Notch Filter using Uniformly Distributed RC line with Multi-Capacitive Layers

Prakit Tangtisanon, Wasan Tancharern, Nouanchang Panyanouvong, Sorapong Saetia,
Chawalit Benjangkaprasert and Kanok Janchitrapongvej

Research Center for Communications and Information Technology, Faculty of Engineering,
King Mongkut's Institute of Technology Ladkrabang, Bangkok, 10520, THAILAND
Phone: 662-739-2382, Fax: 662-326-4176
Email: kjkanok@kmitl.ac.th

Abstract

The paper describes notch type filter using uniformly distributed RC line (herein after called URC). The proposed circuit configuration consists of one notch type filter using lumped URC with three capacitive layers with bridging capacitor (C_a) parallel connected across it and a positive single amplifier. The structure reduces an amount of circuit complexity and is simple to use for applications. Experimental results of SPICE simulations are carried out and sensitivities of circuit parameters are also investigated.

1. Introduction

It is known that URC circuits have several advantages over lumped RC circuits. For example it structure of distributed RC elements in this film is built using smaller substrate area, less isolation and parasitic problems at high frequency.

We have presented papers on active notch filter using a single capacitive layer URC [1] and double capacitive layers URC [2]. In this paper, the notch filter using three capacitive layers URC are proposed.

The structure of the three capacitive layers URC is shown in Fig. 1-a. The circuit symbol of Fig. 1-a and Fig. 1-b are illustrated in Fig. 1-c. This type of URC consists of 3 layers. It is makes up of a uniform resistive sheet, a uniform dielectric sheet and a conducting sheet where a dielectric sheet is located between resistive sheet and conductive sheet. The capacitance (C) is divided into 3 parts where C_0, C_1 and C_2 deposited on a dielectric sheet.

Analysis of Fig. 1-c as an distributed RC transmission line for one of the bottom conductive plate 5 is grounded.

The admittance parameter [Y_{ij}] of the URC in Fig. 1 is given as follows:

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = X \begin{bmatrix} Y & -1 & -a_1(Y-1) & -a_2(Y-1) \\ -1 & Y & -a_1(Y-1) & -a_2(Y-1) \\ -a_1(Y-1) & -a_1(Y-1) & J & l \\ -a_2(Y-1) & -a_2(Y-1) & l & y \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix} \tag{1}$$

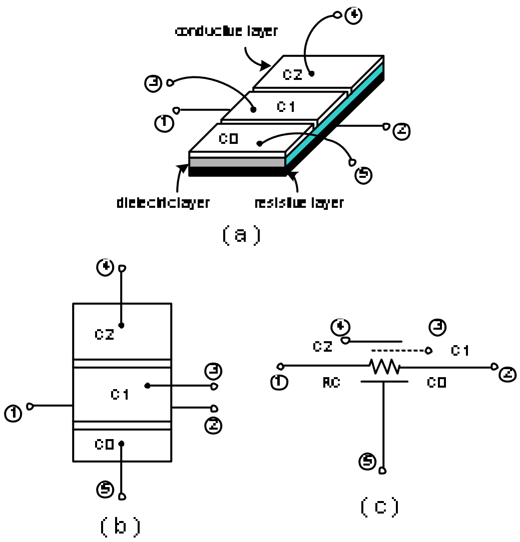

Fig. 1 Structure and circuit symbol of URC with three capacitive layers

where

$$J = a_1\{(1-a_1)P\,sinh\,P + 2a_1(Y-1)\},$$

$$l = a_2\{(1-a_2)P\,sinh\,P + 2a_2(Y-1)\},$$

$$y = a_1 a_2\{2(Y-1) - P\,sinh\,P\},$$

$$X = \frac{P}{R\,sinh\,P},\ Y = cosh\,P,\ P = \sqrt{SRC},$$

$$C_1 = a_1 C,\ C_2 = a_2 C \text{ and } C = C_1 + C_2 + C_3$$

R and C are the values of total resistance and capacitance of the multilayer URC structure. a_1 and a_2 are the ratio of C_1 and C_2 with respect to C. S is the complex frequency.

