

## Low Frequency Active Tuned Oscillator Using Simulated Inductor

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**Abstract:** The generation of sine wave at low frequency is very tedious because the size of the inductors used in the circuit is very large and bulky. Hence the inductor is replaced with the simulated inductor. This study deals with the generation of sine wave from an active tuned oscillator which consists of the simulated inductor and capacitor. The oscillator makes use of the basic blocks of a band pass filter using the simulated inductor and a diode limiter. This circuit has the advantage of improving the quality of the wave by increasing the Q-factor of the band pass filter. It also decreases the Total Harmonic Distortion (THD) in the sine wave. The simulation is done using the analog simulator software PSPICE and the total harmonic distortion is calculated using MATLAB.

**Keywords:** Active tuned oscillator, operational amplifier, oscillators, Simulated inductor

### INTRODUCTION

The inductors cannot be used at low frequencies because of many disadvantages (Umesh and Sushil, 1989; George, 1970; Ford and Girling, 1966; Suhash, 1974). It includes the following:

- When the number of turns are more, the size and weight of the inductors become large
- The quality factor becomes very low
- Their characteristics become non-ideal
- It is impossible to fabricate in monolithic form and are unsuitable with several of the modern techniques for assembling in modern electronic systems

Since the values of inductors are in the order of Henry at low frequencies for any applications in analog circuits, there is a necessity for the replacement of the inductor by some inductor simulator circuit. One such circuit is Antoniou inductor simulator circuit (Sedra and Smith, 2002) which is obtained from the Generalized Impedance Converter to replace such a large inductor. This simulated inductor circuit consists of op-amps, resistors and capacitors. Such circuit find application in the design of analog filters namely low pass filter, high pass filter, band pass filter etc., which gives the exact frequency response of ideal filters (Susan and Jayalalitha, 2010a). It is also used in Bessel filter circuits which give proper group delay (Susan and Jayalalitha, 2011a). Another application of such simulated inductor using grounded L is the low frequency amplifier and LC oscillator (Susan and Jayalalitha, 2011b).

The replacement is possible only if the inductor is grounded. In case, the inductor is a floating inductor, suitable transformation is used to modify the transfer function which will not affect the performance of the circuit. Such transformation results in a new element called Frequency Dependent Negative Resistor (FDNR) which is used in low pass filter (Susan and Jayalalitha, 2010b).

In this study, the generation of sine wave from the basic LCR resonator using the band pass filter which makes use of simulated inductor and the hard limiter is presented.

### INDUCTOR SIMULATION CIRCUIT

The inductor simulation circuit used is obtained from the basic Generalized Impedance Converter (GIC), which consists of two-operational amplifiers and five impedances consisting of either resistor or capacitor (Sergio, 2007). The impedance for the circuit shown in Fig. 1 is obtained from the basic principle of using nodal equations.

The analysis of the circuit is done with the basic assumptions of the operational amplifier (Donald and Shu-park, 1971) as shown below.

- The op-amps are ideal
- Virtual short circuit appears between the two terminals of op-amp
- The input currents drawn by the terminal of the op-amp are zero

From the paper (Susan and Jayalalitha, 2012) impedance of the circuit is obtained as:

$$Z_{in} = V/I = Z_1 Z_3 Z_5 / Z_2 Z_4 \quad (1)$$

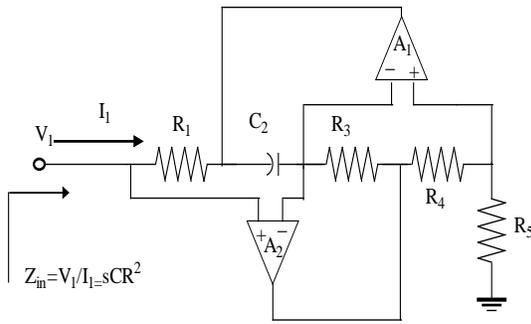


Fig. 1: Antoniou's inductor simulation circuit

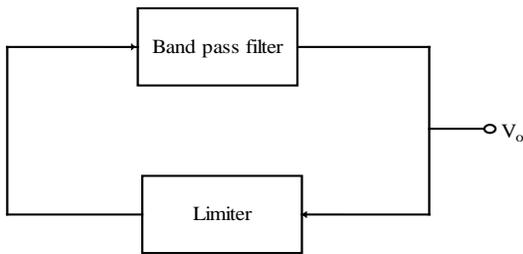


Fig. 2: Basic active tuned oscillator

By choosing  $Z_1 = Z_3 = Z_4 = Z_5 = R$  and  $Z_2 = 1/Cs$  the impedance of the circuit is  $Z_{in} = sCR^2$ . This simulates the inductor whose value is given by  $L = CR^2$

