BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LX (LXIV), Fasc. 4, 2014
Secţia
ELECTROTEHNICĂ. ENERGETICĂ. ELECTRONICĂ

A NOVEL ACTIVE INDUCTOR WITH VOLTAGE CONTROLLED QUALITY FACTOR AND SELF-RESONANT FREQUENCY

BY

MIHAIL BOHOSIEVICI[1,*] and LIVIU GORAŞ[1,2]

[1] "Gheorghe Asachi" Technical University of Iaşi
Faculty of Electronics, Telecommunications and Information Technology,
[2]Institute of Computer Science,
Romanian Academy, Iaşi Branch, Romania

Received: November 20, 2014
Accepted for publication: December 19, 2014

Abstract. In this paper, a novel CMOS differential active inductor with self-resonant frequency and quality factor tuning is presented. Based on a current reuse technique, the proposed active inductor has two additional MOS transistors. Both transistors are used for enhancing and actively modifying the quality factor of the active inductor. The self-resonant frequency of the active inductor can be also modified through a variable current mirror.

Key words: active inductor; quality factor; self-resonant frequency; voltage control.

1. Introduction

An important advantage of active inductors compared to passive ones is tunability. In other words, the quality factor or/and the self-resonant frequency of an active inductor can be modified and their values controlled by electrical signals. An active inductor can be implemented using two main concepts (Yuan, 2008; Bakken & Choma, 2003): gyrator-C or transistor only simulated inductors. Gyrator-C active inductors are usually designed for low-frequency

[*]Corresponding author: *e-mail*: mbohosievici@etti.tuiasi.ro

applications because of the limitations imposed by the use of the operational transconductance amplifiers in the gyrator-C structure and the simulated inductance is obtained through an external capacitor. Transistor only simulated inductor concept is a variation which uses the parasitic capacitances of the transistors to simulate inductors, the necessity of using an external capacitor being eliminated. Transistor only simulated inductors (TOSI) can be designed in CMOS technology to overcome the frequency limitations of the gyrator-C concept, being able to function at Ghz frequencies. Several TOSI structures designed in CMOS technology have been reported in (Andriesei, 2010, Andriesei & Goraş, 2008).

In this paper a novel TOSI structure inspired from the above mentioned references is presented.

2. Structure of the Differential Active Inductor

The structure of the differential active inductor including biasing circuitry (Johns & Martin, 1996) is presented in Fig.1. Transistors *M*9, *M*10, *M*11 and *M*12 are components of a variable current mirror. The biasing source for *M*2 and *M*3 is realized with a stable g_{mi} circuitry. It ensures more stable transistor transconductances, and thus a more stable biasing voltage for *M*2, *M*3, *M*5 and *M*6. The value of total current used by this structure is less than 3 μA which is smaller than the value of the current used by other biasing circuitry. The active inductors are composed of transistors *M*1, *M*2, *M*3, *M*7 and *M*4, *M*5, *M*6 and *M*8. Transistors *M*1, *M*3, *M*4 and *M*6 are biased in the active region. Transistors *M*2 and *M*5 are biased in the triode region.

3. Quality Factor of the Differential Active Inductor

Any active inductor practically behaves as a resonator (Andriesei, 2010; Andriesei & Goraş, 2008). In the case of a TOSI, there are many parasitic capacitances of the MOS transistors and finally, the architecture exhibits a parallel-like resonance.

By comparison with a passive resonator which has a fixed quality factor and self-resonant frequency determined by the values of the components, the active inductor presented in this paper is designed to allow a controlled variation of these parameters.

The PMOS transistors *M*7 and *M*8 have been introduced to inject currents that modify the transconductances of *M*1 and *M*4. These currents obviously depend on the V_{gs} voltage of these transistors. As a result, the variation of these currents leads to modifications of the quality factor and self-resonant frequency which present an interdependency, meaning that a variation of one parameter is followed by the variation of the other parameter.

