



## REALIZATION OF GYRATOR CIRCUIT AND ITS APPLICATION TO HIGH ORDER FILTER

Anshita Jain<sup>1</sup>, Dr R. S. Gamad<sup>2</sup>, Mr D.S. Ajnar<sup>3</sup>  
 Department Of Electronics and Instrumentation  
 Shri G.S. Institute of Technology and Science, Indore, M.P.

**Abstract-**The gyrator circuit has been realized in this paper in such a way that it can replace an inductor in the filter circuit. This is accomplished by utilizing a gyrator, which may convert a load capacitance into an inductance. Its use in high pass and band pass filter has also been demonstrated. The realization circuit has been used in higher order filters and it provide a more comprehensive understanding of the situation and its impact on it. Cadence Software and the UMC library (180 nm technology) are used to generate the simulation results for the same. Simulation based results are reported in this paper.

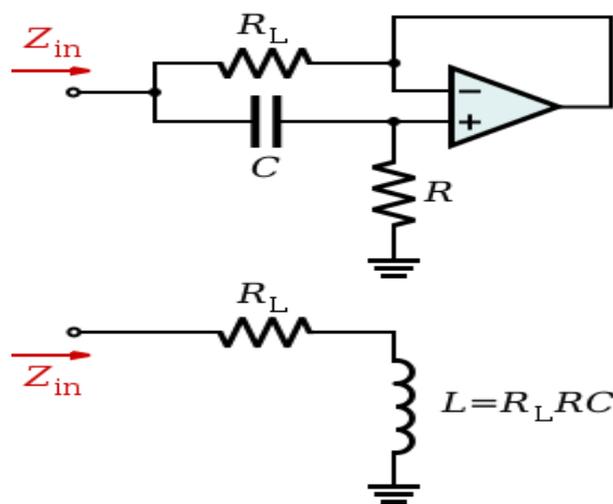
**Keywords-**Gyrators, simulated inductor, power

### I. INTRODUCTION

When used with CMOS technology, inductors require a lot of space. Furthermore, the quality factor of these inductors is low. As a result, off-chip inductors are employed more frequently. So you try to limit it based on your demands, and to test it, stick to circuits that either don't need them or don't require them. Another option is to use circuit techniques to create a faux inductor. Gyrator which uses op-amps and capacitors, are an example of the sort of pseudo inductor. In this paper, we look at how a gyrator element can be used to replace an inductor circuit. We first analyze the gyrator as a two-port circuit, then simulate it with additional filter components to create various filter circuits [2]. After the capacitor, resistor, inductor, and ideal transformer, Bernard D. H. Tellegen proposed the gyrator in 1948 where he introduced gyrator as another element other than the existing elements. The gyrator, unlike the other

elements, is not reciprocal. Gyrators make it possible to network two-port devices in ways that aren't achievable with standard elements. Gyrators, in particular, enable the network realization of circulators and isolators. Gyrators, on the other hand, have no effect on the number of one-port devices that can be implemented. Despite the fact that the gyrator was conceived as a linear element, its use eliminates the need for both the ideal transformer and the capacitor or inductor [1]. As a result, the number of required linear elements is decreased to three.

Gyrator circuits can be built with transistors and op amps using feedback. Tellegen proposed several techniques to construct a real gyrator. A gyrator reverses an electrical component's or network's current-voltage characteristic, which is an essential attribute. The impedance is also reverted in the case of linear elements. Active filters are commonly designed and condensed using this technology [1].



### II. REALIZATION OF INDUCTOR

## USING GYRATOR CIRCUIT

The circuit with passive parts should be linked to an operational amplifier with feedback, which is responsible for buffering the voltage across the resistor and applying it back to the input through, in a way that it acts like an inductance in series with the resistance. This creates the inductor effect, with the current lagging at a 90-degree angle. The simulating gyrator circuit is as shown in fig[1],

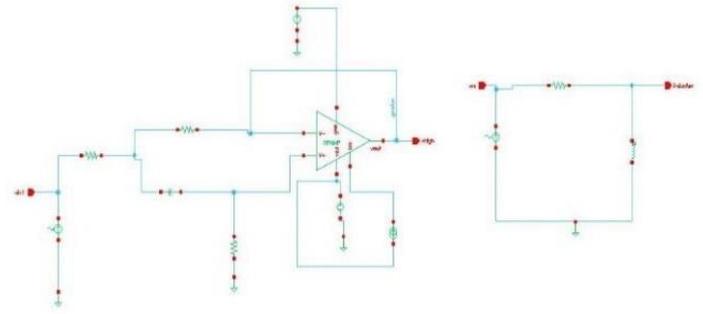


Fig.1 Simulating Gyrator circuit

Impedance Calculation: Consider a virtual ground concept for the above op-amp with input voltage ( $V_{in}$ ) and current through it is ( $I_{in}$ ). The passive element in the circuits is  $R_L$ ,  $C$ ,  $R$  and current through them is  $I_1$ ,  $I_2$  and  $I_3$  respectively. Because of virtual ground concept the voltage across the non-inverting and inverting terminals will be same as [1]

