# On the Design of Active Crossover Network Using Double Capacitive Uniformly Distributed RC Filter

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***Abstract*—This article presents the design of an active crossover network using double capacitive uniformly distributed RC filter (DURC). The proposed circuit includes the active DURC-based low-pass filter circuit together with the active high-pass filter circuit. The advantage property of this crossover network has flat magnitude response of crossover network signal and small phase difference. The proposed network also has low active and passive sensitivities. The simulation results by MATLAB and PSPICE in terms of the magnitude response, phase response, sensitivity and stability are approved the theoretical predictions.**

***Keywords-component; DURC; crossover network; active filter;***

## I. INTRODUCTION

Nowadays, people have more interests in audio systems for their own entertainment. The crossover network is a part of the audio systems, used to separate the audio signal in the range of 20-20KHz, corresponding to low frequency, middle frequency and high frequency speaker type. The main considerations of crossover network design are that the frequency response of the filter in the passband has flat magnitude and high slope cut off, while the summation of frequency magnitude response of low-pass and high-pass filter are flat and the phase difference of low-pass and high-pass filter are small or nearly zero.

The most popular crossover network is Linkwitz-Riley [1][2] because it provides high slope cut off and less phase difference, however, it has constrain as no parameter to adjust in the best property. Otherwise, the designers use DURC as one device in uniformly distributed RC (URC) groups, which is well known with its good property and the URC element structure as in lumped RC network [3]. Now, URC elements have various form structures, such as; basic URC [4]-[7], DURC [8]-[10], and MURC (multi-layers capacitive layers URC) or TURC (three capacitive layers URC) [11]-[12].

In this article, the active crossover network using double capacitive uniformly distributed RC filter circuit is investigated, with flat summation of the frequency magnitude response, and small phase difference. The structure of DURC element can be built-in thin- film or LSI technology with small area.

## II. ACTIVE CROSSOVER NETWORK

Usually, the people can hear sound or audio in the range between 20-20KHz, but the normal loudspeaker cannot provide the signals in all the audio band. It can provide to some frequency band such as; woofer for low frequency, midrange band frequency and tweeter for high frequency. Therefore, the crossover network is essentially required for splitting the frequency range for the desirable frequency.

Crossover network can be divided into 2 categories based on device as; active crossover network and passive crossover network. Moreover, it can be divided into 2 types for loudspeaker as; two-way crossover network for loudspeaker in woofer and tweeter, and three-way crossover network for loudspeaker in woofer, midrange and tweeter.

This article presents an active two-way crossover network with the main property in which the crossover network has two choices for design as; the summation of the frequency magnitude response is flat and low constant, and the phase difference is small or nearly zero.

### *A. Two-way Crossover Network*

Figure 1. shows the two-way crossover network block diagram in audio systems.

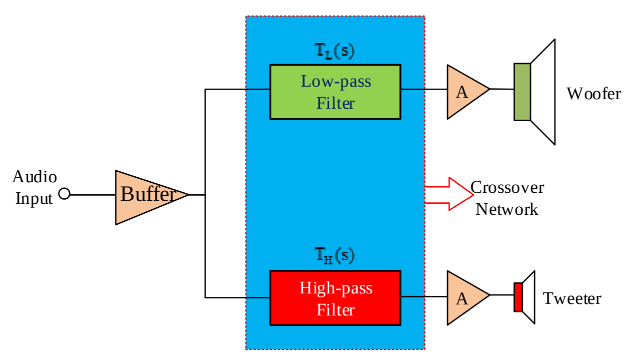


Figure 1. Block diagram of the two-way crossover network.

Typical us the two-way crossover network can be realized by combining the low-pass response and high-pass response. As a result, the output response of two-way crossover network will be inform of all pass response.

$$T_L(s) + T_H(s) = T_A(s) \quad (1)$$

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Note that the equation is centered using a center tab stop. Be sure that the symbols in your equation

where $T_L(s)$ is the transfer function of low-pass filter,

$T_H(s)$ is the transfer function of high-pass filter,

$T_A(s)$ is the transfer function of all-pass summation.

when we set all filter has a unity gain magnitude in Eq. (1). the results can prove in Eq. (2).

$$T_L(s) + T_H(s) = 1 \tag{2}$$

## III. The Proposed Active Crossover Network Circuit

This part presents, firstly, section A introduce the device of double capacitive uniformly distributed RC filter (DURC) in structure, circuit symbol and the property parameter of DURC, section B presents active low-pass filter using DURC, and thirdly, the design of active crossover network using DURC is presented in section C. Finally, section D presents a sensitivity of the proposed circuit.

