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International Journal of Current Research
Vol. 5, Issue, 11, pp. 3404-3407, November, 2013

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

COMPARATIVE STUDY OF LC LADDER FILTER WITH 3-OTA SIMULATED INDUCTORS

*[1]Manjula V. Katageri and [2]Mutsaddi, M. M.

[1]Government First Grade College, Bagalkot, India
[2]Basaveshwar Science College, Bagalkot, India

ARTICLE INFO

Article History:
Received 14th September, 2013
Received in revised form
18th September, 2013
Accepted 26th October, 2013
Published online 19th November, 2013

Key words:

LPF-Low Pass Filter,
OTA – Operational Transconductance Amplifier, Si-L-Simulated inductor.

ABSTRACT

The innovative technique of realising floating inductor using OTA's as an active element and grounded capacitor for the realisation of the floating inductor was comparitively studied in developing four stage LC ladder low pass filters. A comparitive study of 3 OTA's and grounded capacitor of different configarations, as modified technique of floating inductor in ladder filter applications was studied in comparision with gyrator concept. The response of each stage exhibits the shootng characteristics of the output voltage in respect of filtering characteristic property with sharp roll off ratio in the modified technique of floating inductor. A comparative study on four stage LC ladder low pass filter using gyrator concept was exhibiting best performance in filtering action which has high frequency application in instrumentation.

INTRODUCTION

Floating inductance simulation is one of the important technique in analog electronic filter circuit design. Its applications are found in active filters, oscillators and system response compensation. Several methods for realization of floating inductance simulator have been reported in the literarature (Chitpol Koomgaew *et al.*, 2009; Priyanka Soni *et al.*, 2011; Neha gupta *et al.*, 2012; Alexender J. Casson *et al.*, 2011; Hajek *et al.*, 2006; Wandeev Petchmaneelumka *et al.*, 2009; Ananda Mohan 1998). Since OTA is a commercially low cost device for easy implimentation in the monolithic form. In this paper 3-OTA based floating inductor circuits (Chitpol Koomgaew *et al.*, 2009; Priyanka Soni *et al.*, 2011; Neha gupta *et al.*, 2012) of three configarations are studied. The replacement of conventional inductors by simulated one in passive LC ladder filter,which is well known method of low sensitivity high order filter design. The LC ladder low pass filter (LPF) in respective of four stage using three different simulated inductor circuits consisting of three OTA'S and grounded capacitor as only passive element was studied.

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 consists of two current controlled transconductance amplifier with different inputs and push pull outputs.Which has following features

- g_m adjustable over wide range 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. (Datasheet, 2004).

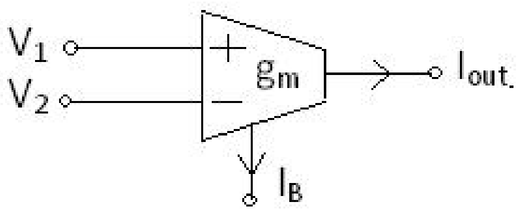

Fig.1. Circuit symbol of OTA

Circuit Discription

The circuits shown in (Fig. 2. Chitpol Koomgaew *et al.*, 2009) (Fig.3. Priyanka Soni *et al.*, 2011), and (Fig.4. Neha gupta *et al.*, 2012) are three different 3-OTA based floating inductor simulation circuits. The equivalent impedance of (Fig.1) & (Fig.2) has the dimention of inductance as

***Corresponding author: Manjula V. Katageri**
Government First Grade College, Bagalkot, India.

$$Z_{in} = \frac{V_1 - V_2}{I_{in}} = \frac{V_2 - V_1}{I_{out}} = \frac{SC}{g_m^2} = SL$$

