SIMULATED POSITIVE AND NEGATIVE INDUCTOR WITH TWO-OPERATIONAL TRANSCONDUCTNCE AMPLIFIER IN LC LADDER LOW PASS FILTER

Manjula V. Katageri[1], M.M. Mutsaddi[2]
[1]Govt.First Grade College, BAGALKOT, INDIA
[2]Basaveswar Science College, BAGALKOT, INDIA
Email: manjula.katageri @gmail.com

Abstract:

The present study reviews two circuits of floating inductance in the application of LC Ladder filter. The main advantage of simulation is to control electronically the value of floating inductance either positive or negative by adjusting bias current and by changing the feedback path, is possible to obtain the inductance in conjugate order without any external resistor and component matching. The circuit performance is discussed in the respect of frequency responses in LC Ladder LPF structure. The circuit has applications as resonant circuit and inductance cancellation circuits.

Key Words: OTA- Operational transconductance amplifier, Inductance simulation, LC Ladder, LPF-low pass filter

1. INTRODUCTION

Floating inductance simulation is one of the important circuits in analog electronic circuit design. This plays an important role in the field of communication, measurements and instruments. Several approaches to realize a floating inductance with grounded capacitor have been proposed in the literature[1-7]. Without any matching resistors it is possible with minimum number of OTA's to convert the signal voltage across grounded capacitor in to the terminal currents of the synthetic floating inductor. A commercial available OTA LM13600/13700 and with only one grounded capacitor as a passive element, can simulate the floating inductance of required value by varying the bias current. Then replacement of conventional inductors by synthetic ones in passive LC ladder LPF[4] filters belongs to well known methods of higher order low sensitivity filter design.

The operational transconductance amplifier is a device in which the input voltage controlls the output current .It contains the feature of linear controlled transconductance with tunable property of biasing current .The magnitude of inductance can be electronically varied by changing the external bias current of OTA. LM13600/LM13700[8] consists of two current controlled transconductance amplifier with different inputs and push pull outputs.Which has following features

* g_m adjustable over 6 decades and is linear
* Excellent mathing between amplifiers
*Linearising diodes
*controlled impedance buffers
*high output signal to noise ratio.

The ideal OTA has $Z_{in} = \infty$, $Z_{out} = \infty$,Band width $=\infty$, Inverting input current = Non inveritng input current

The Fig.1 Shows circuit symbol of OTA. The voltage controlled current source is mathematically expressed as $I_{out} = g_m (V_1 - V_2)$, where $g_m = (I_{bias}/2V_T)$, V_T is thermal voltage = 26mV at room temperature.[8]

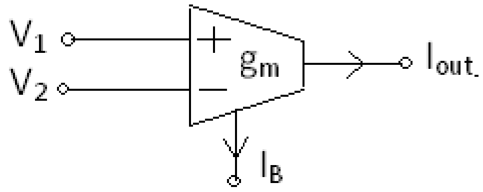

Fig.1 circuit symbol of OTA

2. CIRCUIT DISCRIPTION

The floating inductance[1,3] (positive and negative) can be simulated using 2-OTA's and single grounded capacitor as shown in the fig.2 & fig.3. The positive and negative inductance are simulating just by changing the feedback terminal from first OTA is to positive terminal or negative terminal of second OTA respectively.

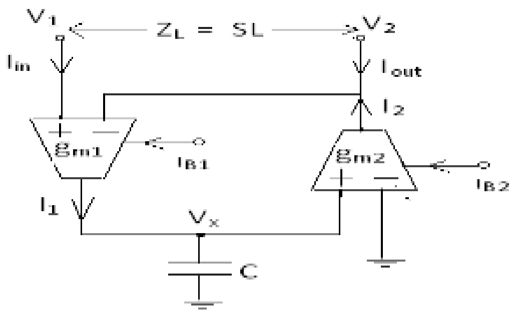

Fig.2 positive floating inductance

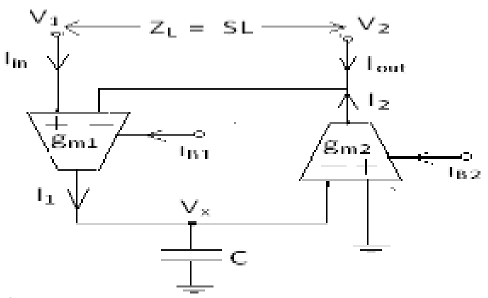

Fig.3 negative floating inductance

In fig.2 & fig.3 IB_1 & IB_2 are input bias currents of OTA_1 & OTA_2 respectively. From Fig. (2) Using OTA properties[1-3]

$$I_1 = g_{m1}(V_1 - V_2) \text{ ------------------------(1)}$$

$$I_2 = g_{m2} V_x \text{ ------------------------------ (2)}$$

$$\text{Where } V_x = \frac{I_1}{SC} = \frac{g_{m1}(V1 - V2)}{SC} \text{ --------------(3)}$$