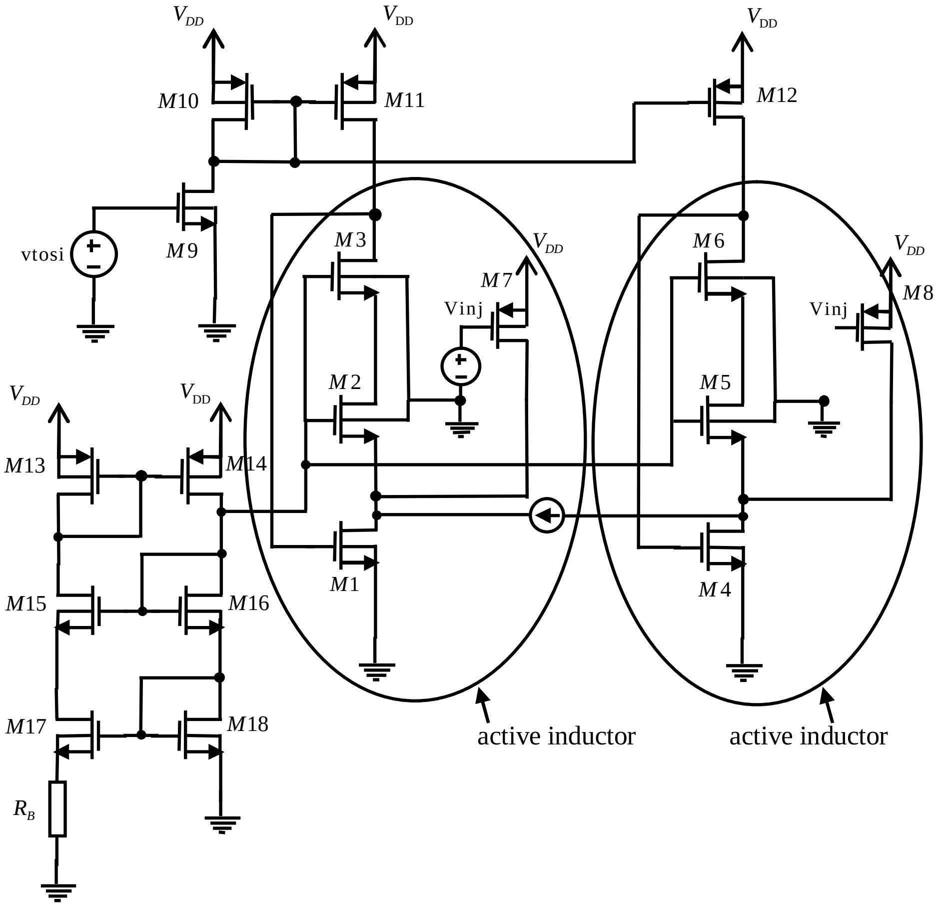


Fig. 1 – The structure of the differential active inductor with biasing circuitry.

The value of the quality factor varies with the voltage applied at the gate of transistors *M*7 and *M*8, Vinj. Thus the quality factor of the active inductor can be modified as shown in Fig 2. The quality factor of the active inductor is modified with the help of Vinj which varies from 0 to 1.5 V. The nonliniar variation of quality factor can be divided into four regions. For values of Vinj between 0 and 600 mV it presents a liniar zone with a slow increase of the value from 1 to 4.5**.** The second region is represented by values of Vinj between 600 mV and 930 mV where the quality factor presents a rapid increase of the value from 4.5 to the maximum value of 36. The third region is determined by values of Vinj between 930 mV and 1.11 V where the quality factor exhibits a rapid decrease from the maximum value to approximately 3**.** The fourth region is determined by values of Vinj between 1.11 V and 1.5 V where the quality factor has a very small variation and settles to a constant value of approximately 1.2.