$L = \frac{C}{g_m^2}$ at $g_{m1} = g_{m2} = g_{m3} = g_m$

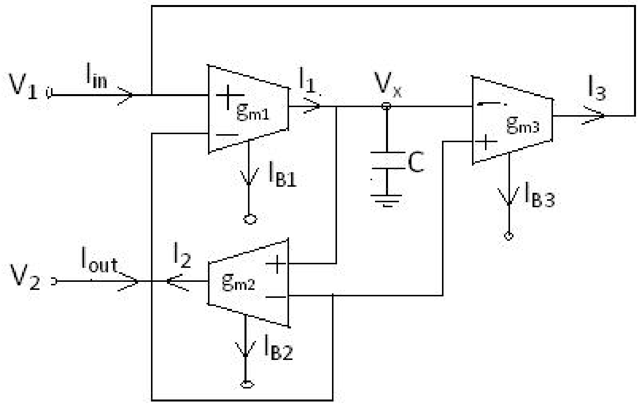

Fig. 2. Paper (Chitpol Koomgaew *et al.*, 2009) 3-OTA based floating inductor

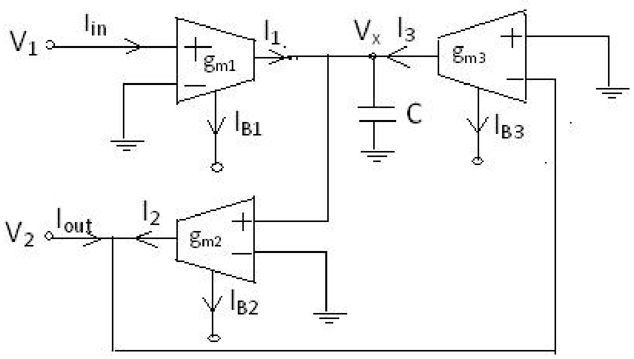

Fig. 3. Paper (Priyanka Soni *et al.*, 2011) 3-OTA based floating inductor

The 3-ota Gyrator type simulated inductor is shown in (Fig.4) gives best performance due its low sensitivity. The output currents of OTA_1 & OTA_2 are

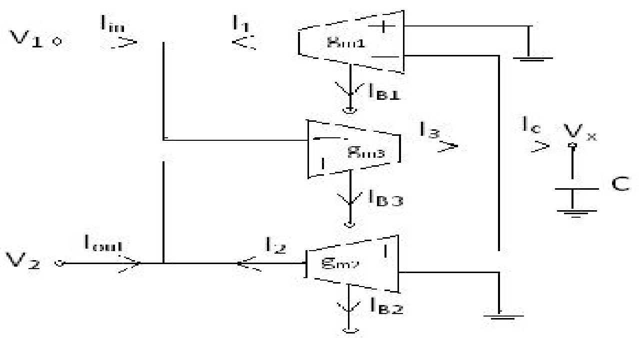

Fig. 4. Gyrator type 3 OTA floating inductor

$$I_1 = -g_{m1} V_x \quad (1)$$

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

$$I_3 = g_{m3} (V_1 - V_2) \quad (3)$$

$$V_x = \frac{I_c}{SC} \quad (4)$$

At $I_c = I_3$, input impedance can be obtained from Eq.s (1),(2),(3) & (4) at $I_1 = -I_{in}$ & $I_2 = -I_{out}$

$$Z_{in} = \frac{V_1 - V_2}{I_{in}} = \frac{V_2 - V_1}{I_{out}} = \frac{SC}{g_{m1} g_{n3}} = \frac{SC}{g_{n2} g_{m3}} = SL \quad (5)$$

If $g_{m1} = g_{m2} = g_{m3} = g_m$ is set , then $L = \frac{C}{g_m^2}$

The evalution of inductors from the known values of C and g_m suits the value of L obtained from cutoff frequency.

EXPRIMENTAL RESULTS

LC ladder simulation

The passive LC ladder Low pass filter (LPF) with 4 stage is shown in (Fig.5) was studied for $C_A = C_B = C_c = C_D$ = 1nF and the passive inductance was replaced with active simulated inductance at $L_A = L_B = L_C = L_D$ = 1mH. for each three different 3-OTA circuits shown in (Fig.6), (Fig.7) & (Fig.8). Using the tunable property of of bias current of OTA the simulated inductance was 1mH at IBias=50μA and $C_1 = C_2 = C_3 = C_4$ =1nf. The simulated results tested through Protuse professonal 7 software. So that each LC low pass filter gives cutoff frequency of $F_c = \frac{1}{2\pi\sqrt{LC}}$ =159KHz

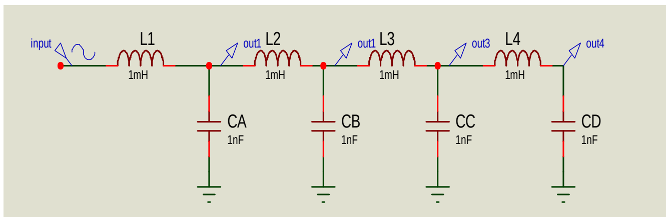

Fig. 5. Passive LC Ladder

Then low pass filter characteristics at four output stages was obtained for the three stated different techniques of simulated floating inductance (Fig. 6,7 & 8). The characteristic response of the low pass filter Shown in (Fig.9) exhibits the response of LPF using three OTA based inductor shown in (Fig.2). A family of low pass filter charactristics of Si-L as shown in (Fig.3) was presented in (Fig.10) with a family of curves. Similarly 3-OTA Gyrator inductance simulator for four stage LC Ladder characteristics is shown in (Fig.11). An observation on three graphs reveals the salient features of 3 OTA Gyrator floating inductor application in the design of LPF.

The method used in (Fig.3) was found to exhibiting overshoot of voltage near cutoff frequency (Fig.10). The appearance of this shooting was due to error signal in the design of filter with the deviation in the value of L due to its quality factor. The Simulated inductance is not stable near the cutoff value. As its value decreases from calculated ones. The roll off ratio output voltage is sharp compared to other configarations.