Substitute eqn.(3) in (2) we get,

$$I_2 = \frac{g_{m2} g_{m1}(V1 - V2)}{SC} \quad \text{this gives}$$

$$\frac{(V1 - V2)}{I_2} = Z_{in} = \frac{SC}{g_{m2} g_{m1}} = Z_L = S\,L \text{------------(4)}$$

So it is evident that input impedance contains the inductance property as

$$L = \frac{C}{g_{m1} g_{m2}} \text{ ------------------------------- (5)}$$

The resulting inductance can be electronically varied by tuning the external bias currents I_{B1} or I_{B2} .

Similarly form Fig.(3) $I_1 = g_{m1}(V_1 - V_2)$,

$$I_2 = -\,g_{m2} V_x \;\&\; V_x = \frac{I_1}{SC} = \frac{g_{m1}(V1 - V2)}{SC} \text{ gives}$$

$I_2 = \frac{-g_{m2} g_{m1} (V1 - V2)}{SC}$ and its input impedance is $Z_L = \frac{-SC}{g_{m2} g_{m1}} = S L$

where $L = \frac{-c}{g_{m1} g_{m2}}$

Hence positive and negative inductance can be simulated.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The positive and negative floating inductances are experimentally tested through the software protuse professional 7 at I_B = 40μA & C_1 = 1μF gives L= 1.69H and for single stage LPF, C_A = 100pf the cutoff frequency is 12.2KHz shown in the Fig.4 & Fig.5. This shows some ripples on positive floating inductance frequency response. Also this LPF of single stage in laboratory tested experiment shows ripples in positive floating inductance response & are cancelled by negative floating inductance response shown in Fig.6 & Fig.7. This simulated single stage LC low pass filter then was extended for simulation for LC ladder network.