2. Notch Filter Circuit

Fig. 2 shows the proposed notch filter circuit using one distributed RC elements with three capacitive layers and one lumped element (C_a). The filter realized form Fig. 1-c. Where the edge point 4 contacted at 1, edge point 3 is floating and 5 is grounded. C_a is a bridging capacitance.

The proposed passive notch filter circuit using are distributed RC with three capacitive layer and a bridging capacitor C_a are shown in Fig. 2.

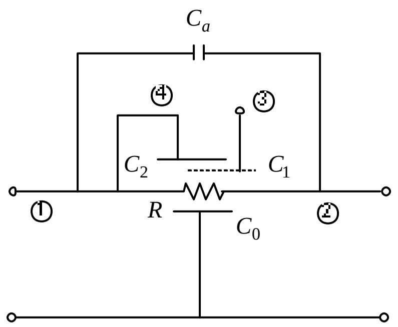

Fig. 2 Passive notch filter circuit

The voltage transfer function $T(p) = V_2/V_1$ of the circuit is given as follows:

$$T(p) = \frac{g + \dfrac{a_1 b \sinh P}{P} + a_2 \cosh P + b\left[1-(a_1+a_2)\right]}{g + \dfrac{a_1 b(\sinh P - P\cosh P)}{P} + b\, l\left[1-(a_1+a_2)\right]} \quad (2)$$

Where

$$g = \{(1-a_1)P\sinh P + 2a_1(\cosh P - 1)\},$$

$$l = \frac{1-a_1}{1-(a_1+a_2)}\cosh P,$$

$$b = \frac{C_t}{C_a},\ a_1 = \frac{C_1}{C_t},\ a_1 = \frac{C_2}{C_t},$$

$$C_t = C_0 + C_1 + C_2,\ P = \sqrt{SRC_t}$$

Fig. 3 shows the proposed active notch filter scheme with a feedback amplifier.

The voltage transfers function of the proposed circuit is given as follows:

$$T(p) = \frac{\left\{g + \dfrac{a_1 b \sinh P}{P} + a_2 \cosh P + b\left[1-(a_1+a_2)\right]\right\}K}{g + \dfrac{a_1 b(\sinh P - P\cosh P)}{P} + bd\left[1-(a_1+a_2)\right]} \quad (3)$$

Where

$$g = \{(1-a_1)P\sinh P + 2a_1(\cosh P - 1)\},$$

$$d = \left\{\left[\frac{1-a_1}{1-(a_1+a_2)} - K\right]\cosh P + K\right\},$$

$$b = \frac{C_t}{C_a},\ a_1 = \frac{C_1}{C_t},\ a_1 = \frac{C_2}{C_t},$$

$$C_t = C_0 + C_1 + C_2,\ P = \sqrt{SRC_t}$$

And K is positive gain.

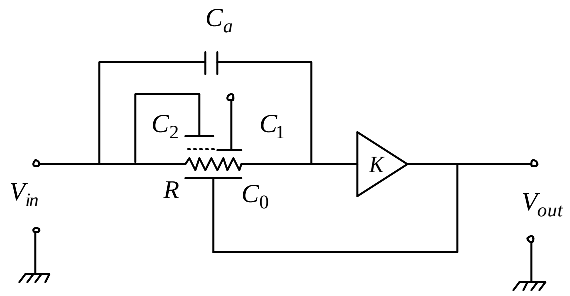

Fig. 3 Proposed active notch filter circuit

It is of interested to consider the parameters a_1 and a_2 of notch filter characteristic in Fig. 3 If we assumed that one of the capacitive layer $C_1 = 0$ $(a_1 = 0)$, it becomes a double capacitive layers URC reported in literature [3]. If $C_1 = C_2 = 0$ or $a_1 = a_2 = 0$, it becomes a conventional active notch filter [4]. shows in Fig. 4a and Fig. 4b respectively.

