4- OTA GYRATOR AS POSITIVE AND NEGATIVE FLOATING INDUCTANCE SIMULATION WITH OVA & OTA IN LC LOW PASS FILTER

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ABSTRACT: A Simulation of Gyrator as a inductance simulation with Operational transconductance Amplifier(OTA) is advantageous over Operational Voltage amplifier OVA in active filter designing networks with tunable factor of I_B (bias current). The 4-OTA Gyrator as floating inductance simulation gives in good agreement with positive and negative feedback configuration with tuning factor of biasing current. The Studied structure has application in active LC Ladder network in multiplexer and telecommunication instrumentations.

Key words: Gyrator, OVA-Operational Voltage Amplifier, OTA-Operational Transconductance Amplifier, Inductance simulation, CFA –Current Feedback Amplifier

I. INTRODUCTION

The simulation of inductance with Gyrator type circuit is one of the basic important application in active filter design[12,13]. The simulation of inductance using OTA is a considerable interest due its transconductance. As inductance simulation using OVA , CFA(current feedback amplifier) requires number of resistors and capacitors. The utilization OTA ,has an important parameter of transconductance to simulate inductance with tunable property of biasing current (I_{Bias}).

An ideal Gyrator is a linear two port device which couples the current on one port to the voltage on other and viceversa, are related with equations

$V_1 = - r_1 I_2$ and $V_2 = r_2 I_1$

Where r_1 and r_2 are gyrator resistances at first and second port respectively is shown in Fig 1,

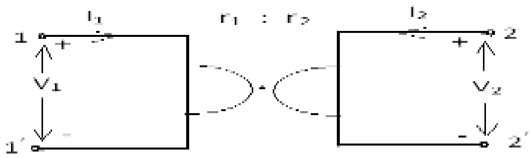

Fig.1 Symbol of Gyrator

At $r_1 = r_2$, the power delivered to the gyrator is zero. Such a device is ideal gyrator. If $r_1 \neq r_2$, the power is made be negative and the device is called active gyrator. Hence the two port parameter of gyrator impedance and admittance are

$$Z = \begin{bmatrix} 0 & -r_1 \\ r_2 & 0 \end{bmatrix} \qquad Y = \begin{bmatrix} 0 & g_2 \\ -g_1 & 0 \end{bmatrix}$$

Where $g_i = \frac{1}{r_i}$. The gyrator is not a reciprocal device. i.e if right hand is short and apply voltage $V_1 = V$ to the left and if left hand side is short and apply same voltage $V_2 = V$ to the right hand side, it gives $I_2 = -I_1$ .This shows gyrator is antireciprocal which stores nor dissipates energy. It is similar to an ideal transformer, being lossess at the two ports.

If the Gyrator is terminated with impedance Z_L . the input impedance is

$$Z_{in} = \frac{V_1}{I_1} = \frac{-r_1 I_2}{V_2/r_2} = r_1 r_2 \left(\frac{-I_2}{V_2}\right) = \frac{K}{Z_L}$$

Where $K = r_1 r_2$ and $Z_L = \left(\frac{-I_2}{V_2}\right)$

Thus gyrator can be considered as an impedance inverter. If the terminated load is a capacitor i.e. $Z_L = 1/SC$, then $Z_{in} = Sr^2C$ at $r_1 = r_2 = r$. Hence capacitance terminated gyrator has the value of inductance, $L = r^2C$ shown in Fig 2.

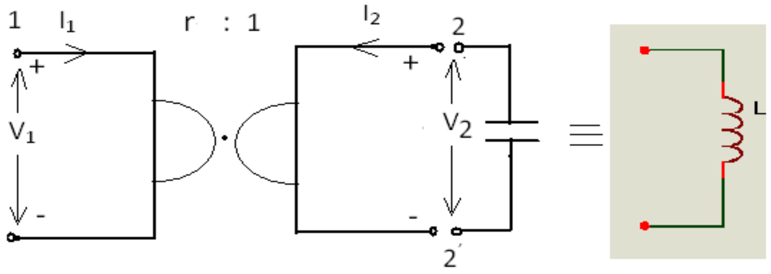

Fig. 2. Simulation of grounded inductance (L)