$$V^+ = V^- = V_1 \quad (1)$$

Applying KCL to the circuit in fig [1],

$$I_{in} = I_1 + I_2 \quad (2)$$

$$I_1 = \frac{(V_{in} - V^-)}{R_L} = \frac{(V_{in} - V_1)}{R_L} \quad (3)$$

$$I_2 = \frac{(V_{in} - V^+)}{X_c} = \frac{(V_{in} - V_1)}{X_L} \quad (4)$$

$$I_2 = I_3 \quad (5)$$

Substitute for  $I_2$  &  $I_3$

$$\frac{(V_{in} - V^+)}{X_c} = \frac{V_1}{R} \quad (6)$$

Simplifying equation (6) using equation (4),

$$V_1 = \frac{V_{in}}{X_c \left( \frac{1}{R_c} + \frac{1}{X_c} \right)} \quad (7)$$

Substitute equation (3) & (4) in equation (2),

$$I_{in} = \frac{(V_{in} - V_1)}{R_L} + \frac{(V_{in} - V_1)}{X_L} \quad (8)$$

$$I_{in} = (V_{in} - V_1) \left( \frac{1}{R_L} + \frac{1}{X_c} \right)$$

$$I_{in} = \left( V_{in} - \frac{V_{in}}{X_c \left( \frac{1}{R_c} + \frac{1}{X_c} \right)} \right) \left( \frac{1}{R_L} + \frac{1}{X_c} \right)$$

$$I_{in} = V_{in} \left( 1 - \frac{1}{X_c \left( \frac{1}{R_c} + \frac{1}{X_c} \right)} \right) \left( \frac{1}{R_L} + \frac{1}{X_c} \right)$$

$$\frac{I_{in}}{V_{in}} = \left( 1 - \frac{1}{X_c \left( \frac{1}{R_c} + \frac{1}{X_c} \right)} \right) \left( \frac{1}{R_L} + \frac{1}{X_c} \right)$$

Simplifying further we get,

$$\frac{I_{in}}{V_{in}} = \frac{1 + j\omega C R_L}{R_L + j\omega C R R_L} \left( X_c = \frac{1}{j\omega C} \right)$$

$$Z_{in} = \frac{V_{in}}{I_{in}} = \frac{R_L + j\omega C R R_L}{1 + j\omega C R R_L} \quad (9)$$

$$\therefore Z_{in} = \frac{V_{in}}{I_{in}} = \frac{R_L + j\omega C R R_L}{1 + j\omega C R L} \quad (10)$$

Multiply equation by  $\left( R + \frac{1}{j\omega C} \right)$  to both numerator and denominator. Hence, we get,

$$Z_{in} = \left( \frac{R_L + j\omega C R R_L}{1 + j\omega C R L} \right) \left( R + \frac{1}{j\omega C} \right)$$

$$Z_{in} = \frac{(R_L + j\omega C R R_L) \left( R + \frac{1}{j\omega C} \right)}{(R_L + j\omega C R R_L) + \left( R + \frac{1}{j\omega C} \right)}$$

$$\therefore Z_{in} = \left( R + \frac{1}{j\omega C} \right) \parallel (R_L + j\omega C R R_L) \quad \dots (11)$$

$$\text{Therefore } L = C R R_L \quad (12)$$

The circuit effectively invert the capacitive reactance into inductive reactance. Which is proved by the above expression.