### *A. Double capacitive uniformly distributed RC filter (DURC)*

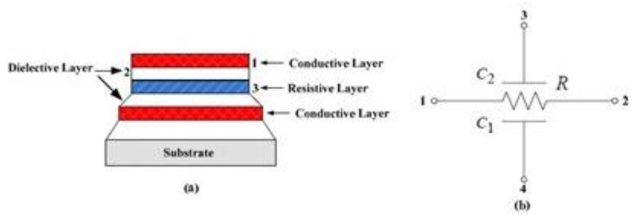


Figure 2. Structure and circuit symbol of DURC.

DURC is one device to analysis same transmission line, and the structure of DURC can fabrication in LSI technology or RC element ladder such as in Figure 2. shows the structure and circuit symbol of DURC and we can analysis the property parameters of DURC with terminal 4 as set to ground (0V) as Eq. (3).

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = X \begin{bmatrix} Y & -1 & -\alpha(Y-1) \\ -1 & Y & -\alpha(Y-1) \\ -\alpha(Y-1) & -\alpha(Y-1) & \delta \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} \tag{3}$$

where $\delta = \alpha[(1-\alpha)P\sinh P + 2\alpha(Y-1)]$,

$X = {}^{P}/_{R\sinh P}$, $Y = \cosh P$, $P = \sqrt{sRC}$,

$\alpha = {}^{C_2}/_{C}$, $C = C_1 + C_2$

when R and C are the value of the total resistance and capacitance of DURC respectively, α is a ratio of $C_2$ and $C_1 + C_2$. s is the complex frequency variable.

### *B. Active low-pass filter using DURC*

The active low-pass filter using DURC as show in Figure 3.

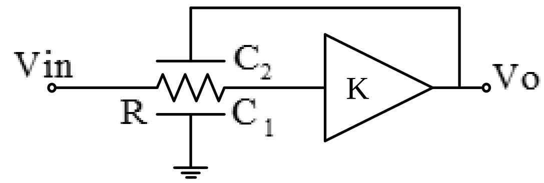


Figure 3. Active low-pass filter using DURC circuit.

For analysis the transfer function of the active low-pass filter using DURC as in Eq. (4)

$$T_L(s) = \frac{K}{\alpha K + (1-\alpha K)\cosh P} \tag{4}$$

where K is a DC gain, P is $\sqrt{sRC}$, R and C are the value of the total resistance and capacitance of DURC respectively, $\alpha$ is a ratio of $C_2$ and $C_1 + C_2$, and s is the complex frequency variable.

The magnitude frequency response of active low-pass filter using DURC form Eq. (4). as shown in Figure 4. and Figure 5.

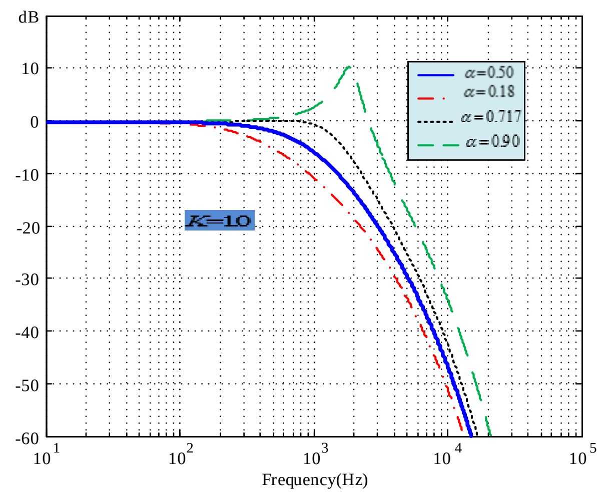


Figure 4. The magnitude frequency response when set K is 1.0 and changes α.

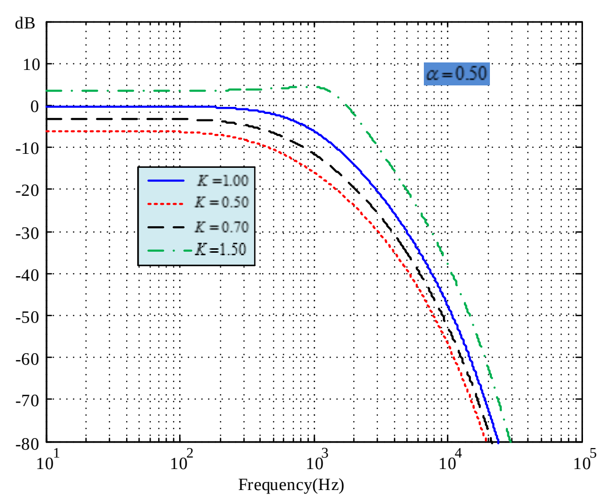


Figure 5. The magnitude frequency response when set α is 0.50 and changes K.