This two port device characterized by a single parameter r is called the pgyration resistance. OVA is a device whose output voltage is controlled by input voltage. The Antoniou gyrator shown in below fig 3. is consists of two OVA with number of impedances. The input impedance is $Z_{11} = \frac{V_1}{I_1} = \frac{Z_1 Z_3 Z_5}{Z_2 Z_4}$ It acts as inductance simulation circuit when Z_2 or $Z_4 = 1/SC$ and all other impedances are resistors, in which Z_5 acts as load resistor. Hence two port gyrator network is realized as Generalized Impedance Converter (GIC), when either of the port is loaded converted as impedance of inductance. Thus impedance converter is $Z_{11} = S L_0$, at $R_i = \frac{1}{g_i}$, $L_0 = \frac{Cg_2}{g_1 g_3 g_5}$ or $\frac{Cg_4}{g_1 g_3 g_5}$, $L_0 = \frac{C}{g_m^2}$ gives grounded inductance simulator .The floating inductance simulator with OVA requires 4-OVA and number of resistors.

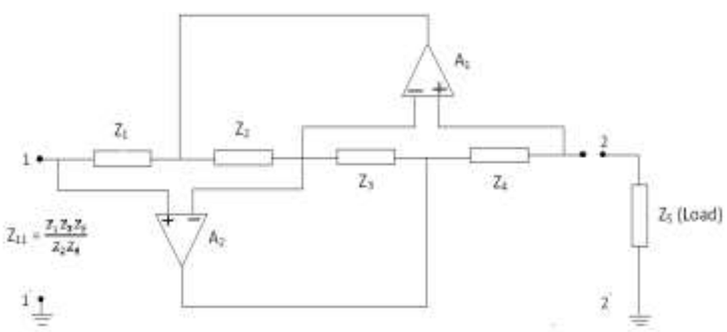

Fig. 3 Antoniou Gyrator

The floating inductance simulated with Operational Transconductance Amplifier. it is a device whose input voltage controls the output current. Ideal OTA has $Z_{in} = \infty$, $Z_{out} = \infty$,Inverting input current is equal to noninverting input current. It Contains the feature of linear controlled with tunable property of biasing current. The Fig. 4 shows circuit symbol of OTA. The Voltage controlled current source is mathematically expressed as, $I_{out} = g_m (V_A - V_B)$ where $g_m = (I_{bias}/2V_T)$ and $V_T = \frac{T}{11600} = 26\text{mV}$ at 28^O C of room temperature, is the thermal voltage.

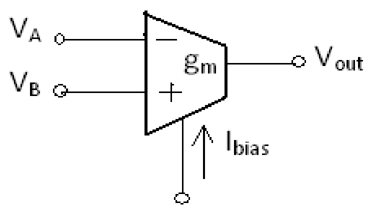

Fig.3 Symbol of OTA

II. CIRCUIT DISCRIPTION

The floating inductance simulator of gyrator type using 4 OTA is shown in fig 4.The voltage across active floating inductance is

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

hence the output currents across OTA_1 & OTA_3 are

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

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

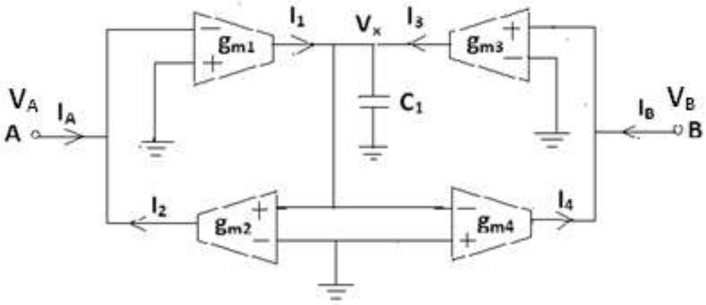

Fig 4.4-OTA floating inductance simulator

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

$$V_x = \frac{(I_1+I_3)}{SC_1} \quad (4)$$

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

$$I_2 = g_{m2} V_x \quad (5)$$

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

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

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

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.[1-6]

III EXPERIMENTAL RESULTS AND DISCUSSION

Experimentally Using LM 13600 OTA a simple single stage second order low pass filter of Fig. 5 is designed. [7-10] The bias current is varied from 0.1µA to 1mA that is of 4 decades. At $C_1 = C_A = C = 1$nf, the cut off frequency is $f_o = 1/2\pi\sqrt{LC}$ can be varying with the bias current. The simulated floating inductor with 4-OTA gyrator is replaced in passive LC low pass filter. The simulated L is taken with output positive feedback and negative feedback circuit. The positive feedback frequency response has 20 dB ripple at cutoff frequencies is shown in Fig.7. The simulated inductance values from frequency response graph are matches with theoretical values. This is shown in Table 1.The negative feedback circuit is shown in Fig.7 has the nature of frequency response shows no ripple, but there is slight variation in cutoff frequency ,that it is matches with -6dB frequency instead of -3dB. Due to negative feedback the ripple is reduced. The experimental results is given in Table 2 . Experimentally work is verified through Protuse professional 7 Software. The 4-ota gyrator can be used to simulate inductance 0.68µH to 2.712 H with respect to the biasing current of 2mA to 1µA.