## III. PROPOSED FILTERS REALIZATION

### WITH CONCEPT

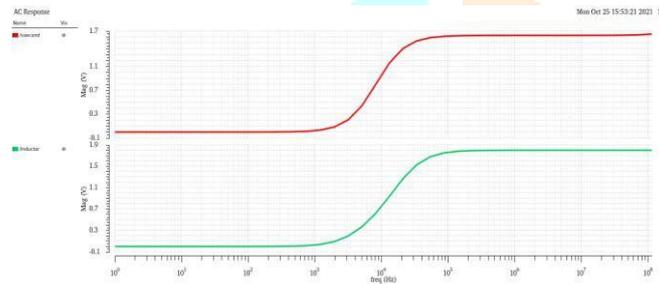
#### A. Realization of High Pass Filter

A high pass RL filter is a filter composed of a resistor and inductor which passes through high-frequency signals. In a circuit, current always follows the route of least resistance. Because inductors have such a high resistance to high-

frequency signals, high-frequency current signals will not pass through the inductor in this circuit. They'll take a different route and pass through a section of the circuit with lower resistance. Instead of passing via the inductor and down to ground, high-frequency signals pass through the output in this circuit. This is why this circuit is classified as a high-pass filter. Little-frequency, or DC, signals, on the other hand, will pass through the inductor because inductors have relatively low resistance. As a result, low-frequency current will follow the route of least resistance.

Fig.2 Replacement of inductor by gyrator circuit in High Pass Filter

Problem: Consider value  $R=10K\Omega$  and  $L=200mH$  for RL network then cut-off frequency is  $f_c=7.95KHz$ . But in HPF which has gyrator, values for components  $R=R_1=10K\Omega$ ,  $R_2=20K\Omega$



&  $C_1=1nF$  Where  $L$  is calculated by using gyrator inductor equation (12).

Fig.3 AC response of high pass filter (a)gyrator circuit (b)inductor

Simulation result of AC response and phase & magnitude is shown in figure 4.

Fig.4 Magnitude and Phase response (a)gyrator circuit (b)inductor

From below figure we see that the practical cut-off frequency is calculated, values are  $f_c = 7.35KHz$  &  $f_c=8.05KHz$  for Gyrator HPF and equivalent RL HPF respectively.

### B. Second Order High Pass Filter

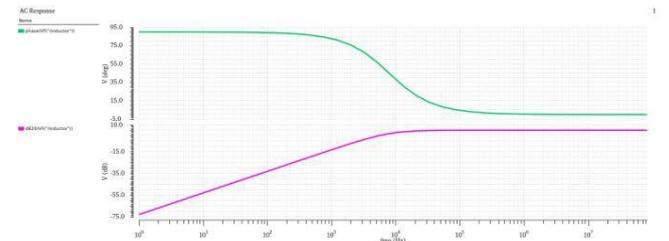
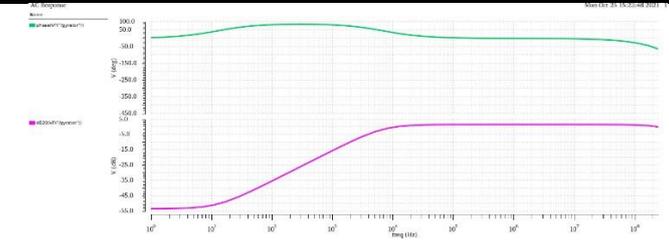
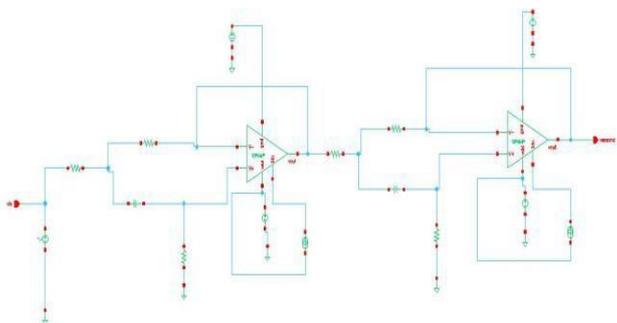
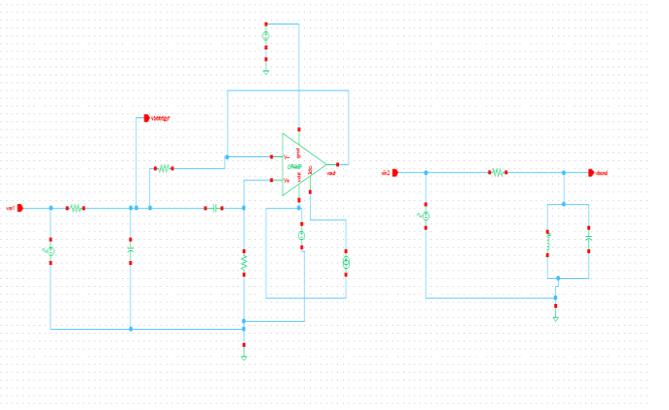
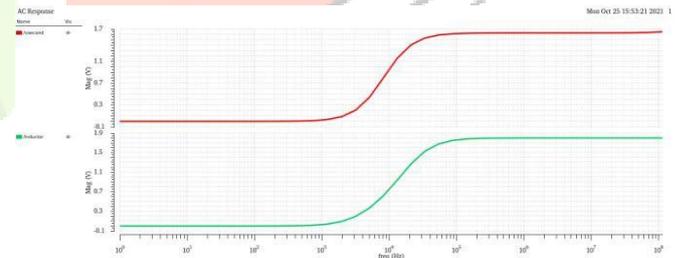