The magnitude frequency response in Figure 4. and Figure 5. are shows the property of this low-pass filter by parameter K and α to change flat magnitude response in the passband and steeper slope in the stopband.

In this design, we choose value of the parameters K is 1 and α is 0.50. Its best value for this active crossover network.

### *C. The proposed active crossover network.*

The active low-pass filter using DURC as show in Figure 6.

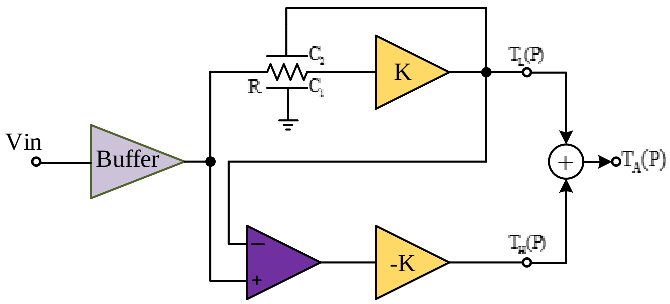


Figure 6. The proposed active crossover network using DURC circuit

Form Figure 6. we can analysis the transfer function of high-pass filter as Eq. (5)

$$T_H(s) = 1 - \frac{K}{\alpha K + (1-\alpha K)\cosh P} \quad (5)$$

Transfer function of low-pass filter in Eq. (4) and transfer function of high-pass filter in Eq. (5) are set K is 1, the summation response of this crossover network as below;

$$T(p) = T_L(p) + T_H(p) \quad (6)$$

$$T(p) = \left\{\frac{K}{\alpha K + (1-\alpha K)\cosh P}\right\} + \left\{1 - \frac{K}{\alpha K + (1-\alpha K)\cosh P}\right\} \quad (7)$$

$$T(p) = \left\{\frac{1}{\alpha + (1-\alpha)\cosh P}\right\} + \left\{1 - \frac{1}{\alpha + (1-\alpha)\cosh P}\right\} = 1 \quad (8)$$

And the magnitude frequency response of the transfer function of low-pass filter and transfer function of high-pass filter in the proposed active crossover network circuit as shown in Figure 7.

### *D. Sensitivity analysis*

The basically of filter circuit should be low sensitivity in passive and active device, with the example sensitivity $S_R^{T(p)}$ of the proposed circuit at low-pass filter can analysis in Eq. (9). and the sensitivity response of the proposed circuit as shown in Figure 8.

$$S_R^{T(p)} = -\frac{P}{2}\left\{\frac{(1-\alpha K)\cosh P}{\alpha K + (1-\alpha K)\cosh P}\right\} \quad (9)$$

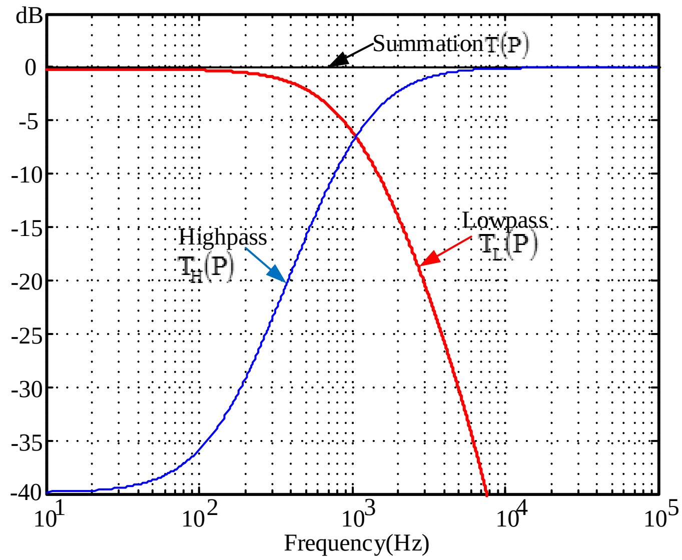


Figure 7. The magnitude response of the proposed circuit.

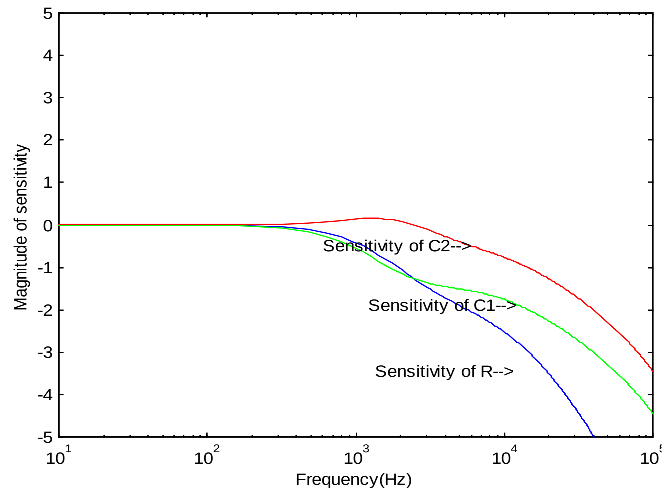


Figure 8. The sensitivity response of the proposed circuit.

