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CMOS Microwave Bandpass Filter using High Q Active Inductor

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***Abstract*—In this paper, microwave CMOS bandpass filter (BPF) has been proposed. The proposed BPF consists of passive MIM (metal-insulator-metal) capacitors and high Q active inductors using feedback parallel resonator. In the previous works, many BPFs were researched and developed. However, they had relatively low Q-factors and low operating frequencies due to the passive spiral inductors and capacitors. The proposed BPF can improve these drawbacks by using high-Q active inductor. The center frequency of the designed BPF is 5.25 GHz and it has wide bandwidth around 200 MHz for IEEE 802.11a band of WLAN applications. The proposed circuit was simulated with TSMC 0.18 um process and the overall chip size is 930 × 650 um^2. Finally, in the simulation results, we can get 2.2 ~ 2.7 dB of insertion loss at -10 dBm input power level in the pass-band. The power consumption is 28 mW.**

Keywords—1-port active inductor, bandpass filter, high Q

I. INTRODUCTION

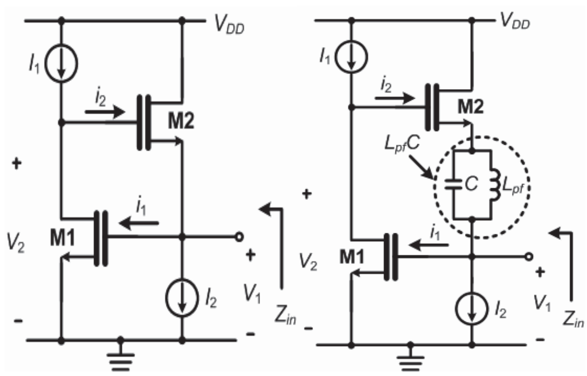
With the development of wireless communication system and the continuous expansion of the market using them, wireless communication circuits and devices are drawing more and more interest. Recently many studies have been conducted specially on the WLAN (Wireless Local Area Network) band. In order to design an application circuit or a transmission/ reception module operating in such a band, development of a high-speed integrated circuit for efficiently transmitting various information is required. In addition, the research into RF integrated circuit (RFIC) has been actively pursued in response to the demand for small area, low cost, and less power consumption.

Filters serve to pass only the desired signal from frequency signal input to the circuit so that only the necessary frequency signal is selected. A bandpass filter (BPF) is an electronic device or circuit that allows the desired signals to pass, and discriminates against signals at other frequencies. Conventional RFIC BPFs were implemented with spiral inductors and capacitors [1]-[3], or varactor diodes to provide variability [4][5]. However, the performances of the overall BPF depend on the Q-factor (quality factor) of the constituent elements, and has strong effect on insertion loss, especially in the pass band. In the case of the conventional spiral inductor, Q-factor is too low to match such desired request. In order to overcome these disadvantages, this paper introduces an active inductor that has a high Q-factor at the desired frequency. The capacitors are realized with metal-insulator-metal (MIM) capacitors having relatively much higher Q-factor than the spiral inductor to implement BPF. As a result, the electrical performances of the designed BPF circuit are improved.

The proposed BPF is a capacitive coupled BPF with Chebyshev type for the stopband characteristics and connection of capacitor implemented as an admittance inverter between the resonant circuits.

II. CMOS HIGH Q 1-PORT INDUCTOR

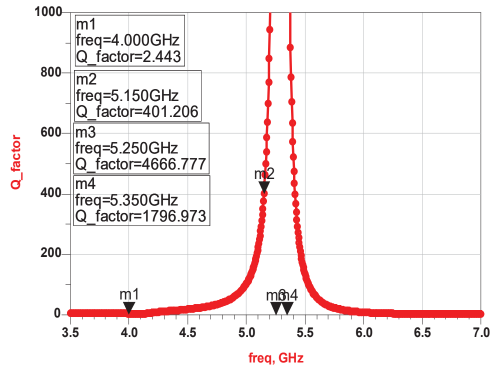
Fig. 1 shows the conventional grounded active inductor (GAI) and high Q active inductor using feedback parallel resonator. The conventional GAI realized with basic gyrator-*C* structure. The gyrator-*C* consists of two transistors, and generates inductive reactance from parasitic capacitances of those transistors. However, the conventional GAI has a limitation to increase the Q-factor and operating frequency range. There have been some works by adding arbitrary circuit into the conventional GAI to enhance Q-factor. Among these works, the active inductor using feedback parallel resonator in [6] had the prominent effect on increasing Q-factor of GAI. This active inductor using feedback parallel resonator is adopted in the proposed BPF design in order to get high Q-factor.