**Basic tuned oscillator:** The block diagram given in the Fig. 2 shows the basic active tuned oscillator. It consists of a high Q band pass filter with a hard limiter connected in positive feedback. The output of the band pass filter is a sine wave whose frequency is the centre frequency,  $f_0$  of the band pass filter. This output is fed back through a limiter which produces a square wave whose levels are determined by the limiting levels of the limiter and whose frequency is  $f_0$ . The square wave is then fed to the band pass filter which filters out the harmonics and provides the spectral purity sinusoidal

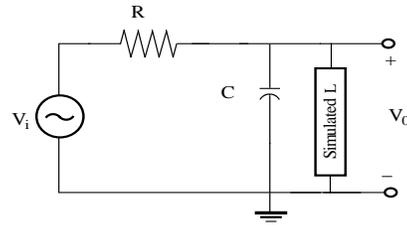


Fig. 3: Block diagram of band pass filter obtained from LCR resonator circuit

wave as the output at the fundamental frequency  $f_0$ . The purity of the sine wave will be the direct function of the selectivity of the band pass filter. The frequency stability of the oscillator will be directly determined by the frequency stability of the band pass filter.

### DESIGN AND RESPONSE OF BAND PASS FILTER USING SIMULATED INDUCTOR

Oscillators like RC phase shift and Wein Bridge can be used for audio frequency. But when tuned oscillators are designed at such low frequencies, the value of inductors becomes large. So there is need for the use of simulated inductor for the oscillator

To design a tuned oscillator for a frequency 100 Hz using the band pass filter, assuming  $C = 16 \text{ nF}$ , gives the value of  $L$  as  $158.5 \text{ H}$ . Such a high value of inductor can be implemented using the simulated inductor. The band pass filter is obtained from the basic circuit of the LCR resonator and is given in the Fig. 3. By properly connecting the input, output and ground nodes of the parallel LCR circuit i.e., in proper mode, it will act as a band pass filter. The transfer function of such filter is given by:

$$T(s) = \frac{s \left( \frac{1}{CR} \right)}{s^2 + s \left( \frac{1}{CR} \right) + \frac{1}{LC}} \quad (2)$$

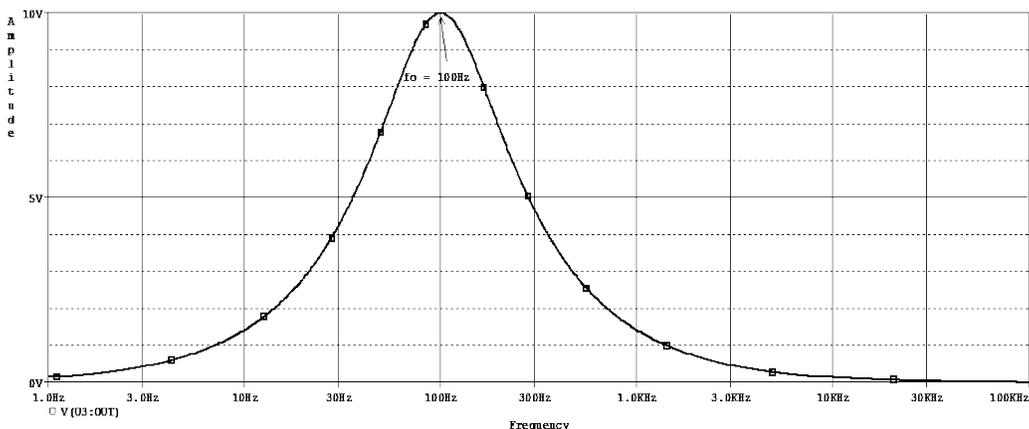


Fig. 4: Frequency response of band pass filter

The frequency response of the band pass filter for the centre frequency  $f_0 = 100\text{Hz}$  is shown in the Fig. 4.