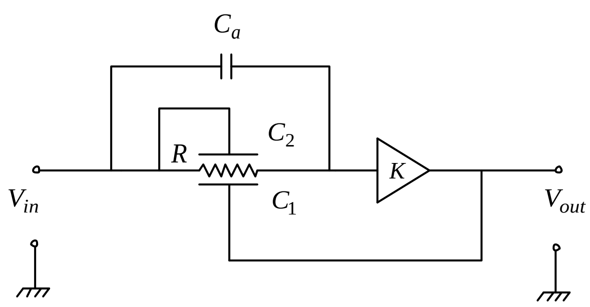

Fig. 4a an active notch filter with $a_1 = 0$

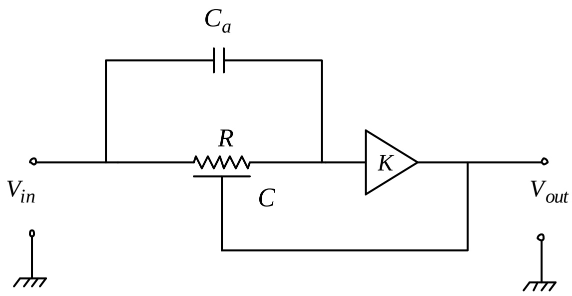

Fig. 4b a conventional active notch filter with $a_1 = a_2 = 0$

3. Simulation results

With an appropriate choice the parameters given below.

$$
\begin{aligned}
&R = 250KW \\
&C_0 = 481.25\,pF, C_1 = 18.5\,pF, C_2 = 0.25\,pF \\
&C_a = 24.485\,pF \qquad (4) \\
&a_1 = 0.037, a_2 = 0.0005, b = 20.4202 \\
&K = 0.94
\end{aligned}
$$

The simulation results by P-SPICE of the frequency response of Fig. 3. and Fig. 4. is shown in Fig. 5.

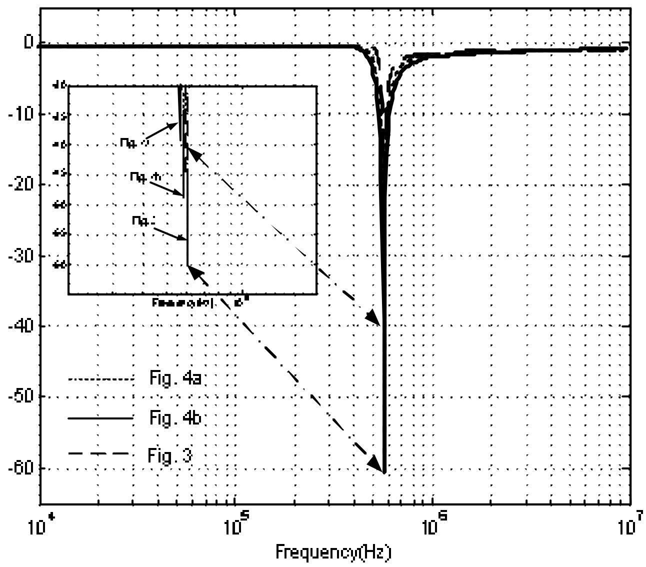

Fig. 5 Frequency response of Fig. 3 and Fig. 4

Fig. 5 shows the behaviour of the proposed active notch filter in comparison with the notch filter of Fig. 4a and the conventional active notch filter. It is seen that the proposed circuit has a steeper rate response than does the notch filter of Fig. 4a and the conventional notch filter in Fig. 4b.

4. Sensitivity

The sensitivity is defined as a ratio of the normalized incremental change of the transfer function $T(p)$ due to the normalized change of circuit parameter X_i

$$S_{X_i}^{T(P)} = \frac{dT(p)}{dx_i} \cdot \frac{X_i}{T(p)} \qquad (5)$$

The results in Fig. 6 and Fig. 7 show the sensitivities of $T(p)$ with the change of capacitance C_0 and resistive R respectively. It is seen that sensitivities of the proposed circuit is lower than the conventional notch filter.

