van del' Pol & Van del' Mark [1927] as early as 1927, the science of chaos is relatively new. One of the first models which were shown to exhibit chaotic behaviour in numerical solution was the fluid convection model introduced in 1963 by E. N. Lorenz [1963] in his studies on atmospheric weather. Since then, many articles have been published illustrating chaotic behaviour in wide ranging systelns [Kennedy, 1994; Restituto & Vazques,1998; Sprott, 2000; Wojcik, 2001; Roy & Basuray, 2003; Kiers et al., 2004]. During the last few decades, the great expectations that were promised by research in chaotic electronic circuits have been proved through its wide applications, such as signal encryption and secure communication [Cuomo & Oppenheim, 1993; Sivaprakasam & Shore, 2000].

Nonlinear electronic circuits provide an excellent tool for the study of chaotic behaviour. With great advances in nonlinear circuit theory over the past 30 years, it is possible to explain highly complex nonlinear behaviours with simple mode1s and minor extensions to linear circuit theory. Some of these circuits treat time as a discrete variable, and others as a continuous variable. Chua's circuit [Matsumoto et al., 1985; Murali & Lakshillanan, 1992; Chua, 1994] is one of the most famous circuits of the latter type because it is simple, robust and has a number of distinct routes to chaos[Miliou et al, 2009]. This remarkable circuit is the only physical system for which the presence of chaos (in the sense of Shilnikov) has been established experimentally, confirmed numerically and proved mathematically [Chua et al., 1986; Silva, 1993]. Since Chua's circuit is endowed with an unusually rich repe110ire of nonlinear dynamical phenomena, it has become a paradigm for chaos [Matsumoto et aI., 1998; Letellier et aI., 1996]. Several modifications were made to the original topology in order to yield a circuit that would be more amenable to practical implementations[Mahmoud et al., 1999; Kilic, 2003].

Unfortunately, at the frequency ranges of interest, the inductor required for the circuit cannot be integrated and this led researchers to simulate the inductance. There are many other reasons for this. Inductors are only available in fewer standards compared to other circuit elements and must be separately made for most applications. They are not as ideal as other circuit elements, and in terms of spatial dimensions, they are larger than other circuit elements, unless the inductance is small. It cannot be integrated on a chip. Moreover, many commercially available inductors have a core, which has an adverse effect of adding distortion to the signal. Given the sensitive dependence of chaos on initial conditions [Glendenning, 1994], this would be largely undesirable. The solution is to simulate the inductance [Morgul, 1995a; Torres & Aguirre, 2000; Radwan et al., 2003]. Therefore, in our project we also wish to emulate an inductor using a current mode building block.

II. HISTORICAL BACKGROUND

Chaos phenomenon has been studied extensively from three decades ago, in various areas of science such as biology, ecology, physics, optics, etc. [1]. In electronics, a very interesting and simplest autonomous third-order circuit which exhibits bifurcation and chaotic phenomena can be implemented as shown by Fig. 1, where the most important element is a nonlinear resistor called Chua's diode (NR). Chua's circuit is the only chaotic system which can be easily built, simulated, and tractable mathematically, such that its simplicity and robustness has made it the circuit of choice for generating chaotic signals for practical applications, namely: visual sensing, neural networks, nonlinear waves, music and secure communications [2]. As shown in Fig. 2, NR can be described by a piecewise linear I-V characteristic consisting of two slopes whose limits are determined by two voltage-ranges to establish the breaking points to generate chaotic phenomenon [4–21]. On the other hand, NR has been implemented by using operational amplifier[4], a CMOS IC design by using operational trans-conductance amplifiers (OTAs) was presented in [1], and a realization by using commercially available current feedback operational amplifiers (CFOAs) was given in [4, 5]. The last realization is better than the others because the performance of a CFOA does not depend on the gain-bandwidth tradeoff [22, 23].
Furthermore, this device can be implemented in standard CMOS IC technology by using voltage followers (VFs) [24, 25], and current mirrors (CMs). Most important is that VFs and CMs have the advantage of wider bandwidth compared to other more complex analog building blocks, so that VFs, CMs and also current followers(CFs), are good candidates to implement novel analog signal processing applications [11]. For instance, by superimposing or by connecting VFs with CFs and CMs, one gets directly the design of current conveyors [25], which are also quite useful to implement chaotic applications [12].