### ACTIVE TUNED OSCILLATOR USING SIMULATED INDUCTOR

The oscillator uses a variation in the band pass filter based on Antoniou inductor simulation circuit as shown in Fig. 5. The resistor  $R_2$  and  $C_4$  are interchanged. The complete oscillator circuit is shown in Fig. 6. The resistor  $R_6$  and the two diodes are used as level limiters.

The circuit is simulated using PSPICE. The sine wave obtained at the point 'V1' is shown in Fig. 7. After getting the sinusoidal wave, the non sinusoidal waveforms can be obtained by using suitable additional

circuits. A square wave is obtained at point 'V3' by using a suitable comparator and a diode limiter consisting of back to back diodes. A triangular wave is obtained by using the integrator with suitable designed values. The square wave and triangle wave obtained at point V3 and V4 are shown in Fig. 8 and 9 respectively.

### EFFECT OF QUALITY FACTOR Q

The Quality of the filter is very important and affects the purity of the sine wave (Orchard and Desmond, 1970). The circuit is simulated for different values of  $R_{1\text{pot}}$  which decides the Q factor. The response of the circuit simulated for  $R_{1\text{pot}} = 200\text{k}\Omega$  and designed for a frequency of 100Hz gives the Total Harmonic Distortion (THD) as 5% which is calculated