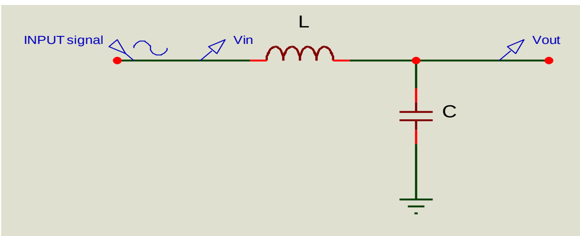

Fig.5 LC low pass filter

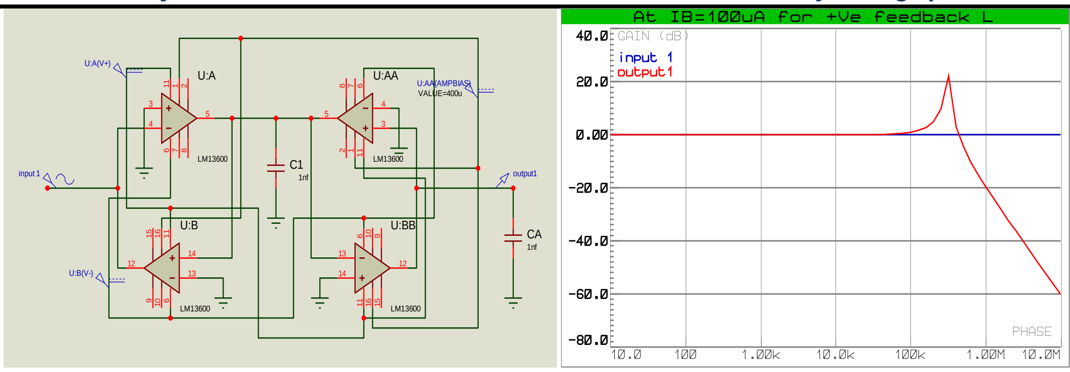

Fig. 6 4-OTA Gyrator with +Ve Feedback Simulated L & its Freq. Response graph

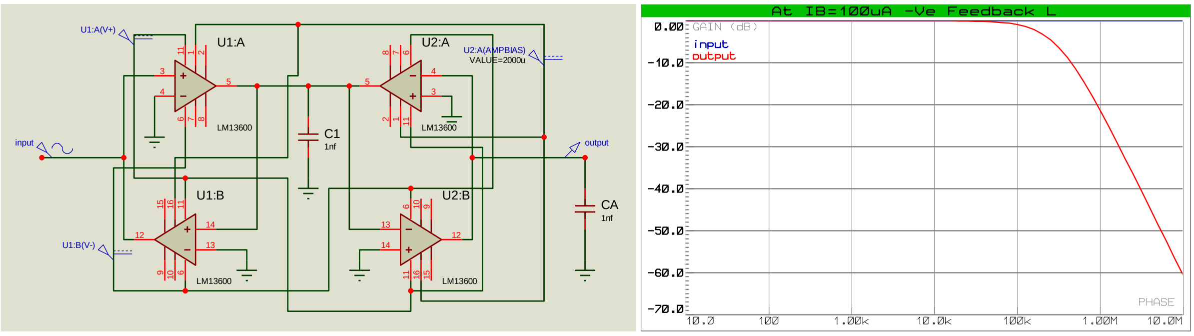

Fig. 7 4-OTA Gyrator with -Ve Feedback Simulated L & Frequency Response graph

Table 1

For +Ve Feedback floating inductance gyrator, At C_1 = C_A = 1nf					
I_B (μA)	L(Th) $\frac{C}{g_m^2} = \frac{C}{(19.2 I_B)^2}$ (H)	Theoretical $f_0 = \frac{1}{2\pi\sqrt{LC}}$ (Hz)	Software results		
			Max.Gain Freq.f_0(Hz)	Max.Gain (dB)	L (H)
1	2.712	3.0 K	3.12 K	22.2	2.6.01
5	108.4 m	15.2 K	15.7 K	21.8	101.4 m
10	27.1 m	30.0 K	31.4 K	22.8	25.3 m
50	1.084 m	152.7 K	152.0 K	21.8	1.082 m
100	271.0 μ	305.0 K	315.0 K	22.0	251.9 μ
500	10.8 μ	1.52 M	1.57 M	17.9	10.14 μ
1000	2.71 μ	3.05 M	3.11 M	15.2	2.58 μ
2000	0.678 μ	6.1 M	5.6 M	13.6	0.79 μ

