A CMOS 65nm UHF Bandpass Filter Employing Active Inductor for Small-Satellites

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Abstract—The active inductor (AI) is a promising strategy for use in analog receiver filters applied to aerospace devices, as it occupies a smaller silicon area. This paper presents the preliminary design of an AI implemented in a 65-nm CMOS process, which obtained an L of 14.97 nH with a quality factor of 3.7. It was employed to implement an L-C band-pass filter at 401.5 MHz intended for small-satellite RF receivers. The power consumed by the complete circuit was 1.08 mW at 1.2 V.

Keywords—UHF, bandpass-filter, active inductor, aerospace applications.

I. INTRODUCTION

Small aerospace systems, such as pico and nano-satellites, are very used today due to the reduced cost and their applicability. Miniaturized circuit implementations are very demanding in these applications to make it possible to embed a complete system in a small area with reduced weight.

The RF communication sub-system is one of the main parts of a small satellite and also is one of the most complex systems. These systems normally operate at the UHF frequencies band (400-403 MHz) in which it is very challenging to implement distributed microwave circuits due to their size and also RF integrated circuits (RFICs) present poor performance of the magnetic elements at this frequency band.

In RFICs, inductors are key elements, since they are used in the development of analog blocks of transceiver systems, such as low-noise amplifiers, RF transformers and filters [4]. The design of passive inductors often becomes challenging, as they occupy a considerable area of silicon and require special technology, such as thicker metal layers or a high resistivity substrate.

However, the inductive behavior in frequency can be synthesized using active inductors (AIs), occupying only 1 to 10% of the area of passive inductors. They are designed from the theory of gyrator-C, thus, the transconductors are changed for two transistors $M_1$ and $M_2$ in the same back-to-back connection [3], as shown in Fig. 2. Transistors $M_3$ and $M_4$ work as current sources.

From small-signal model of the circuit shown in Fig. 2 is extracted the input impedance $Z_{in}$ equation, as follows:

$$Z_{in}(s) = \frac{sc_D + A}{s^2C_DC_X + s(C_XA + C_DB) + AB + gm} \tag{1}$$

The total transconductance is modeled by $g_m = g_m1g_m2$, and the output conductances are defined by $A = g_{ds2} + g_{ds4}$ and $B = g_{ds1} + g_{ds3}$. And also, the parasitic capacitance $C_D$ and $C_X$ is given by the equation below:

$$C_D = C_{db2} + C_{gd1} + C_{gd4} + C_{db4} \tag{2}$$

$$C_X = C_{sb1} + C_{gs2} + C_{gs3} + C_{db3} \tag{3}$$

The generated inductance is given by transconductances of $M_1$ and $M_2$, therefore, this parameter is dependent on the current flow in its own transistors [2]. So, to synthesize an inductance value of $L = 14.97$ nH is needed a drain current...
$I_D = 400 \, \mu A$ on both branches. The current flow through of these transistors is given by the voltage biases $v_{bias_1}$ and $v_{bias_2}$ provided from current-mirrors.

All the four transistors has the same channel length $L = 0.50 \, \mu m$, the channel width $W$ and multipliers of each one follows: $M_1 (W = 3.00 \, \mu m, M = 40), M_2 (W = 3.00 \, \mu m, M = 40), M_3 (W = 3.30 \, \mu m, M = 40)$ and $M_4 (W = 4.20 \, \mu m, M = 80)$. The cadence virtuoso design environment @ was used to simulate the circuit and to extract the equivalent input impedance of the designed active inductor. The frequency response of the designed AI circuit with a quality factor (Q) of 13.59 and SRF of 1.3 GHz is shown in Fig. 3.

III. PROPOSED BANDPASS FILTER

The proposed UHF analog bandpass filter is designed using a simple LC resonator topology, as shown in Fig. 4. This network is composed of one inductor and one capacitor on a parallel connection [1], and the resonant frequency must be equal to 401.5 MHz, the central frequency of the 400–403 MHz band. The transfer function of the proposed filter is given by the equation below:

$$H(s) = \frac{s/(CR)}{s^2 + s/(CR) + 1/(LC)}$$

(4)

As the AI presents $L = 14.97 \, nH$, the value of $C$ is defined to be 8.5 pF and the input resistance $R$ to 140 $\Omega$. The proposed BPF reached a quality factor equal to $Q = 3.701$ and the frequency response of the filter is shown in Fig. 5. It presented an insertion loss of 9.37 dB and a bandwidth of 382 MHz (242-624 MHz).

IV. CONCLUSION

This paper has presented the preliminary design of a band-pass filter based on an active inductor implemented in a 65nm CMOS process. The AI implemented an inductance of 14.97 nH with Q of 13.59 at 401.5 MHz. The implemented BPF presented a bandwidth of 382 MHz with an insertion loss of 9.37 dB.

In future works, we intend to improve the active inductor circuits implementation in order to reduce the BPF insertion loss, implement a higher-order filter and fabricate the circuit for experimental validation.

REFERENCES