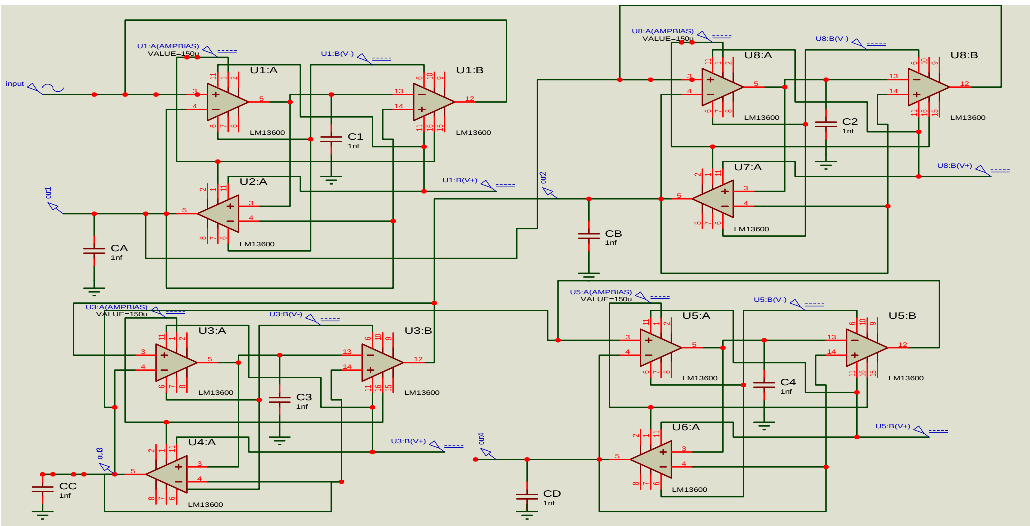

Fig.6. Active LC Ladder using Simulated L of paper (Chitpol Koomgaew *et al.*, 2009)

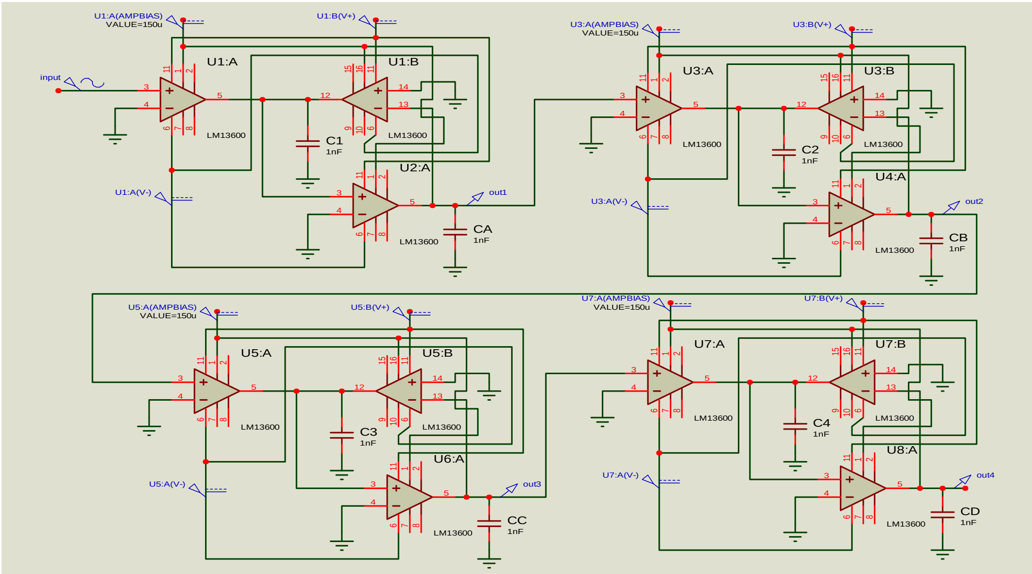

Fig.7. Active LC Ladder using Simulated L of paper (Priyanka Soni *et al.*, 2011)]