Fig.5 Second order high pass filter using gyrator



Circuit

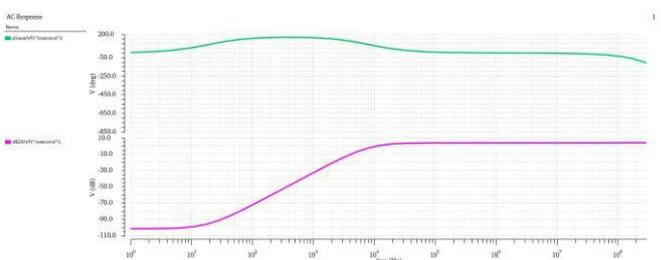
Problem: Consider the same high pass filter used



earlier and cascade it with the same configuration to generate a filter of highest(second) order and then do the required calculations. The AC response for the second order configuration is shown below.

Fig.6 AC response of high second order pass filter

(a) gyrator circuit (b)inductor



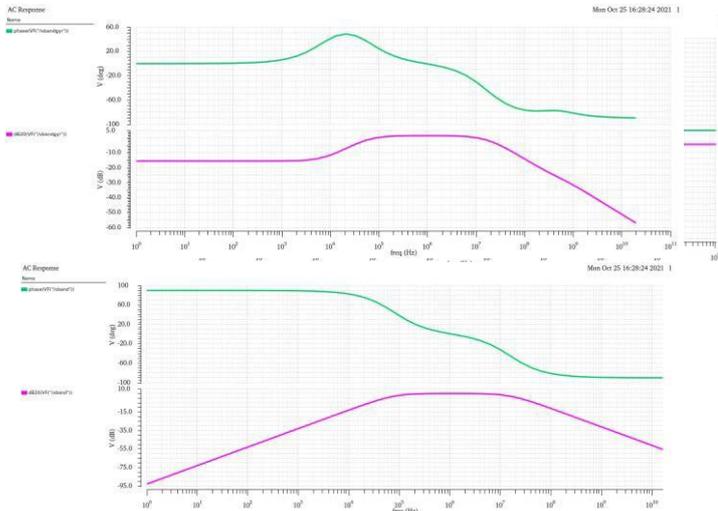
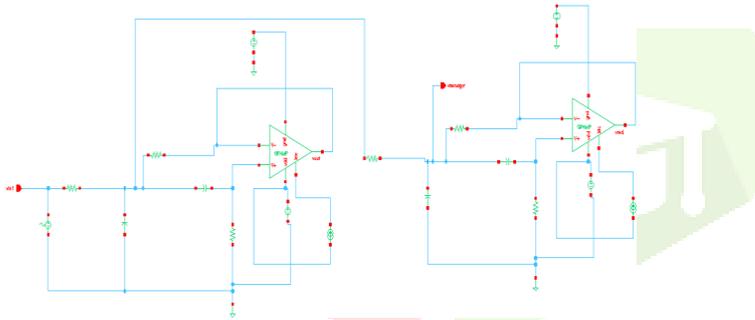


Fig.7 Magnitude and Phase response (a)gyrator circuit (b)inductor

From above figure it can be seen that the practical cut-off frequency is calculated, values are  $f_c=17.64$  KHz &  $f_c=21.38$ KHz for gyrator second order HPF and equivalent RL second order HPF respectively.

### C. Bandpass Filter

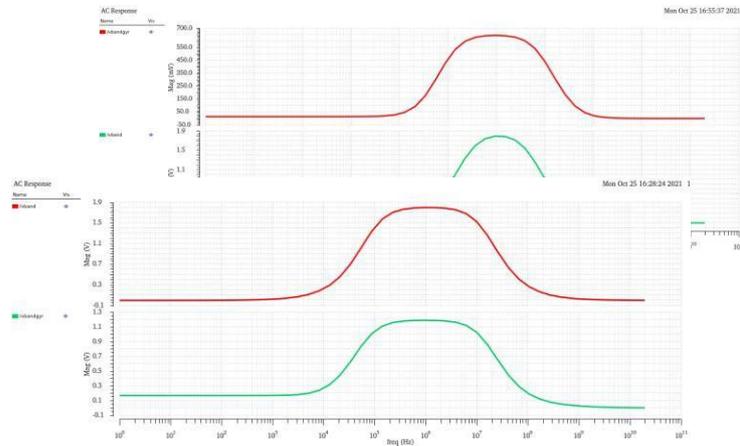
A bandpass filter circuit/device is used to allow only a pre-defined set of frequencies to pass through it. It will filter out all frequencies that