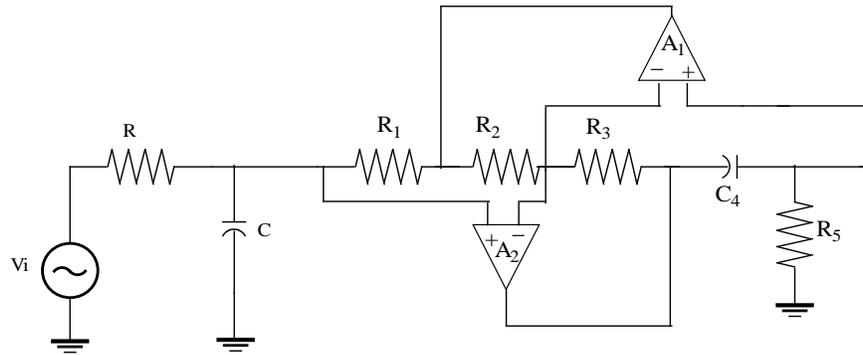


Fig. 5: Band pass filter using simulated L obtained from parallel LCR circuit

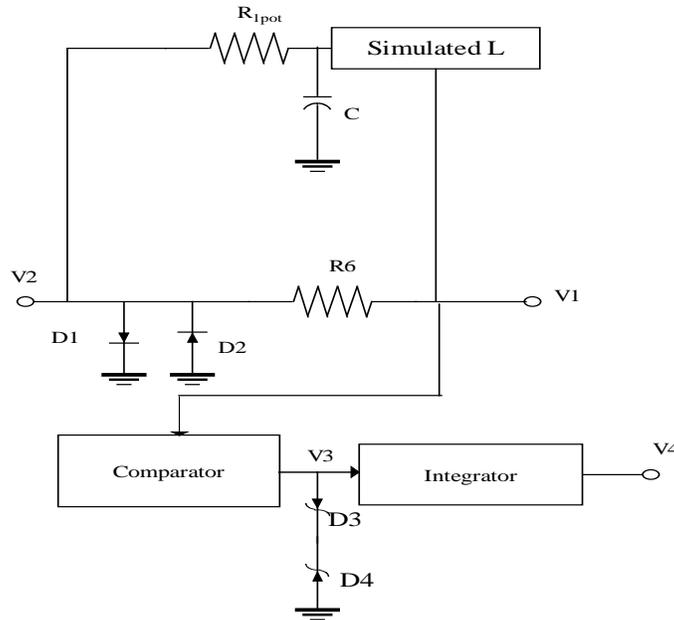


Fig. 6: Active tuned oscillator circuit

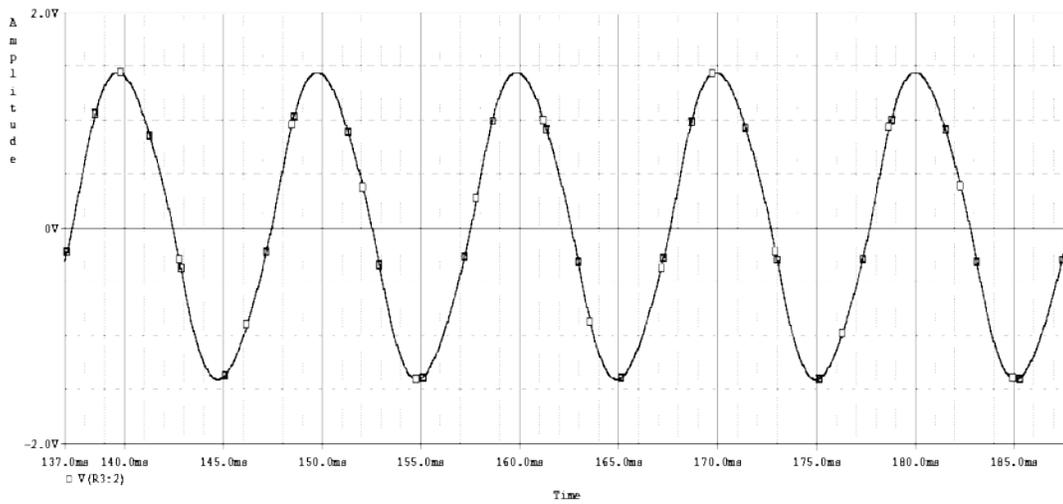


Fig. 7: Output waveform at point V1

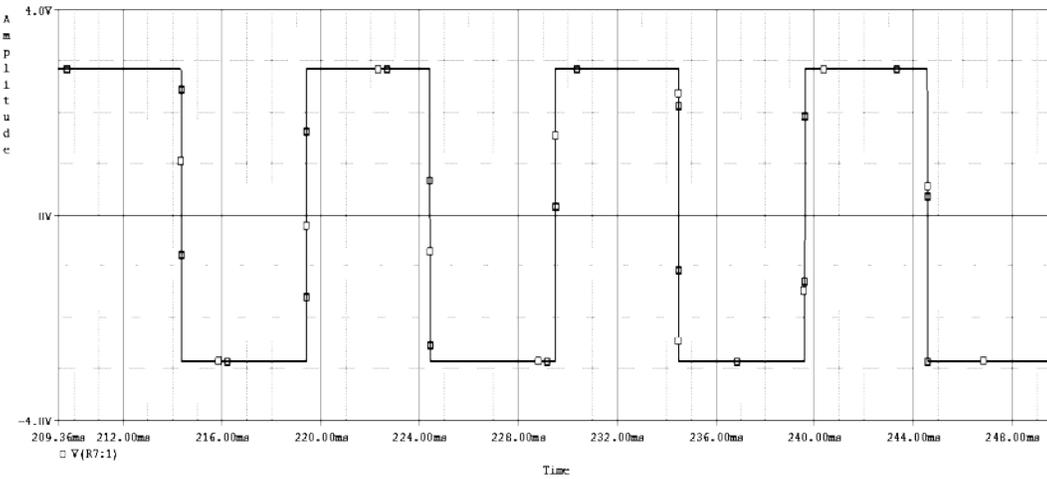


Fig. 8: Output waveform at point V3

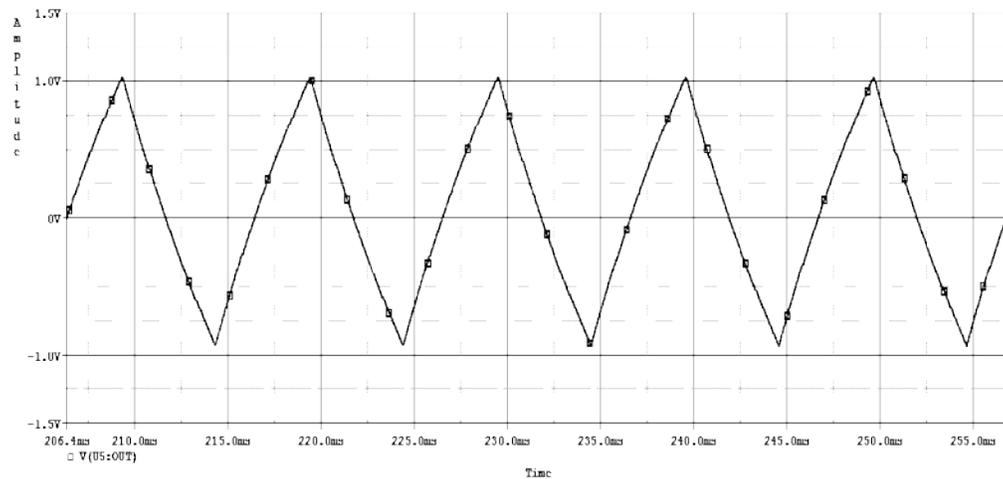


Fig. 9: Output waveform at point V4

Table 1: Experimental readings for the frequency response of band pass filter

Input frequency (Hertz)	Amplitude (Volt)	Input frequency (Hertz)	Amplitude (Volt)
15	0.185	190	0.56
20	0.190	195	0.54
25	0.190	200	0.52
30	0.195	205	0.50
35	0.195	210	0.48
40	0.195	215	0.46
45	0.20	220	0.44
50	0.20	225	0.42
55	0.20	230	0.38
60	0.22	235	0.32
65	0.24	240	0.30
70	0.28	245	0.28
75	0.30	250	0.24
80	0.32	255	0.22
85	0.36	260	0.20
90	0.42	265	0.20
95	0.44	270	0.20
100	0.48	275	0.195
105	0.50	280	0.195
110	0.56	285	0.195
115	0.60	290	0.195
120	0.68	295	0.195
