Comparative Study of Microwave CMOS Differential Active Inductor

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Recent development of the microwave communication circuits by using CMOS technology leads to the special emphasis on the high Q inductor investigation in order to implement high selectivity filter [1,2]. But, the common Q-factor cannot reach the value larger than 10 as the existence of the undesirable resonance due to parasitic capacitance and parasitic series resistance in CMOS inductors. Therefore, there is great interest in using active inductor that uses active element to compensate the resistive losses so as to increase its Q-factor. In this paper, we propose two novel active inductor architectures. Their simulation results are also reported and compared in order to demonstrate their usefulness. These two proposed active inductor designs are both based on the conventional gyrator-C impedance conversion of capacitor C as shown in Fig. 1 [3]. Its simulated Q-factor of $Z_{in} = R + jX$ of Fig. 1 is about 100 to 200 which is indeed insufficient for the mobile communication handset like Inmarsat-C that requires an Q-factor as high as 400 for example. In such a way, the design for these two active inductors is to use the Fig. 1 circuit as basic cell whilst additional compensation will be simply implemented by series/parallel connection of a negative resistor as depicted in Fig. 2 with the basic cell.

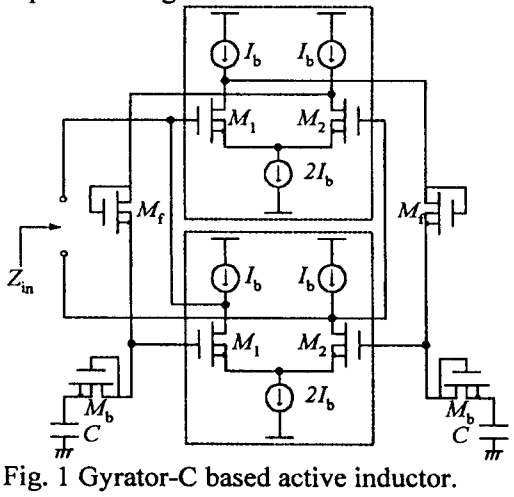

Fig. 1 Gyrator-C based active inductor.

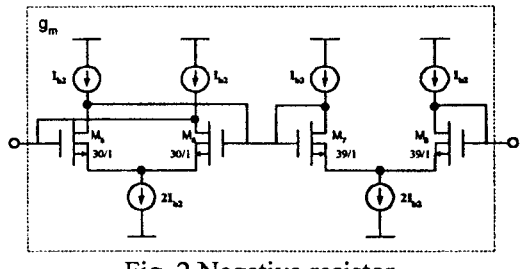

Fig. 2 Negative resistor.

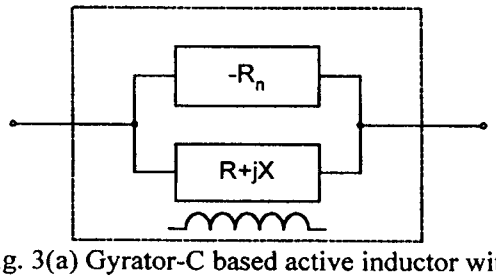

Fig. 3(a) Gyrator-C based active inductor with parallel compensation.

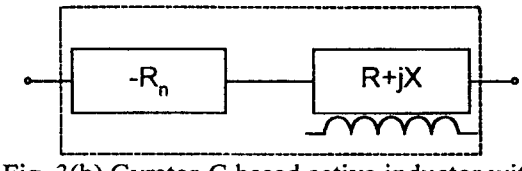

Fig. 3(b) Gyrator-C based active inductor with series compensation.

The first approach as illustrated in Fig. 3(a) is to connect a negative resistance ($-R_n$) with the addressed gyrator-C active inductor cell in parallel whilst the second ones is connected in series as depicted in Fig. 3(b). In fact, two pairs of differential transistors construct this negative resistor. It provides the

compensation to reduce resistive loss of the basic gyrator-C active inductor in certain frequency range, thus the Q-factor can be improved.