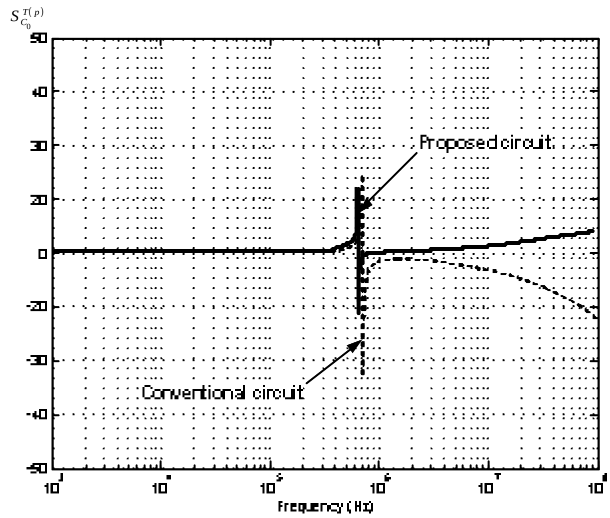

Fig. 6 Sensitivity $S_{C_0}^{T(p)}$

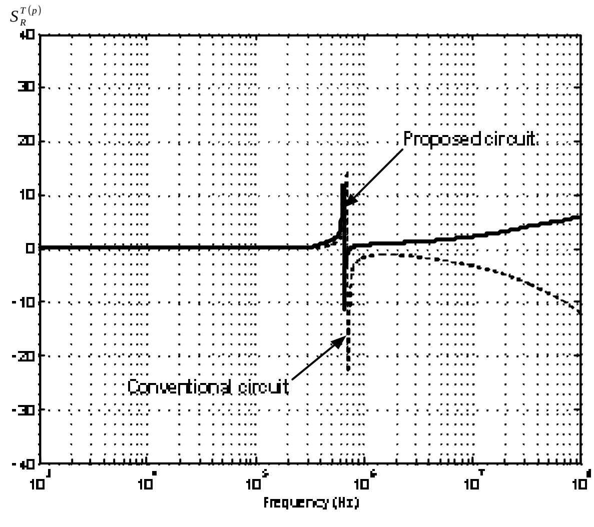

Fig. 7 Sensitivity $S_R^{T(p)}$

5. Stability

The stability of the circuit can be obtained from the denominator of Eq.(3). For stability considerations the Nyquist contour is encircled at origin as shown in Fig. 8. It is seen that the positive gain $K \geq 1$ the circuit is conditionally unstable.

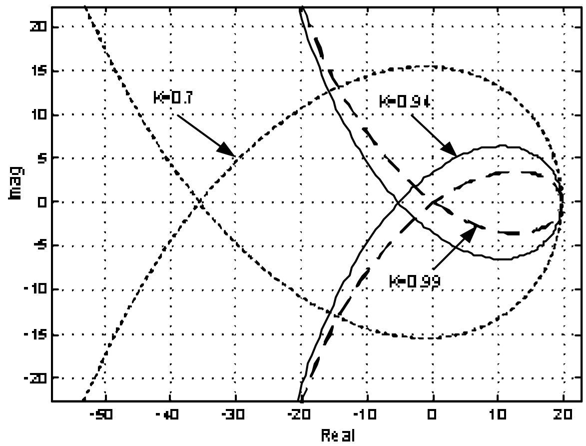

Fig. 8 Stability of the proposed circuit

6. Conclusion

The active notch filter using three capacitive layers URC is proposed and discussed. It is shown that capacitive ratio a_1 and a_2 are used to improve the magnitude response. Thus the magnitude response of the notch filter has steep slope at notch frequency with high Q than does the conventional notch type filter. In addition, Sensitivities and stability are investigated. The proposed circuit can be suitable to fabricate by LSI process.

References

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