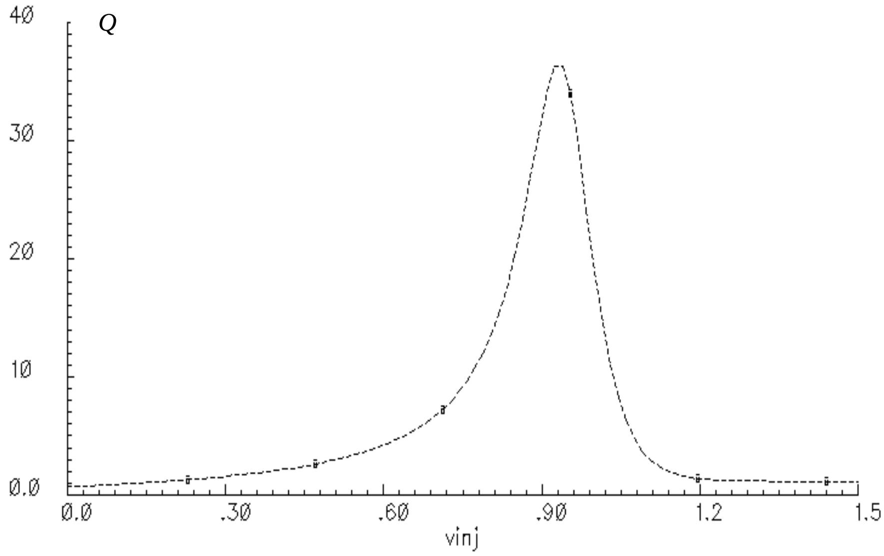


Fig. 2 – Variation of the quality factor with respect to Vinj.

The self-resonant frequency of the active inductor is not constant when Vinj varies and has the maximum value of 1.331 Ghz when Vinj has a value of 600 mV and the quality factor has a value of 4.5, as shown in Fig. 3. When the quality factor has the maximum value of 36 the self resonant frequency has a value of approximately 1.06 Ghz.

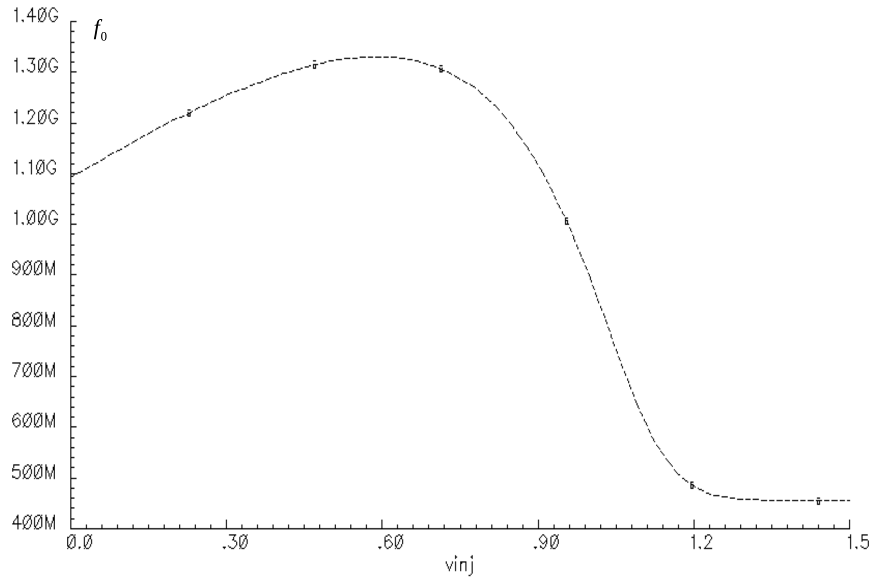


Fig. 3 – Variation of the self-resonant frequency; Vinj varies from 0 to 1.5 V.

From both analyses a conclusion can be drawn: the self-resonant frequency is not constant when Vinj is modified between 0 V and 1.5 V. The quality factor can be varied between a minimum value of 1 and a maximum value of approximately 36**.** The maximum value is attained when Vinj has a value equal to 930 mV; the self-resonant frequency is equal to 1.06 Ghz.

4. Self-Resonant Frequency of the Differential Active Inductor

The self-resonant frequency of the differential active inductor can be modified by means of a variable current mirror controlled by the voltage vtosi applied at the gates of the transistors *M*10 and *M*12. The value of the frequency can be varied from 272 Mhz to 2.5 Ghz as shown in Fig. 4.