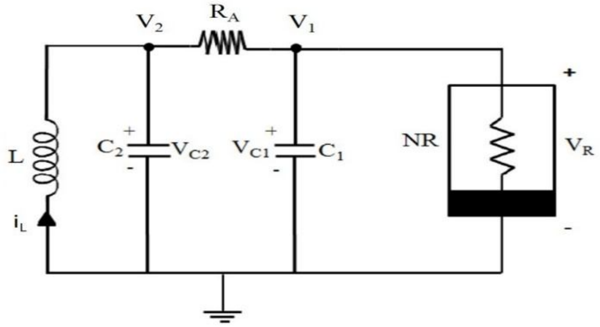

Fig 1: Chua's circuit

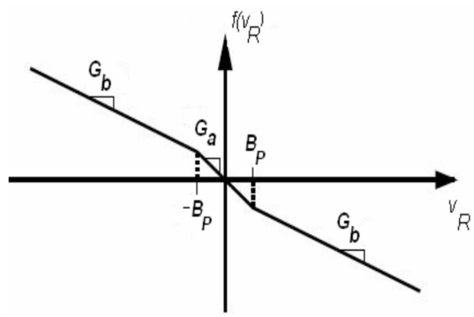

Fig 2: I-V Characteristics of Chua diode

III. BLOCK DIAGRAM

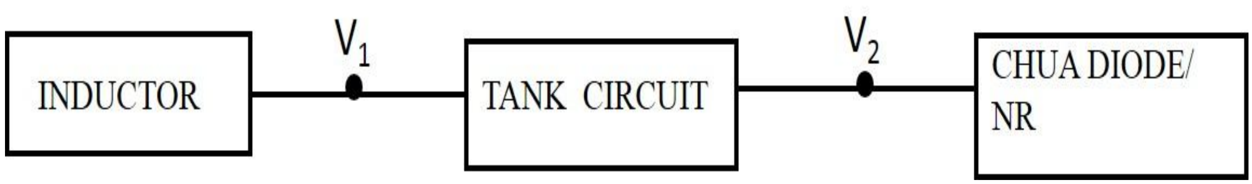

Fig 3: Block diagram of chaotic oscillator

A. Description

The above block diagram is based on the circuit diagram of chaotic oscillator shown in figure 3. Tank circuit consists of one resistor and two capacitors across which the output signals V_1 and V_2 are produced. These signals are nothing but the chaotic signals. Inductor acts as an energy-storing device along with the two capacitors used in the tank circuit. The piecewise linear three segment negative resistor (NR) break points plays an important role in generation of chaotic oscillation. This NR is nothing but Chua diode.
As stated above, for literature survey, we have thoroughly studied total eight papers and noted the various methodologies and components used along with their drawbacks. For example in ref [1], we found that the author has used a building block namely OTRA (Operational Trans-resistance Amplifier) using 0.5µm technology. Though the circuit proposed in ref [1] successfully demonstrates the phenomenon of chaotic oscillations, it has certain drawbacks such as it contains more number of passive components, low operational frequency and no separate port for inductor current.

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Table 1 Comparison of all the references surveyed

	Ref [1]	Ref[2]	Ref[3]	Ref[4]
Name of the paper	Chua's oscillator using operational transresistance amplifier.	Inductorless realization of Chua's oscillator using DVCCTA.	Improved realization of canonical Chua's circuit with synthetic inductor using current feedback operational amplifiers,	Implementation of Chua's circuit using simulated inductance.
Author name	Kushwaha, A. K., Paul, S. K.	Kushwaha, A. K., Paul, S. K.	R. Jothimurugan, K. Suresh, P. Megavarna Ezhilarasu, K. Thamilmaran,	Gopakumar, K., Premlet, B., & Gopchandran, K. G.
Publication agency	Rev. Roum. Sci. Techn.– Électrotechn. et Énerg.	Springer Analog Integrated Circuit and Signal Processing	Int. J. Electron. Commun.	International journal of electronics
Year	2016	2016	2014	2011
Methodology used	OTRA (0.5um technology)	DVCCTA(0.25um technology)	CFOA(current feedback operational amplifier)	Operational amplifier
Drawbacks	No. of passive components are more. No separate port for inductor current. Low frequency.	No separate port for inductor current. Low frequency.	Low frequency. No port for inductor current.	No. of passive components are more. No separate port for inductor current. Low frequency.

	Ref [5]	Ref[6]	Ref[7]	Ref[8]
Name of the paper	An improved Chua's circuit and its use in hyper chaotic circuit.	Implementation of a chaotic oscillator by designing Chua's diode with CMOS CFOAs.	Improved implementation of Chua's chaotic oscillator using current feedback opamp.	Inductorless Chua's circuit.
Author name	Gandhi, G.	Cuautle, E. T., & Herndez, A. G.	Elwakil, A. S., & Kennedy, M. P.	Torres, L. A. B., & Aguirre, L. A.
Publication agency	Springer Analog Integrated Circuit and Signal Processing	Springer Analog Integrated Circuit and Signal Processing	IEEE	Electronic letter
Year	2006	2006	2000	2000
Methodology used	CCII using Bipolar Junction Transistor	CFOA(current feedback operational amplifier)	CFOA(current feedback operational amplifier)	Operational amplifier
Drawbacks	No. of passive components are more	No. of passive components are more. No separate port for inductor current.	No. of passive components are more	No separate port for inductor current.