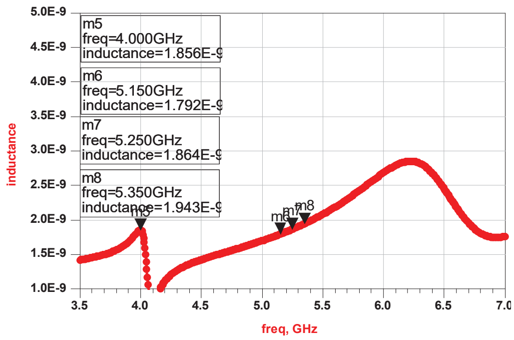
(a) (b)

Fig. 1 (a) Conventional GAI and (b) high Q active inductor using LC parallel resonator.

Fig. 2 shows the Q factor and the inductance of the active inductor using feedback parallel resonator. By adjusting the transistor size, the transconductance is controlled to match the target operating frequency. In this application, we match the high Q active inductor to the frequency of 5.25 GHz, where the highest Q factor and relatively stable inductance are obtained. The inductance of proposed GAI is 1.79 nH ~ 1.93 nH from 4 GHz to 5.35 GHz.



(a)

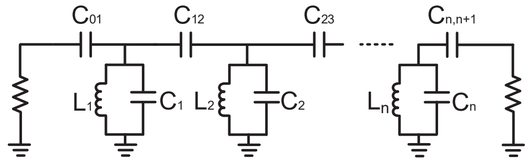


(b)

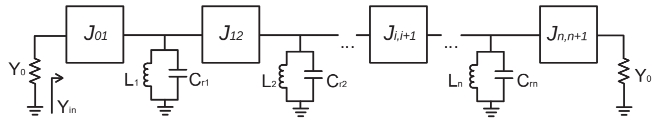
Fig. 2 (a) Q-factor and (b) inductance characteristics of active inductor using feedback parallel resonator

III. CAPACITIVE COUPLED BAND PASS FILTER

In this paper, the capacitive coupled band pass filter is designed with 1-port active inductor using feedback parallel resonator. In the design of conventional BPF, the prototype low-pass filter is designed at first and then transformed to the BPF by transforming low pass prototype lumped elements to serial or parallel resonant circuits. Fig. 3 shows the structures of the proposed BPF using lumped elements and admittance inverters (*J*-inverters). In this paper, *J*-inverters using capacitors are used in order to save circuit size. The *J*-inverters and element values are expressed by (1) and (2). For the simplicity of the analysis, inductance values are chosen to be the same value L_r, and symmetric structure is adopted in this analysis.



(a)



(b)

Fig. 3 Structures of proposed CMOS BPF using: (a) lumped elements and (b) *J*-inverters.

$$J_{01}=\sqrt{\frac{G_0 W\omega_0 C_{r1}}{g_0 g_1}}=\sqrt{\frac{G_0 W}{g_0 g_1(\omega_0 L_r)}}$$
$$J_{ii+1}=\sqrt{\frac{\omega_0{}^2 C_{ri}C_{ri+1}}{g_i g_{i+1}}}=W\sqrt{\frac{1}{g_i g_{i+1}(\omega_0 L_r)^2}} \quad (1)$$
$$J_{nn+1}=\sqrt{\frac{\omega G_{n+1}\omega_0 C_{rn}}{g_n g_{n+1}}}=\sqrt{\frac{WG_{n+1}}{g_n g_{n+1}(\omega_0 L_r)}}$$