125	0.70	300	0.195
130	0.74	305	0.19
135	0.76	310	0.19
140	0.80	315	0.185
145	0.79	320	0.185
150	0.78	325	0.185
155	0.76	330	0.18
160	0.74	335	0.18
165	0.71	340	0.18
170	0.68	345	0.18
175	0.65	350	0.18
180	0.64	355	0.18
185	0.60		

using MATLAB. For this lowest THD and  $R_{1pot} = 200k\Omega$ , the value of Q is found to be 2 and it is calculated using the equation  $Q = \omega_0 CR_{1pot}$ .

The purity of wave increases with high value of Q thereby decreasing the value of THD.

### EXPERIMENTAL VALIDATION OF SIMULATION

The single tuned oscillator has been designed for the frequency of 140 Hz and verified experimentally with designed values given below:

Tuned Oscillator

$$f_o = 140\text{Hz}, C_4 = C = 0.01\mu\text{F}, L = 129$$

$$R_1 = R_2 = R_3 = R_5 = 113.58k\Omega, R_6 = 1k\Omega$$

$$R_{1pot} = 200k\Omega$$

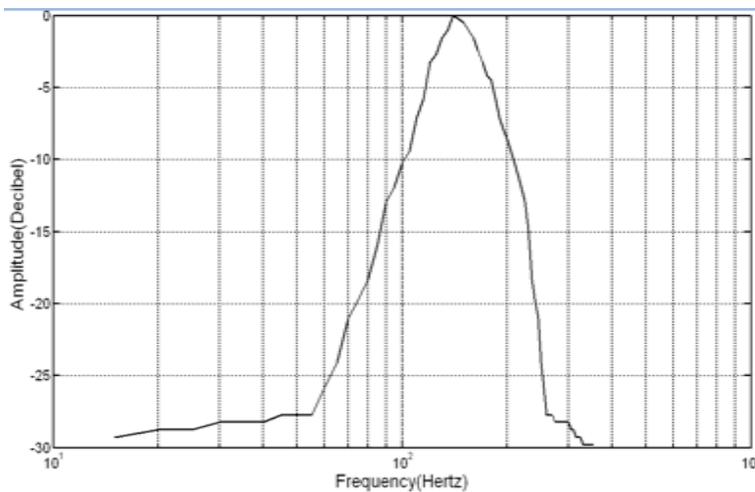
The band pass filter with center frequency of 140 Hz is tested experimentally and the readings are tabulated in Table 1.

