Inductorless Realization of Resonant Filters Using Gyrator Circuits

Chandaka Jahnavi
Department of Electronics and Communication Engineering
Rajiv Gandhi University of Knowledge Technologies, Srikakulam

Abstract

In analog signal processing, resonant filters are frequently employed in applications like audio electronics, instrumentation, and communication systems that demand high frequency selectivity. Although traditional LC-based resonant filters perform exceptionally well, they are severely limited in integrated circuit design, mostly because inductors are large and difficult to fabricate. In order to get around this, active circuits with gyrators are used to accurately model inductors. Gyrator-based designs are very flexible for filter implementation because they allow for tunable inductance. In order to achieve both notch (band-stop) and band-pass characteristics, a gyrator-based resonant filter was created in this work. Theoretical analysis was used to determine the circuit behaviour, which was then verified by realistic simulation using the eSim software.

1 Introduction

One of the most common applications for LC filters is the resonant filter. Resonant filters are frequency-selective circuits that use resonance to significantly boost or emphasize specific frequencies, creating a peaked response at the filter's cutoff frequency. This can be configured to be either a notch (aka band stop) or bandpass filter. Inductors are the bulky in nature and large area if it is implemented in CMOS technology . Moreover, these inductors have poor quality factor. Hence, off chip inductors are used more often. So you try to minimize it according to the needs and to try it we stick to circuits that either don't need them Alternative way is to be realize pseudo inductor by circuit techniques. Gyrator circuits are one of this type of pseudo inductor which uses op-amp and capacitors. In this paper we design resonant filters using gyrator element which substitute the inductor circuit.We simulate gyrator circuit along with other filter components such as resistors and capacitor to realise different types of resonant filter circuits i.e, notch flter and bandpass filter.

2 Purpose of Gyrator Circuits

Engineers new to power electronics often find magnetic components puzzling, especially multiwinding devices and integrated magnetics. Gyrator-capacitor modeling offers an alternative way of understanding such components. a gyrator is an ideal two-port circuit element that reflects an impedance at one port as its reciprocal at the other. In other words, it takes the dual of the impedance - perhaps a better name would be a 'dualizer'. For example, a capacitance at one port is reflected as an inductance at the other

3 Working Principle

Using an operational amplifier, resistors, and capacitors, a gyrator acts like an inductor. The gyrator acts as an inductor in a resonant circuit with a capacitor, creating a series or parallel network.

- In a series resonant circuit, the inductive reactance of the gyrator and the capacitive reactance cancel each other out, which makes the circuit very low impedance. This makes a notch filter, which lets signals at the resonant frequency flow through while blocking others.
- When the simulated inductor and capacitor are in a parallel resonant circuit, they make a high-impedance path at resonance. This is called a band-pass filter, and it lets signals at the resonant frequency through while blocking others.

The inductance presented by the gyrator is given by:

$$L = (R_2 - R_1) \cdot R_1 \cdot C_1 \tag{1}$$

In most cases, $R_2 \gg R_1$, so it is approximated as:

$$L \approx R_2 \cdot R_1 \cdot C_1 \tag{2}$$

Substituting the values $R_2 = 100\,k\Omega$, $R_1 = 100\,\Omega$, and $C_1 = 100\,nF$:

$$L \approx 100 \times 10^3 \cdot 100 \cdot 100 \times 10^{-9} = 1\,H \tag{3}$$

The resonant frequency of the LC network is calculated as:

$$f = \frac{1}{2\pi\sqrt{L \cdot C}} \tag{4}$$

For $L = 1\,H$ and $C = 100\,nF$:

$$f = \frac{1}{2\pi\sqrt{1 \times 100 \times 10^{-9}}} = \frac{1}{2\pi \cdot 0.000316} \approx 503\,Hz \tag{5}$$

4 Proposed System and eSim Realization

The series resonant path is made up of the first gyrator–C network and R4 (10 k). This path has the lowest resistance when it is in resonance. The series resonant leg basically cuts off the signal at the resonant frequency. This is why Output1 has a big drop in signal level (a notch) at f0.

At resonance, the parallel resonant path has the largest impedance. It is made up of R6 (10 k) and the second gyrator–C network. The output node measured as Output2 will have a peak at f0, which is a band-pass reaction.

The design is implemented and validated in eSim as shown in figure 1.

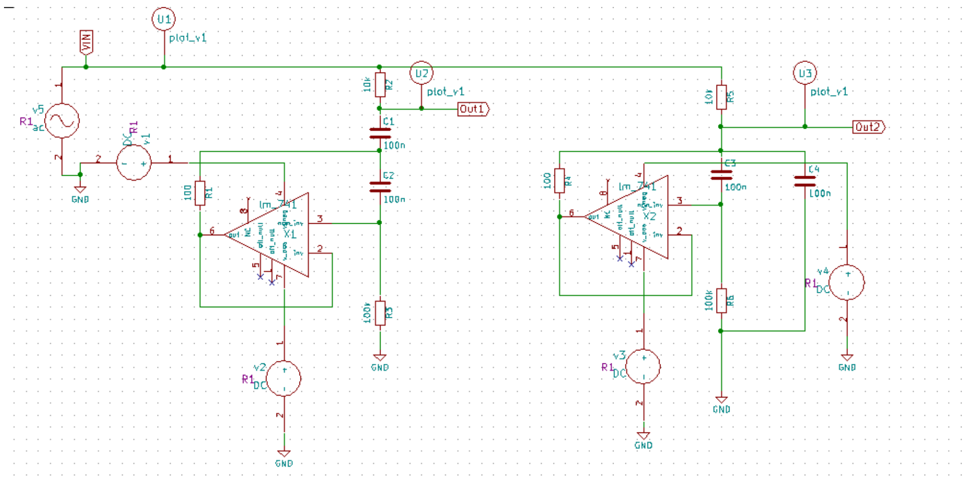

Figure 1: Gyrator Notch & Bandpass Filters in eSim

5 Simulation Results

Figure 2 shows a typical simulated output waveform for notch filter rejecting response at frequecy f0. Figure 3 is the response for bandpass filter allowing at frequency f0.