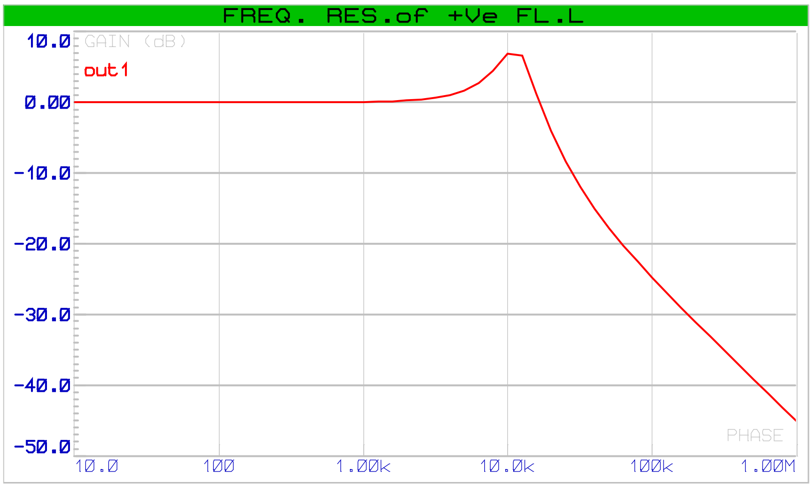

Fig. 4

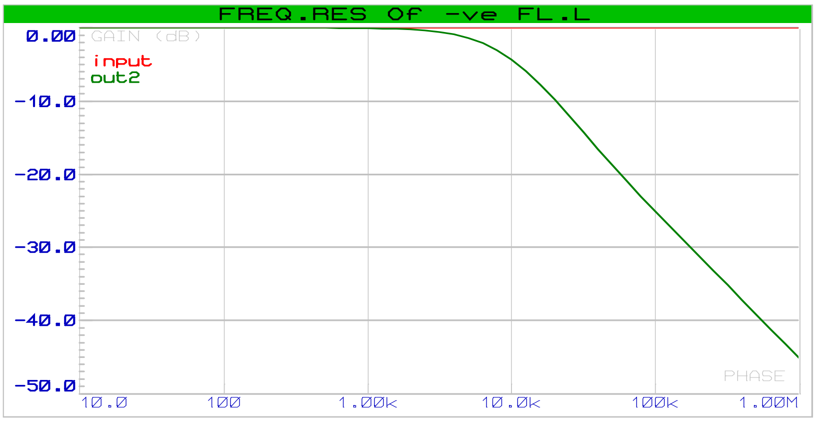

Fig. 5

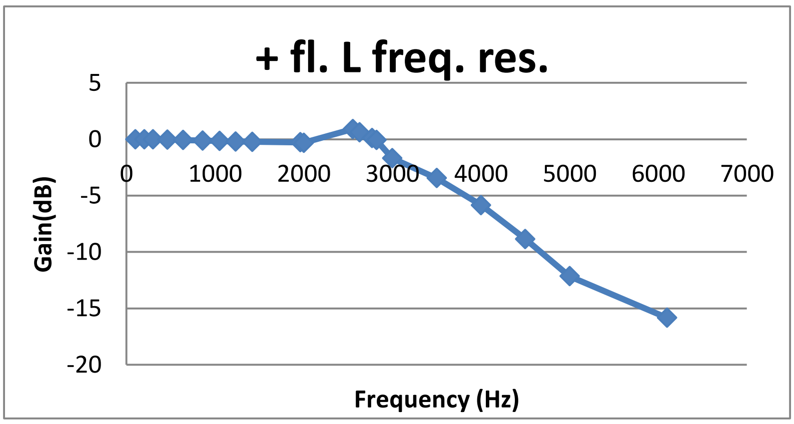

Fig. 6

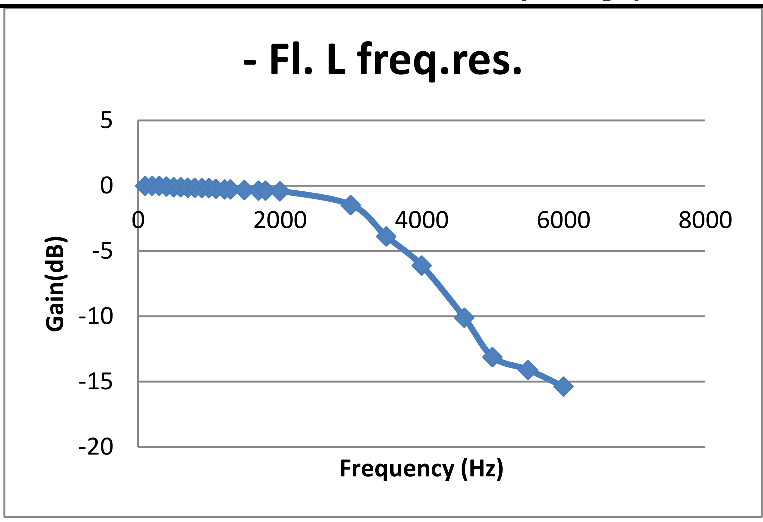

Fig. 7

3.1 LC Ladder Simulation:

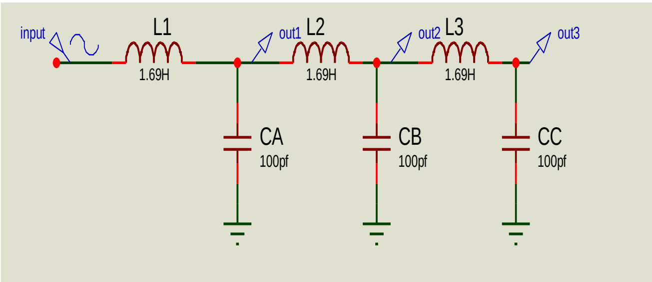

Fig.8

The passive LC ladder[4] Low pass filter (LPF)[6] with 3 stage is shown in Fig. 8 is studied for $C_A = C_B = C_c =$ 100pF and the passive inductance is replaced with active simulated inductance at $L_A = L_B = L_C =$ 1.69H for both positive and negative inductance circuits shown in Fig.9 & Fig.10. Using the tunable property of of bias current of OTA the simulated inductance is 1.69H at IBias=40μA and $C_1 = C_2 = C_3 =$ 1uf. So that each LC low pass filter gives cutoff frequency of $F_c = \frac{1}{2\pi\sqrt{LC}}$ =12.2KHz for each ladder and with respect to this roll off rate also increases gives a very good agreement with protuse professional 7 software.