are less than or equal to the provided value. The ActiveBand Pass Filter is a frequency selective filter circuit used in electronic systems to separate a signal at one specific frequency, or a range of signals that lie within a defined "band," from signals at all other frequencies. This band or frequency range is established between two cut-off or corner frequency points designated "lower frequency" (L) and "higher frequency" (H), with any signals outside of these two points attenuated.

Fig.8 Replacement of inductor by gyrator circuit in Bandpass filter

Problem: Consider value  $R = 10K\Omega$ ,  $C=1pf$ ,  $L = 20mH$  Then  $f_c=1.12MHz$ . but in BPF which has a gyrator, values for circuit are  $R=10K\Omega$ ,  $C=1pF$ ,  $R_1=1K\Omega$ ,  $C_1=1nF$ ,  $r=20K\Omega$ . According to equation  $L= R_1C_1r = 20mH$  then the bandwidth for



BPF RLC circuit and BPF gyrator circuit are 15.87MHz and 17.10MHz respectively.

Fig.9 AC response of bandpass filter (a)inductor(b)gyrator circuit

Simulation result of AC response and the phase

& Magnitude shown in figure 10

Fig.10 Magnitude and Phase response(a)gyratorcircuit (b)inductor

### D. HIGHER ORDER BANDPASS FILTER

Consider using the same band pass filter as before and cascading it with the same setup to construct a highest(fourth) order filter, then performing the necessary calculations. Simulation result of AC response and phase & magnitude are shown in figure 12.

Fig.11 Higher order band pass filter using gyratorcircuit

Fig.12 AC response of Higher order bandpass filter (a) gyrator circuit (b)inductor

From figure below the bandwidth for BPF RLC circuit and BPF gyrator circuit are 6.07MHz and 5.93MHz respectively.

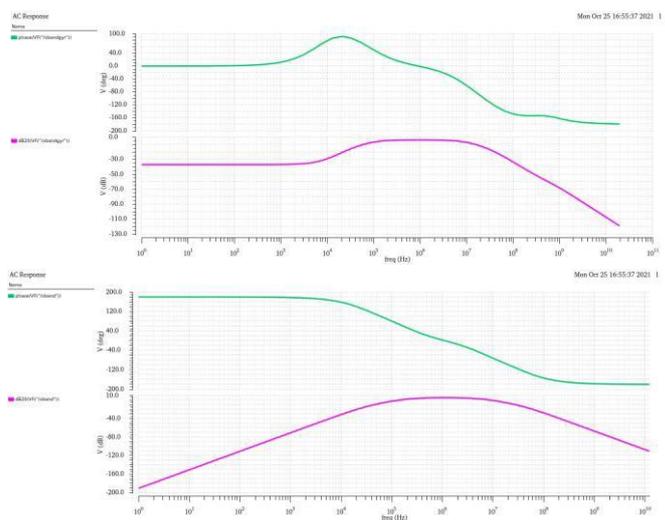


Fig.13 Magnitude and Phase response (a)gyrator circuit (b)inductor

TABLE I  
COMPARISON OF CRITICAL FREQUENCY  
IN BOTH CASES

Frequency (fc)	Inductor as an element	Gyrator circuit In place of inductor
High-pass filter	8.05KHz	7.35KHz
Second-order high pass filter	21.38KHz	17.64KHz
Bandpass filter	1.13MHz	0.97MHz
Higher-order bandpass filter	1.15MHz	1.14MHz

#### IV. CONCLUSIONS

In this paper, by using the corresponding pseudo inductance value of the gyrator circuit as a two-port circuit, high-pass and bandpass filter circuits are employed with inductance as one of the circuit elements and simulated them in cadence simulation environment as a proof of concept. In order to gain additional insight, their higher order configurations were also examined at the same time. The results reveal that only if phase variations can be controlled a gyrator circuit can be used to replace inductance. For the comparative circuits, the DC power computation remains the same. However, only grounded inductors produce satisfactory results. In CMOS technology, the gyrator circuit concept will replace inductance. Validation of these filters allows for circuit design without an inductor, often known as virtual inductor or simulated inductor.

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