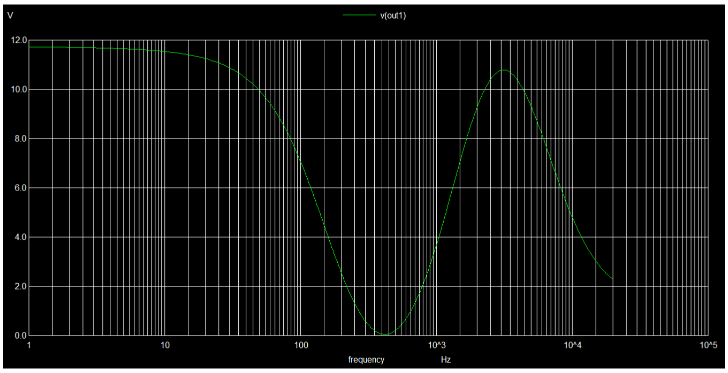

Figure 2: Gyrator based Notch filter response in eSim

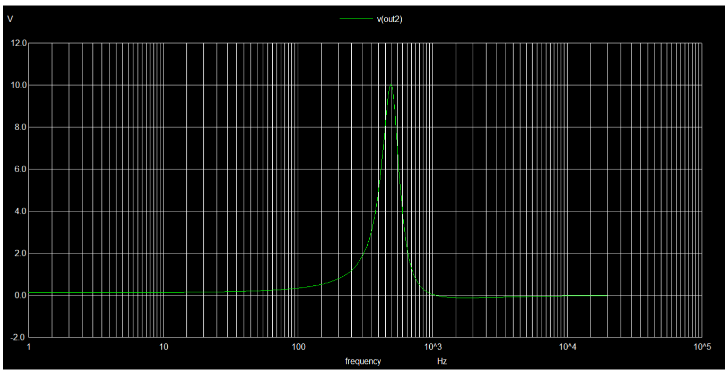

Figure 3: Gyrator based Bandpass filter response in eSim

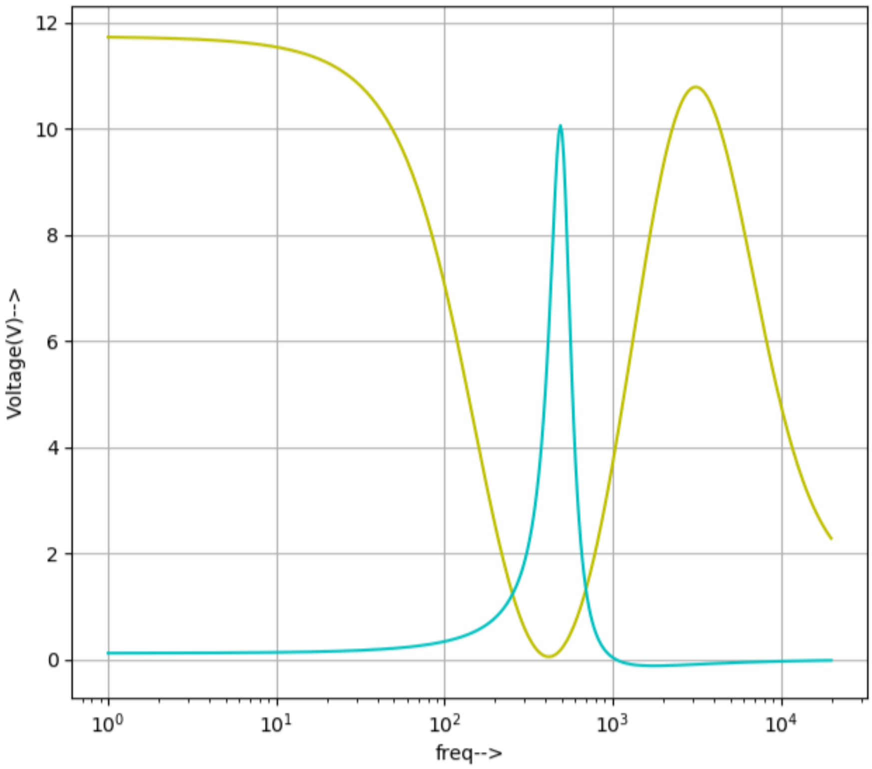

Figure 4: proposed filters response in eSim

6 Conclusion

A gyrator-based resonant filter was designed and simulated using eSim to realize both notch and band-pass responses. By replacing inductors with active gyrator circuits, the design was able to keep the same behaviour as classic LC filters while making them smaller and more adjustable. Simulation confirmed the expected 503 Hz resonance, validating the theoretical analysis and demonstrating the effectiveness of gyrator filters for practical applications.

References

1. Gyrator Resonant Filters
2. An Introduction To Gyrator Theory - Bryan T Morrison
3. Gyrator-Capacitor Modeling:A Better Way of Understanding Magnetic Components