It's seen that the sensitivity of the proposed circuit has low sensitivity.

## IV. SIMULATION RESUKTS

In order to verify the results of the theoretical analysis given above, the proposed active crossover network has been simulation by MATLAB and PSPICE program. For PSPICE simulation in a gain amplifier (K) use IC number LF411LT with set supply voltage of ±10V and DURC element is approximated by the ladder lumped RC ladder elements of 10 sections as shown in Figure 9.

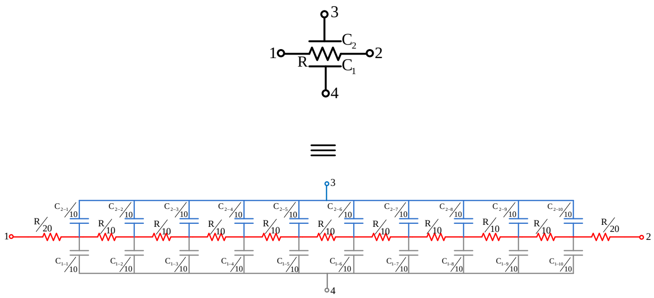

Figure 9. DURC Model in PSPICE using RC ladder.

With the parameter and value of DURC as follows;

$$R = 500\text{k}\Omega, C_1 = 5\text{nF}, C_2 = 5\text{nF} \quad \alpha = 0.5, \text{and } K = 1. \tag{10}$$

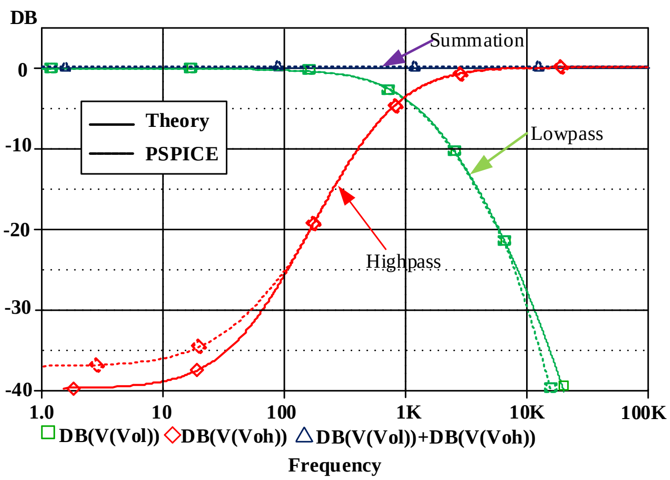


Figure 10. Simulation results in magnitude response of the proposed circuit.

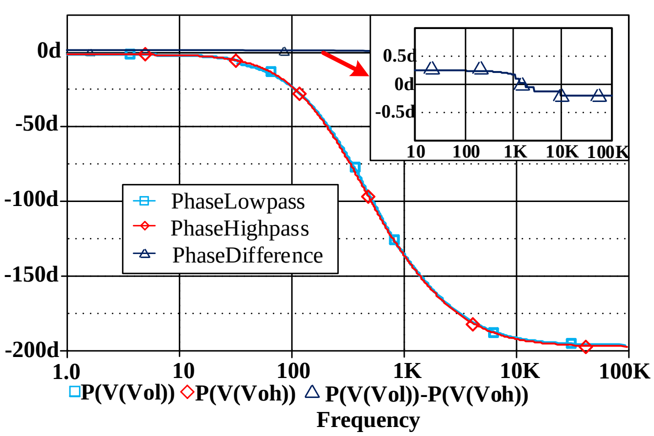


Figure 11. Simulation results in phase response of the proposed circuit.

As simulation results the magnitude frequency response in Figure 10. The frequency cutoff of crossover network $f_c = 1.0\text{KHz}$ at $-6\text{dB}$, and the phase response in Figure 11. It's seen that the simulation result is found to be in good agreement with the theoretical values.

## V. Conclusion

Active crossover network using DURC filter has been described. The proposed circuit use one active low-pass filter using DURC and one active high-pass filter circuit from differential of input signal and low-pass filter which are minimum component count circuit and hence the proposed a low-cost solution. The proposed circuit offers low-pass, high-pass and summation allpass characteristics of crossover network, as well as low active and passive sensitivities. For MATLAB and PSPICE simulation are good agreement with the theoretical values.

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