The frequency response of the band pass filter is shown in Fig. 10a, whose centre frequency is found to be 140 Hz.

The output of the oscillator taken at point  $V_1$  is shown in Fig. 10b and the other waveforms namely square and triangular waveforms obtained at different points of the circuit are given in the Fig. 10c and d, respectively.

### CONCLUSION

The oscillator is designed for low frequency using simulated inductor for the generation of sine wave, square wave and triangular wave from the basic active tuned circuit. The waveforms obtained by simulation using PSPICE at different points of the oscillator are presented and its validation is also presented experimentally.



(a)

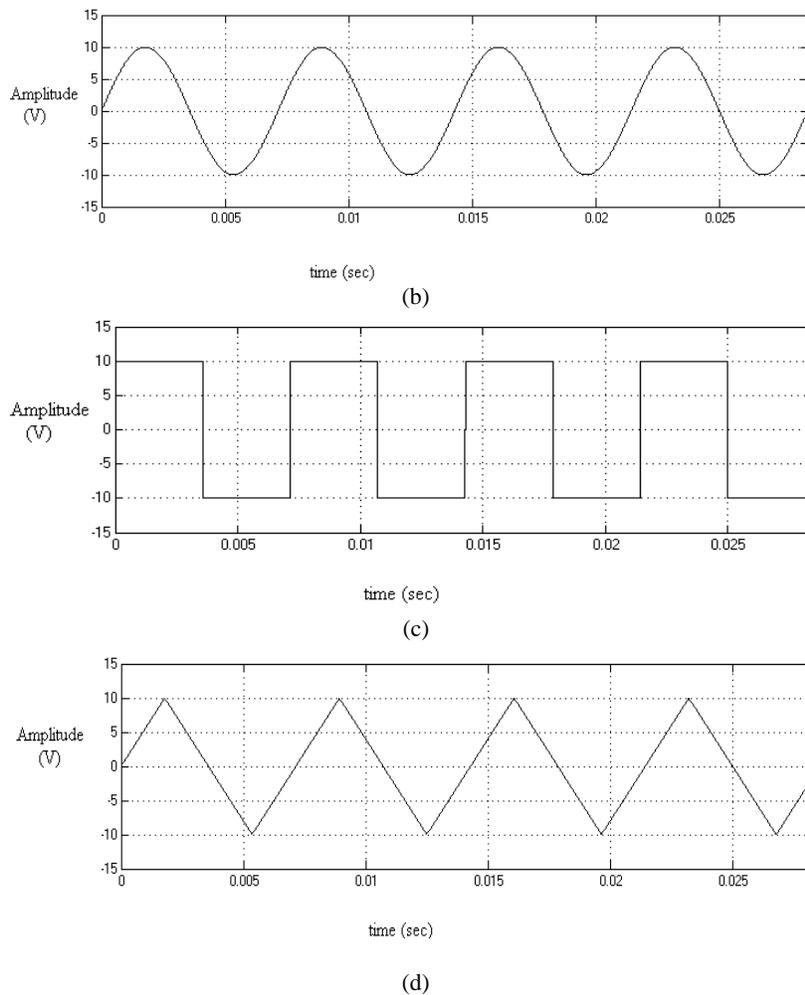


Fig.10: Results obtained at various points experimentally

**APPENDIX**

Design: values

Single tuned Oscillator

$f_0 = 100 \text{ Hz}$ ,  $C = C_2 = 16\text{nF}$ ,  $L = 158.47\text{H}$

$R = 99.523\text{k}\Omega$ ,  $R_6 = 1\text{k}\Omega$

$R_{1\text{pot}} = (50\text{-}250) \text{ k}\Omega$

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