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LC Active Low Pass Ladder Filter by Lossless Floating Inductor Gyrator

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Abstract: *A traditional approach of simulating floating inductance in active gyrator of OTA of equal transconductance is successively used in obtaining LC ladder consisting of four stages .The calculations done on floating inductance evaluate the respective cut off frequencies as expected from the calculation of resonant frequency. The equal transconductance of gyrators is more advantageous in the low pass filter design. A unified approach of gyrator LC filter with floating inductor is successively used for studying the response. This has the property of reducing noises at high frequency signal processing applications.*
Keywords: *OTA-Operational transconductance amplifier, Floating inductor, gyrator*

I. Introduction

The low sensitivity active filters are obtained by LC ladder filter using gyrator and capacitors. The main advantage of this method is the simplicity in the design, associated with low sensitivity. The floating inductor is little complicated because of the cascading arrangement of the gyrators and the shunt capacitors between them [1,2]

In most of the signal processing applications gyrators [2,3] of equal transconduactance arranged in parallel with opposite directions are the suitable forms of realizing a floating inductor. Other types of gyrator realizations are also used for different applications. The circuit of fig.2 is equivalent to the floating inductor of inductance 1mH, which is obtained for bias current of 52µA at 1nF capacitor, when all OTA's behaves as ideal one. If the transconductances are different then the power gain losses are not reflected by single floating inductance. Hence a model consisting of four stages is used to study the cascading effect over the respective input and output impedances at each stage. The proposed structure reflects the voltage and current gains at all successive output stages with a marked roll off ratio, elimination of noises and idealistic approach of cutoff frequencies.

The response of four stage ladder using discrete components is presented. From the comparison it is possible to bring out the salient features of ungrounded inductance simulations using two gyrators at a time. In the circuit arrangement the simulation of two grounded inductance of equal transconductance are used to obtain a single floating inductor.

II. Circuit Description

The floating inductance simulator of gyrator type shown in fig 1.The voltage across active floating inductance is[3,4,5]

$$V_{AB} = (V_A - V_B) \quad (1)$$

Hence the output currents across OTA_1 & OTA_3 are

$$I_1 = -g_{m1} V_A \quad (2)$$

$$I_3 = g_{m3} V_B \quad (3)$$

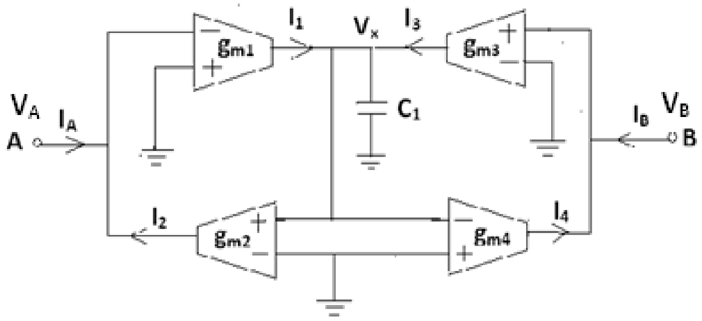

Fig 1

The output voltage V_x of OTA_1 & OTA_3 is connected with the grounded capacitor C_1 is

$$V_x \quad = \frac{(I_1 + I_3\ )}{SC} \tag{4}$$

This V_x becomes input voltage for OTA_2 & OTA_4 gives output currents, are

$$I_2 \quad = \quad g_{m2} \quad V_x \tag{5}$$

$$I_4 \quad = - g_{m4} \quad V_x \tag{6}$$

Where $g_m = I_B / 2V_T$, I_B is bias current and V_T is thermal voltage. For superior performance $g_{m1} = g_{m2} = g_{m3} = g_{m4} = g_m$, after substituting V_x from eqn. (4) in eqn. (5) & (6),we get

$$I_2 = \frac{g_m^2}{SC}(-V_A + V_B) \quad \text{and} \quad I_4 = \frac{g_m^2}{SC}(V_A - V_B) \tag{7}$$

Then $I_A = - I_2$ & $I_B = -I_4$, from (7) $I_A = - I_B$. Therefore its equivalent impedance Z_{AB} is expressed as

$$Z_{AB} = (V_A - V_B)/I_A = - (V_A - V_B)/I_B = SC/g_m^{\ 2} = SL$$

The synthesized floating inductance is $L = C/g_m^{\ 2} = (4\ V_T^{\ 2}C\ /\ I_B^{\ 2})$. This inductance can be electronically tuned by varying the external bias current[4,5,6].

III Experimental Results and Discussion.

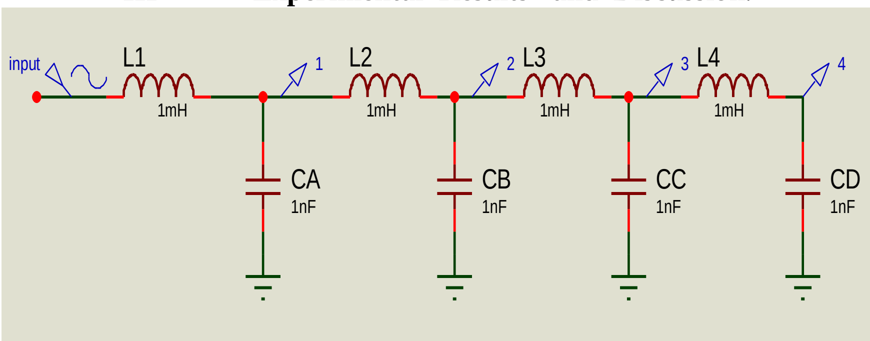

Fig 2.