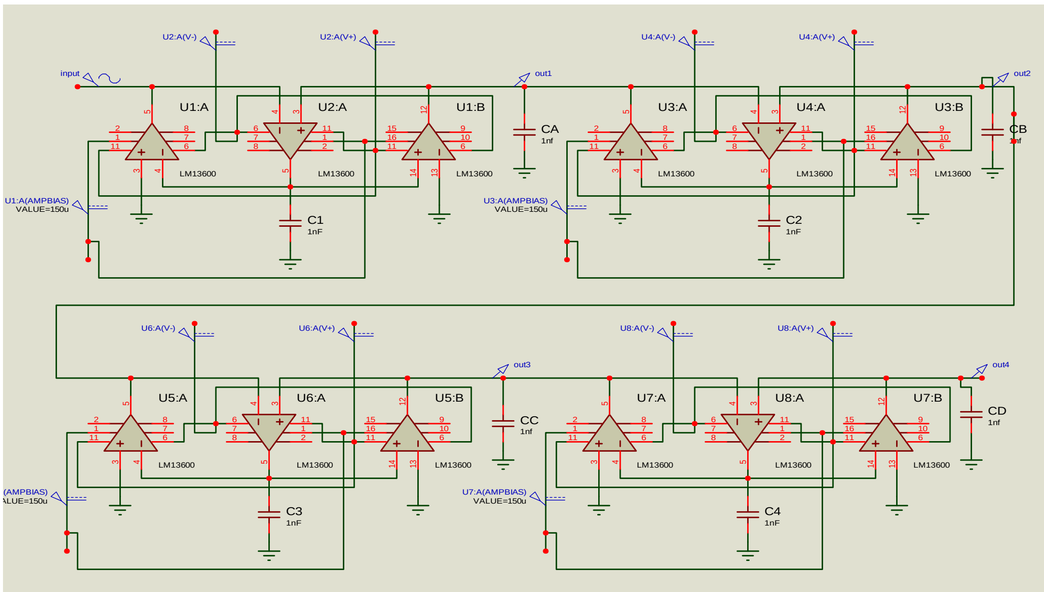

Fig.8. Active LC Ladder using gyrator type of Simulated inductance

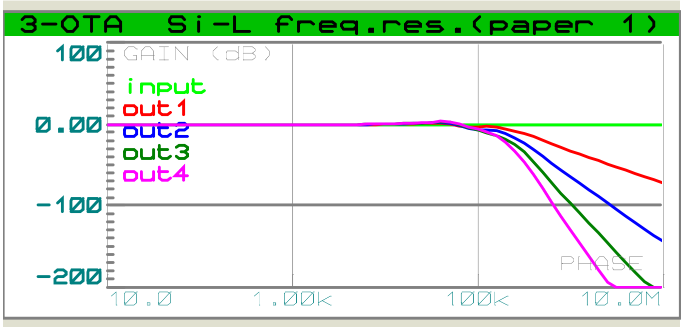

Fig.9.

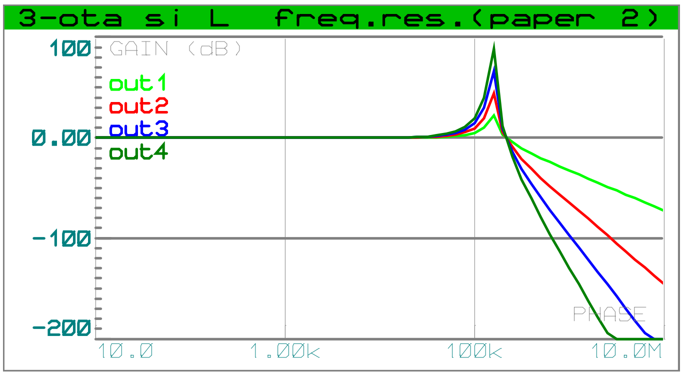

Fig.10.

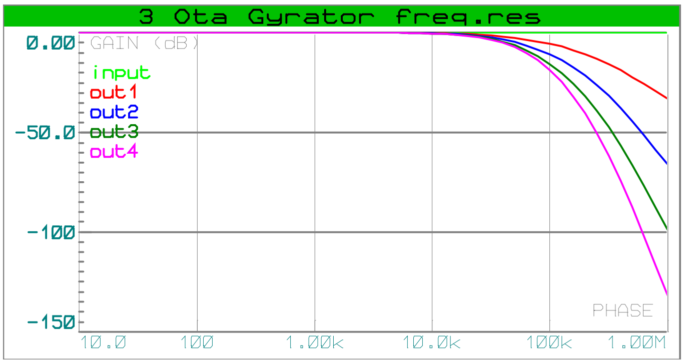

Fig.11.

A close observations on the three characteristics of the filter shown in (Fig.9), (Fig.10) & (Fig.11) shows that 3 OTA Gyrator technique was one of the best method for simulating floating inductor in obtaining approximate to ideal Butterworth filter characteristics. In Successive stages of LC ladder roll off rate increases from- 40dB/decade, -80dB/decade, -120dB/decade & -170dB/decade gives low sensitive Butterworth response.

Conclusion

A comparative study of four stage LC ladder using three different circuits of 3-OTA Simulated inductors a gyrator type circuit is one of the best method for simulating floating inductance which eliminates the noise at the passage of pass band to stop band with the roll off rate at -40dB/decade per stage. Such a characteristic property of the filter is desirable in instrumentation applications.

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