One of the most recent papers is mentioned in ref [2] where the building block DVCCTA (Differential voltage current conveyor trans-conductance amplifier) has been used with 0.25 µm technology. This paper was published in the year 2016 in Springer- Analog Integrated Circuit and Signal Processing. In this circuit both NR1 and NR2 along with the inductor, are realized using DVCCTA and moreover in this circuit there is a separate port for inductor current which was missing in the paper mentioned in ref [1]. This circuit also has low operational frequency and more number of passive components. Similarly, other references have used various building blocks such as CFOA(current feedback operational amplifier), Operational amplifier and CCII (Second generation current conveyor) and have drawbacks similar to ref [1] and [2]. In our project, we have tried to remove all the drawbacks mentioned above.

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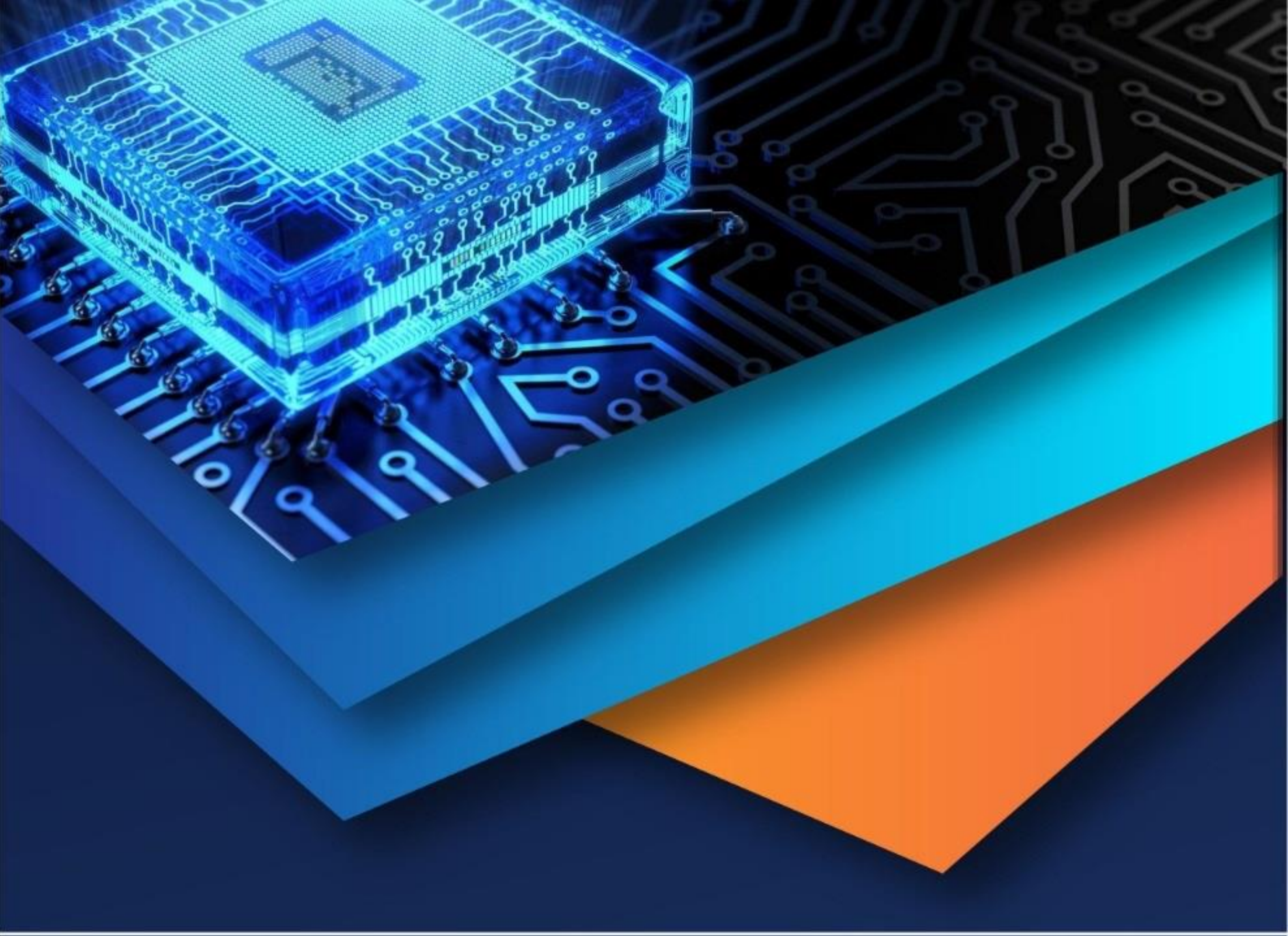

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