In realisation of floating inductor LC ladder[1] filter, several techniques are proposed for simulation of floating inductor. The tehnique used in simulating floating inductce in LC filters at idealistic approach in which the cutoff frequencies agreeing with calculations. The elctronically variable property of inductor with tunable advantage of bias current is studied. Which performs good agreement with grounded capacitor at c_1=1Pf & 1nf and $I_{B1} = I_{B2} = I_{B3} = I_{B4} = I_{B,}$ is set to 52µA gives the values of inductance L=1µH & 1mH respectively. By realising LC ladder for L=1mH and C_A = 1nf, the transition of lowpass is at cutoff frequency of 159KHz, which shows an accurate result of simulation. This is verified through softwre protuse professional 7 using LM13600 commercial avalable OTA[8], which has g_m adjustable over 6 decades & excellent matching conditions.The amplifier performs good agreement to the gyrator type floating inductance.

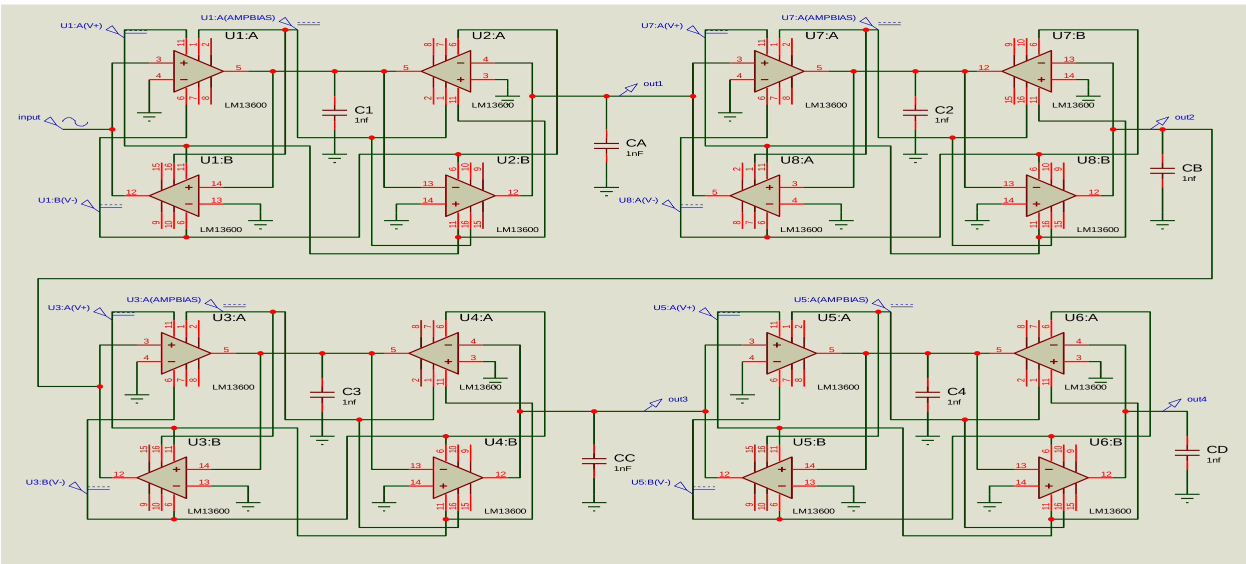

Fig 3.

In the response of successive stages the maximum gain is 0dB, there by showing an increasing marked roll off ratio -40db/decade per stage and eliminating ripples completely nearby cutoff frequencies of the filters at all stages. The comparison with LC Ladder filter using discrete components of same value in all successive four stages is shown in fig3. and fig 4. From the fig it is observed that noise signals are varying with stages erratically are eliminated. Their by explaining the limitations in low frequency filters. The proposed LC Ladder filter has the advantage of eliminating the noise signals and can function as a building block of cascade filter [6-10].

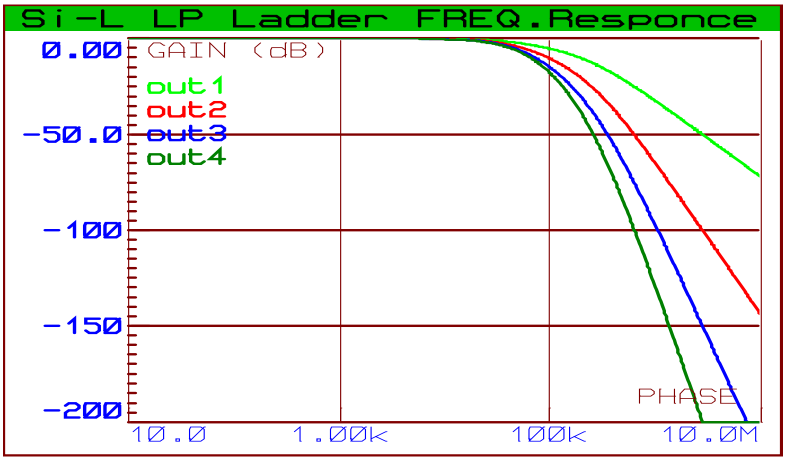

Fig.4

IV. Conclusion

From the overall study of LC Ladder active filters, it is possible to obtain slightly different half power frequencies with the maximum gain at each stage to zero dB. From the comparison with discrete LC ladder filter, the limitation such as appearance of noise signals can be eliminated in the proposed design. The roll off ratio -40dB/decade per stage has an increasing trend with the successive stages which changes the half power frequencies to nearby values. Such a characteristic property of the filter is desirable in instrumentation applications [1-10]

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