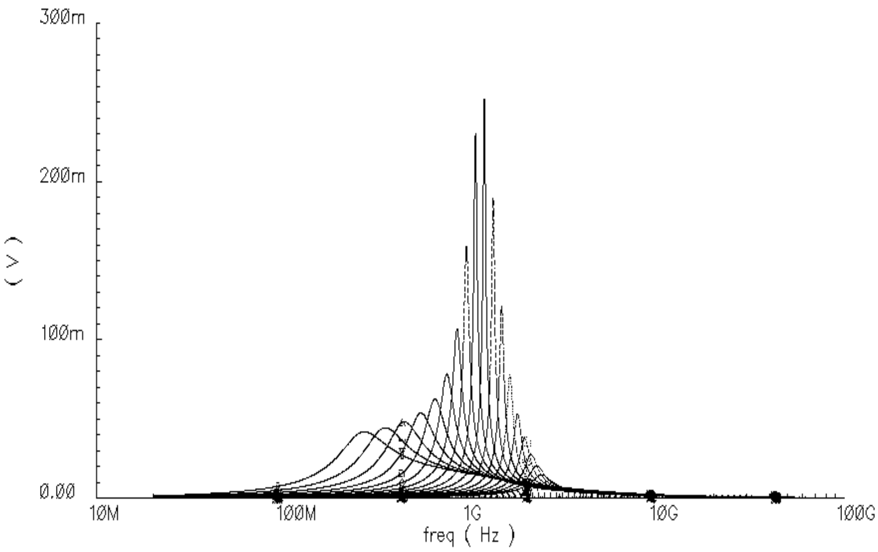


Fig.4 Variation of self-resonant frequency; vtosi varies from 0 V to 1 V

The quality factor of the active inductor is not constant when vtosi varies, and has a different type of variation. The frequency response was realized with a resolution of 40 steps and it shows a maximum value for magnitude equal to approximately 250 mV at a frequency equal to 1.122 Ghz. The variation of vtosi in 0,…,1 V interval determines a nonliniar behavior of the quality factor and can be analyzed as follows. For values of vtosi between 0 and 300 mV the quality factor has a slow increase of the value from 0 to approximately 2**.** Next region is represented by values of vtosi situated in 300 mV - 420 mV interval where the quality factor has a rapid increase and reaches the maximum value of approximately 35. In the third region, determined by values of vtosi between 420 mV and 620 mV, the quality factor has a rapid decrease from 35 to 0, as shown in Fig. 5**.**

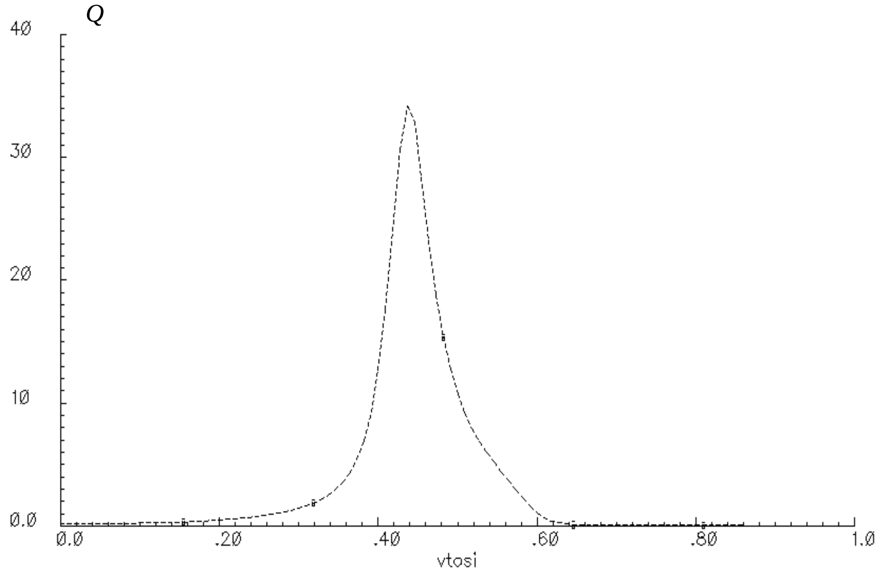
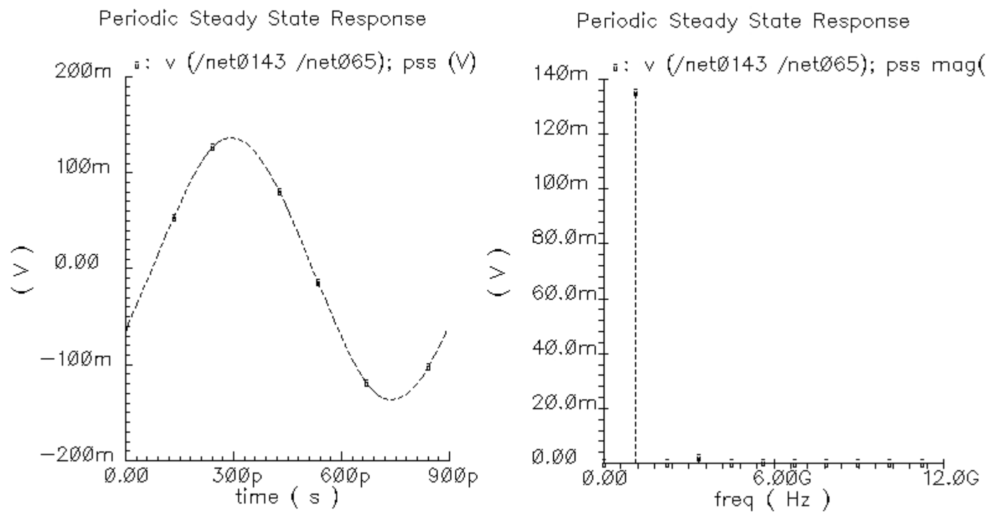