Fig.11 and Fig.12 shows the positive feedback frequency response has ripples compared to the negative feedback response when the signals passing from pass band to stop band frequencies. The roll off rate at each stage is increases from -40dB/decade, -80db/decade and so on. So Butterworth response may possible after few stages. The positive feedback network has an application as resonant circuit and negative feedback network on undesirable inductance cancellation[6,7] in transmissionline.

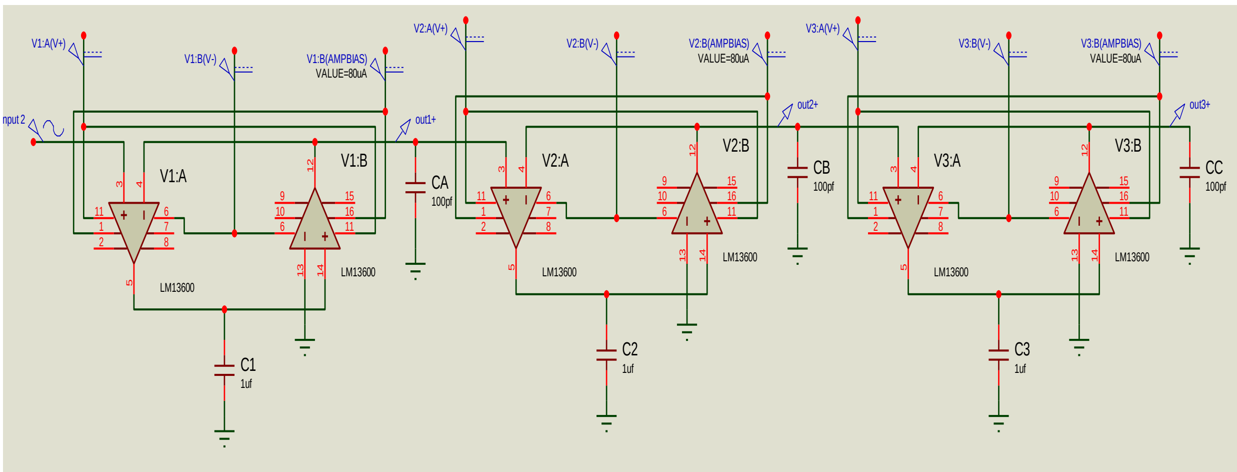

Fig.9 LC Ladder with positive fl. Inductance

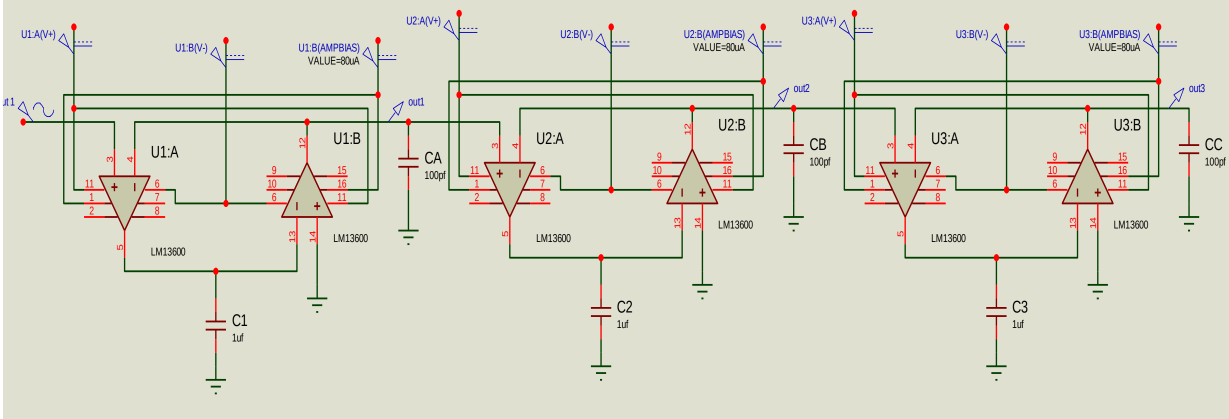

Fig.10 LC Ladder with negative fl. inductance