$$C_1=\frac{1}{\omega_0{}^2 L_r}-C_A-C_{12},$$
$$C_i=\frac{1}{\omega_0{}^2 L_r}-C_{ii+1}-C_{i-1i}, \quad (2)$$
$$C_n=\frac{1}{\omega_0{}^2 L_r}-C_B-C_{n-1n},$$

$$\text{where } C_A=C_B=\frac{C_{01}}{1+\left(\frac{\omega C_{01}}{Y_0}\right)^2}, L_1=L_2=\ldots=L_n=L_r.$$

IV. EXPERIMENT AND RESULT ANALYSIS

To show the validity of the proposed CMOS BPF, the design specifications were referred to the commercial ceramic BPF of MURATA company. According to the attenuation versus normalized frequency for equal-ripple filter prototype, when the ripple is 0.1dB, the stage number N should be 2. As a result, a 2-stage BPF is proposed in this design. The center frequency is 5.25 GHz and it has a wide bandwidth of around 200 MHz. We use ADS (Advanced Design System, Keysight), HFSS (High Frequency Structure Simulator, Ansoft), and RF spectre (Cadence) for simulation. The proposed circuit was designed by TSMC 0.18 um and the overall circuit size including pads was 930 × 650 um^2. In the simulation results, we can get 2.1 dB of insertion loss in the pass-band as Fig. 4 shows. The power consumption is 28 mW in simulation. Fig. 5 shows the layout of the proposed CMOS BPF.

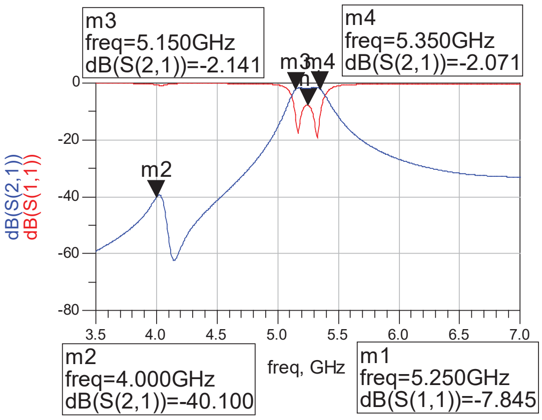


Fig. 4 Simulation result of proposed BPF

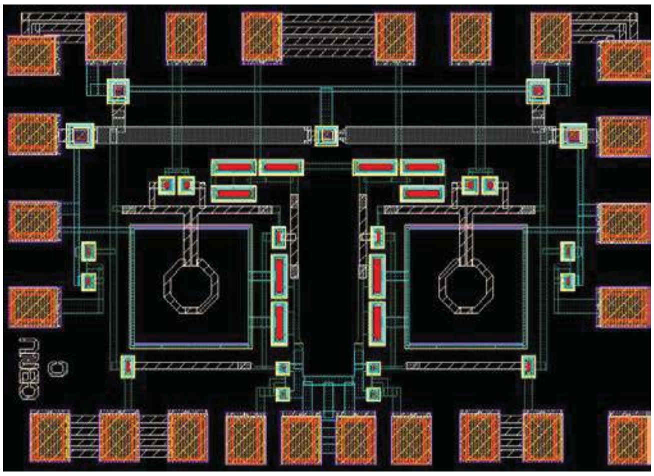


Fig. 5 Layout of proposed BPF

V. Conclusion

In this presentation, microwave CMOS bandpass filter (BPF) using high Q active inductor has been proposed. Whereas the conventional CMOS BPF on microwave frequency range is not realizable due to some drawbacks such as insertion loss due to low Q-factor, the proposed CMOS BPF can be realized with high Q-factor active inductor using feedback parallel. We expect the fabricated CMOS BPF get the satisfactory results. This design method can contribute microwave CMOS circuit designs. But the high power consumption is remained to be solved for the future work.

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