Fig. 5 – Variation of quality factor; vtosi varies from 0 V to 1 V.

The periodic steady state analysis with a current source which has an amplitude equal to 1 μA, and a frequency equal to 1.122 Ghz shows that the differential output voltage has a negligible distortion and the fundamental component has a value of 135 mV, as shown in Fig. 6.



a *b*

Fig. 6 – PSS analysis of the differential active inductor: *a* – time; *b* – spectrum.

5. Conclusions

In this paper a novel differential active inductor with self-resonant frequency and quality factor tuning is presented. It was demonstrated that the quality factor can be modified between 1 and approximately 36. The self-resonant frequency of the active inductor can be modified with certain constraints regarding the quality factor and the voltage swing with negligible distortion is very good.

REFERENCES

Andriesei C., Goraş L., *On Frequency and Quality Factor Independent Tuning Possibilities for RF Band-pass Filters with Simulated Inductors*. Romanian J. of Information Sci. a. Technol., **11**, *4*, 367-382 (2008).

Andriesei C., Goraş L., *On the Tuning Performance of an Active RF Bandpass Filter*. Acta Technica Napocensis, **49**, *3* (2008).

Andriesei C., *Study of Active Filters Topologies for Telecommunications Applications*. Ph. D. Diss., Cergy-Pontoise Univ., Technical University "Gheorghe Asachi" of Iaşi, 2010.

Bakken T., Choma J., *Gyrator-Based Synthesis of Active On-Chip Inductances*. Analog Integrated Circ. a. Signal Proc., **34**, 171–181, Kluwer Academic Publ. (2003).

Johns D.A., Martin K., *Analog Integrated Circuit Design*. John Wiley & Sons, 1996.

Yuan F., *CMOS Active Inductors and Transformers, Principle Implementation, and Applications*. Springer, 2008.

O NOUĂ INDUCTANȚĂ ACTIVĂ CU FACTOR DE CALITATE ŞI FRECVENȚĂ DE REZONANȚĂ PROPRIE CONTROLATE ÎN TENSIUNE

(Rezumat)

Se prezintă o nouă structură de inductanță activă cu factor de calitate şi frecvență de rezonanță proprie modificabile prin intermediul unor tensiuni. Pentru îmbunătățirea factorului de calitate şi respectiv pentru modificarea acestuia au fost introduse două tranzistoare suplimentare. Frecvența proprie de rezonanță poate fi modificată cu unele constrângeri în ceea ce priveşte factorul de calitate şi este controlată de tensiunea aplicată pe grila unui tranzistor ce intră în componența oglinzii variabile de curent. Tensiunea diferențială de ieşire nu este distorsionată şi are o amplitudine relativ mare.