18-19

Peak Search Algorithm for Frequency Analysis of Nonlinear Circuits

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1. Introduction

The circuit elements in the real world should contain nonlinear characteristics. The SPICE can treat nonlinear elements, however the standard method of SPICE cannot obtain frequency characteristics easily. In this study, we propose a method to analyze nonlinear circuits and to obtain the peaks of the frequency characteristics of the circuit by using the sine-cosine circuits [1] and the ABM function of SPICE. Computer simulation results for a ladder circuit including nonlinear capacitors show that the proposed method can successfully obtain the peak frequencies.

2. Nonlinear Capacitor

The characteristic of the electric current which flows through a capacitor can be indicated as

$$i = dq/dt = (\partial q/\partial v)(dv/dt) \tag{1}$$

From this, the characteristic of a nonlinear capacitor is expressed with an expression using q and v as Eq. (2).

$$v = G(q) = aq + bq^2 + cq^3 \tag{2}$$

We expand i, q and v to Fourier series, and obtain the coefficients of the voltages by using the trapezoidal formula as follows.

$$\begin{aligned} V_{2k-1} &= 1/\pi \int_0^{2\pi} (G(q)\cos k\theta) d\theta \\ &= (1/2K)(G_0 + G_{2K}) + (1/K)(G_1 \cos k\theta_1 \\ &\quad + G_2 \cos k\theta_2 + ... + G_{2K-1} \cos k\theta_{2K-1}) \end{aligned} \tag{3}$$

$$\begin{aligned} V_{2k} &= 1/\pi \int_0^{2\pi} (G_{(q)} \sin k\theta) d\theta \\ &= (1/K)(G_1 \cos k\theta_1 \\ &\quad + G_2 \cos k\theta_2 + ... + G_{2K-1} \cos k\theta_{2K-1}) \end{aligned} \tag{4}$$

3. Simulation Result

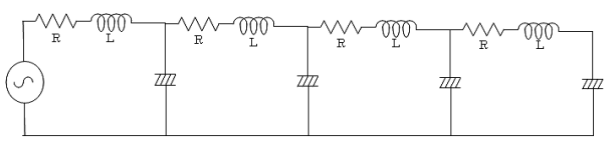


Figure 1: Circuit model. L=0.1[H] R =0.1[Ω] (for low Q) and 0.055[Ω] (for high Q). Capacitor is linear C=1.0[F] or nonlinear $G(q) = q + 0.8q^3$.

The circuit model is shown in Fig. 1. The circuit is forth-order RLC ladder circuit. We consider the cases that the capacitors are linear and nonlinear and the resistors are large (low Q) and small (high Q).

Figure 2 shows the sine-cosine circuit for this circuit model. Figures 3(a) and (b) show the obtained frequency characteristics for the cases of the linear and the nonlinear capacitors, respectively. After obtaining these frequency characteristics, we detect the peak values by using the algorithm combining the differentiator and the nonlinear limiter [2]. The peak values for nonlinear and high Q are obtained as Peak 1 = 0.998, Peak 2 = 0.720, and Peak 3 = 0.361.

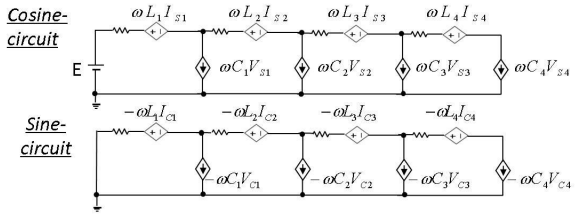
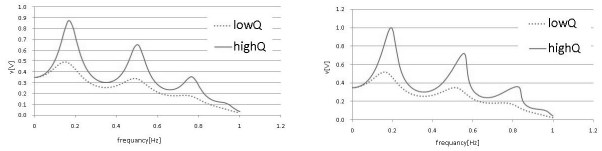


Figure 2: Sine-cosine circuit.



(a) (b)

Figure 3: Frequency characteristics. (a) Case for linear capacitor. (b) Case for nonlinear capacitor.

4. Conclusions

In this study, we have proposed a peak search algorithm for nonlinear circuits. Simulation results showed that the proposed algorithm could detect peak values of the nonlinear ladder circuit.

References

[1] J. Kawata, Y. Taniguchi, M. Oda, Y. Yamagami, Y. Nishio and A. Usida, "Spice-Oriented Frequency-Domain Analysis of Nonlinear Electronic Circuits," IEICE Trans. Fundamentals, vol.E90-A, no.2, pp.406-410, 2007.

[2] A. Kusaka, T. Kinouchi, Y. Yamagami, Y. Nishio and A. Ushida, "A Spice-Oriented Frequency Domain Analysis of Electromagnetic Fields of PCBs," Proc. of NCSP'09, pp.526-529, 2009.