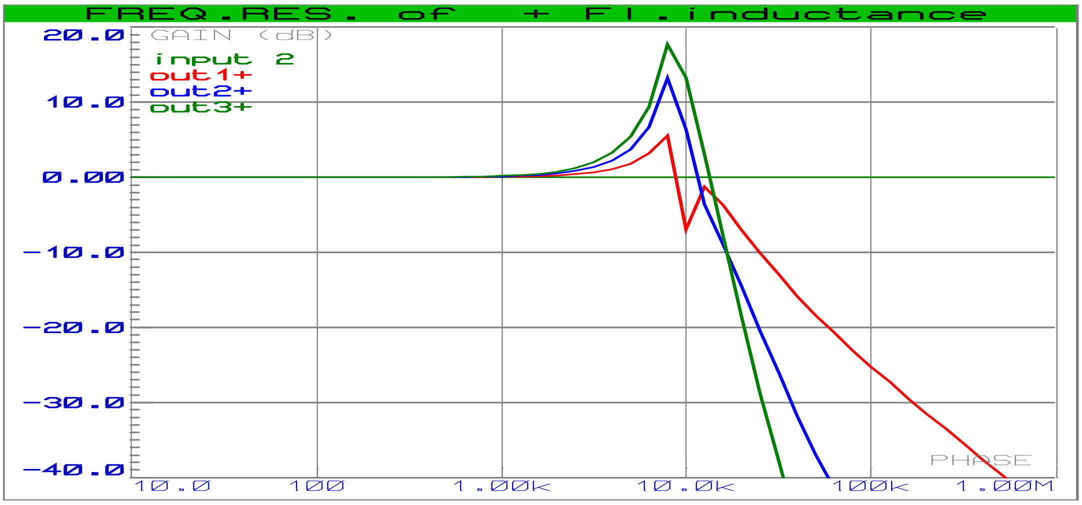

Fig.11

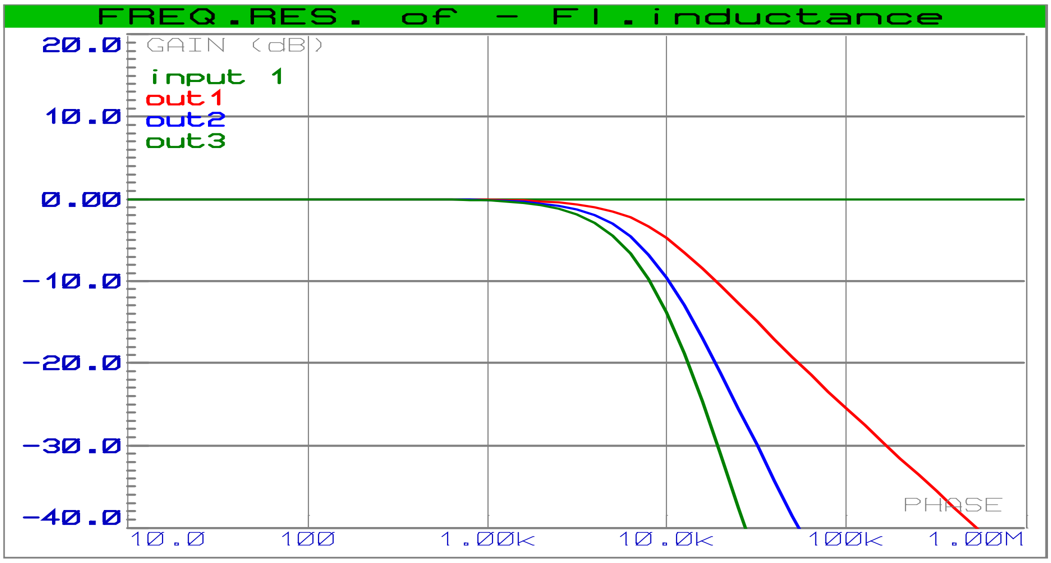

Fig.12

4. CONCLUSION

The two OTA positive and negative floating inductance simulation networks gives good performance through LC ladder low pass filter. These floating inductances use minimum number of OTA's and one passive element as grounded capacitor has an electronically tunable property of biasing current. The protuse professional 7 results show good agreement to theoretical anticipation, which has application in video filter with extreme requirements on the group delay responses.

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