In order to demonstrate the proposed structures' usefulness, two *L*-band CMOS differential active inductor are designed with the addressed structures in Fig. 3 and compared in the frequency range of 1GHz to 3GHz. These *L*-band active inductors are designed in 0.6μm CMOS process and simulated by SpectreS in CADENCE. Their simulation results as shown in Figs. 4 and 5 for parallel and series compensation respectively. Both of the structures show good performance when compared with the uncompensated ones (Fig. 1 gyrator-C active inductor cell). In parallel compensation, the Q-factor is achieved as high as 450@2.36GHz with transistors biased at W/L = 54 and I_b = 10mA. Whilst the series compensation Q-factor is achieved 618@1.90GHz biased with W/L = 14 and I_b = 3mA. In addition, the simulated inductances of these two active inductors are respectively 50nH and 74nH in 0.5MHz frequency band around their own resonance frequencies. Based on the above, this shows that the series compensation (Q=618) may obtain higher Q-factor when compared with the parallel ones (Q=450).

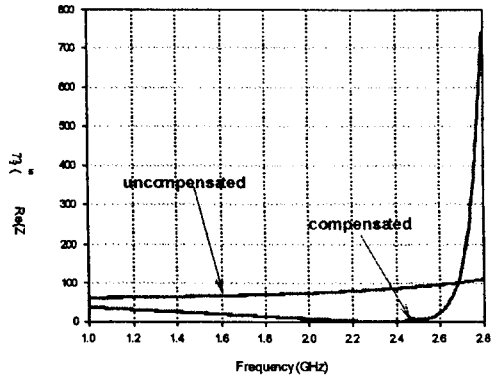

Fig. 4(a) Real part of input impedance of proposed active inductor by parallel compensation.

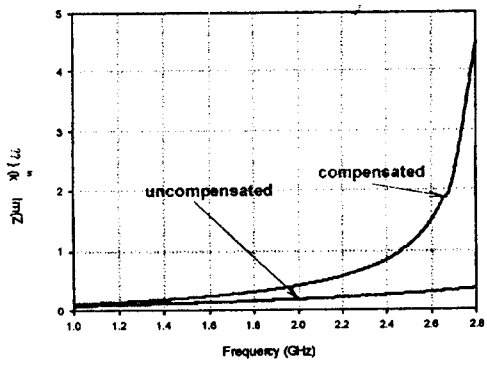

Fig. 4(b) Imaginary part of input impedance of proposed active inductor by parallel compensation.

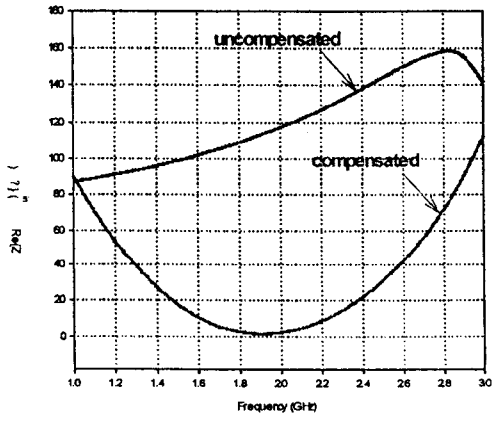

Fig. 5(a) Real part of input impedance of proposed active inductor by series compensation.

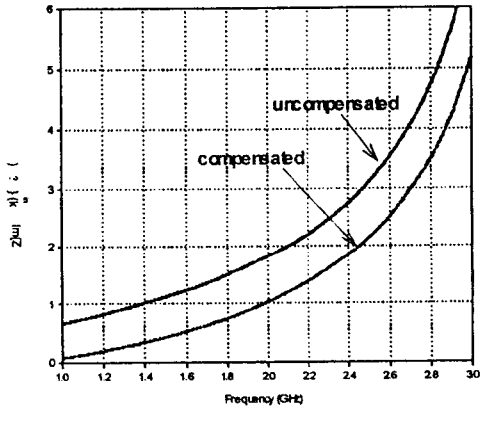

Fig. 5(b) Imaginary part of input impedance of proposed active inductor by series compensation.

References

[1] R.A. Duncan, K.W. Martin and A.S. Sedra, "A Q-enhanced active-RLC bandpass filter," in *Proc. IEEE Int. Symp. On Circuits and Systems*, May 1993, pp. 1416–1419.

[2] Y.T. Wang and A. Abidi, "CMOS active filter design at very high frequencies," *IEEE J. Solid-State Circuits*, SC-25 (6), pp. 1562–1574, Dec. 1990.