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SPICE-Oriented Steady State Analysis of Oscillator Including Op-Amp

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1. Introduction

Analysis of oscillator circuits is very important for designing communication circuits. In particular, the analysis of an accurate oscillatory frequency is requested. In this article, harmonic balance method, Newton homotopy method and arc-length method are used for solving oscillation circuit composed of RLC circuit and a negative resistance realized by using an op-amp [1].

2. Algorithms

For the Fourier expansion, we assume the electric current of the inductor as follows.

$$i_L(t) = I_0 + \sum_{k=0}^{M}[I_{2k-1}\cos k\omega t + I_{2k}\sin k\omega t]. \quad (1)$$

In this case, we can express the voltage across the inductor as follows.

$$v_L = L\frac{di_L}{dt} = \sum_{i=1}^{k}[-k\omega LI_{2k-1}\sin k\omega t + k\omega LI_{2k}\cos k\omega t]. \quad (2)$$

When we compare (1) and (2), the relation of the voltage and the current are as follows.

$$V_{L,2k} = -\omega LI_{L,2k-1},\ V_{L,2k-1} = \omega LI_{L,2k}. \quad (3)$$

In the case of capacitor, we can obtain similar equations.

Thus, the characteristics of inductors and capacitors are replaced by the simple linear current-controlled voltage sources and voltage-controlled current sources respectively.

Also, the following newton homotopy method is applied.

$$H(v,\rho) = f(v) - (1-\rho)f(v_0) = 0. \quad (4)$$

That is, the STC (solution curve-tracing circuit) leaves from the point $(v_0, 0)$, and the solutions are obtained at the points to satisfy ρ =1.

3. Simulation Result

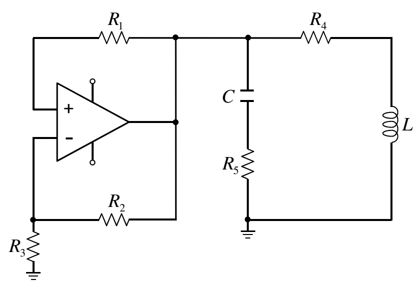

Figure 1: Simulation circuit.
C=10[μF],L=2.7[mH],R_1=1[kΩ],R_2=1[kΩ],
R_3=220[Ω],R_4=0.33[Ω],R_5=0.1[Ω].

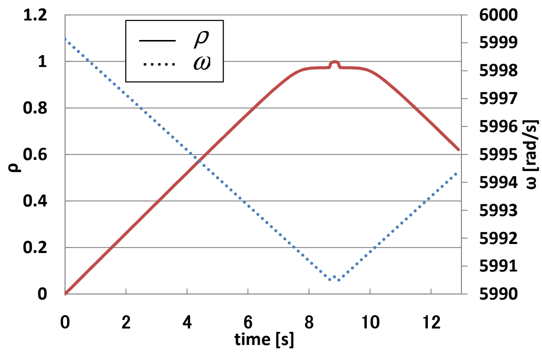

Figure 2: Simulation result.

The circuit model is shown in Fig. 1. We show the simulation result in Fig. 2 which is obtained by using the op-amp to realize the characteristics of negative resistance as shown in Fig. 1. The oscillatory frequency is given when ρ =1 in Fig. 2 and the frequency is 5990.6[rad/s]. The oscillation of an oscillator in steady-state waveform is shown in Fig. 3. The value of ω is 6073[rad/s] and we can say that the oscillator operates around the obtained oscillatory frequency.

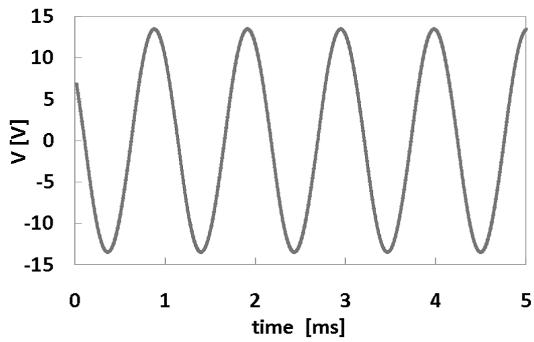

Figure 3: Steady-state waveform.

4. Conclusions

In this study, we analysed an oscillator including an op-amp with SPICE. In the conventional method, we used ABM (analog behavior model) to obtain the characteristics of negative resistor. We replaced negative resistor by op-amp and analysed the circuit. The result shows that we can obtain the oscillatory frequency by using the proposed algorithm.

References

[1] H. Yabe, Y. Yamagami, Y. Nishio and A. Ushida, "Analysis of Oscillator Circuits Having Multiple Oscillations", *Proc. NOLTA'02* vol. 1, pp. 331-334, Oct. 2002.