Table 2

For –Ve Feedback floating inductor Gyrator, At C_1 = C_A = 1nf				
I_B (µA)	L(Th) $\frac{C}{g_m^2} = \frac{C}{(19.2 I_B)^2}$ (H)	Th $f_0 = \frac{1}{2\pi\sqrt{LC}}$ (Hz)	Software results	
			-3 dB freq. f_0 (Hz)	-6dB freq. (Hz)
1	2.712	3.0 K	1.95 K	3.04 K
5	108.4 m	15.2 K	9.85 K	15.3 K
10	27.1 m	30.0 K	19.6 K	30.4 k
50	1.084 m	152.7 K	97.9 K	153.0 K
100	271.0 µ	305.0 K	196.0 K	304.0 k
500	10.8 µ	1.52 M	962.0 K	1.5 M
1000	2.71 µ	3.05 M	1.87 M	2.91 M
2000	0.678 µ	6.1 M	3.60 M	5.61 M

CONCLUSION: The Gyrator is one of the important two-port network to simulate the inductance. Using OVA simulated floating L requires more components to simulate the floating inductance. The 4 OTA simulated floating inductance of gyrator type has easily tunable with biasing current to vary the required value of simulated inductance. The circuit with positive feedback Lowpass filter has ripple at cutoff frequency and it is matches with theatrical values at -3 dB frequencies and the circuit with negative feedback low pass filter reduces the ripple at cutoff frequency with shifting of -3dB frequency to -6dB. So the 4-ota gyrator can be used to simulate inductance 0.68µH to 2.712 H with respect to the biasing current of 2mA to 1µA respectively. The floating inductance has application in instrumentations ,telecommunication networks.

REFERENCES:

[1] Ivan S. Uzunov, Theoretical model of ungrounded Inductance realized with two Gyrators, *IEEE Transactions on circuits and circuits and systems-II: Vol.55,NO.10, oct-2008..*

[2] Priyanka soni, Prof.B.P. Singh, Monika Bhardwaj, Design of OTA based Floating Inductor, *IEEE 978-1-4244-9190-2/2011.*

[3] Neha Gupta, Meenakshi Suthar, Sapna Singh , Priyanka soni, Active filter design using two OTA based floating inductance simulator. *International journal of VLSI & signal processing Applications, Vol.2, issue 1,Feb 2012 (47-50),ISSN 2231-3133.*

[4] Wandee petch maneelumka, Simple floating inductance simulators using OTA's, *International instrumentation and Measurement , 978-1-4244-3353-7/2009*

[5] Kittisak Longsom boon, Wandee petchmaneelumka, Thepjit Cheypoca &Vanchai Riewruja, OTA based electronically variable floating inductance simulator, *11[11] International conference on control, automation and systems, oct -26-29, 2011.*

[6] Chitpol koomgaew,wandee petchmaneelumka & Vanhairiewruja ,OTA based floating inductance simulator *,ICROS –SICE International joint conference ,Aug-18-21,2009.*].

[7] Datasheet- National Semiconductor corporation 2004,LM13600/LM13700 dual operational Transconductance amplifier with idealizing diodes and buffers.

[8] Shahram Minaei, Erkan Yuee, Oguzhan CieeKoglu , Lossless Active Floating Inductance simulator, *IEEE Computer society, International workshop on electronic design,2005.*

[9]. Bhaba Priyo Das, Neville WatSon and Yonghe Liu, 2010, "Simulation of Voltage controlled tunable All pass Filter using LM13600 OTA " International Journal of Electrical and Computer Engineering 5:6

[10]. Prashant K. Mahapatra, Manjeet Singh and Neelesh Kumar,1999, "Realisation of active filters using operational Transconductance Amplifier (OTA), Journal of Instrumentation Soc. Of India 35(1),1-9

[11].Firat KACAR,Hakan KUNTMAN,CFOA – based Lossless and Lossy Inductance simulators, Radio engineering ,Vol.20, No.3,September 2011..

[12]. Hulsemann. " A text Book on Active filter designing"

[13]. Vasudev K. Aatre , june 1997, " A text Book on Network Theory and Filter Design"

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