Active High pass filter with Notch Characteristic using Uniformly Distirbuted RC Line

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Abstract: This paper describes the high pass filter with notch charecteristics. The proposed circuits configuration consists of two uniformly distributed RC line (herein after is called URC) and two gain amplifiers (K_1 and K_2). With the appropriate K_1 and K_2 , the circuit has a steeper slope of magnitude response at pass band steeper than using a single gain amplifier.

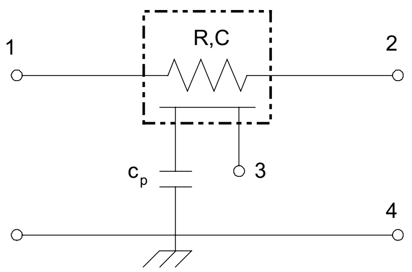
Keywords: High Pass Filter , URC

1. INTRODUCTION

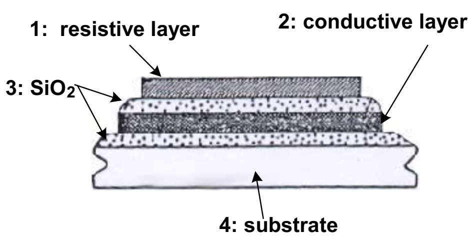
The uniformly distributed RC line with a single amplifier have been published in many case [1], [2], [3], [4]. Herein, the paper proposed an active high pass filters using two lumped URC and two amplifiers. The lumped URC (R_1C_1) behavior as a high pass filter in conjunction with amplifier K_1 and active notch filter circuits with amplifier K_2 respectively.

2. UNIFORMLY DISTRIBUTED RC LINE (URC)

A crossed sectional structure of the URC is illustrated in Fig. (a) The circuit symbol of Fig. 1(a) is illustrated in Fig. 1(b)



(a)



(b)

Fig. 1(a) A distributed RC line and
(b) It's symbol

The 3-ports floating admittance parameters matrix $[Y_{ij}]$ of the URC in Fig. 1(a) is given as follows:

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = X \begin{bmatrix} Y & -1 & -(Y-1) \\ -1 & Y & -(Y-1) \\ -(Y-1) & -(Y-1) & 2(Y-1) \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} \qquad (1)$$

Where $X = \dfrac{P}{R\sinh P}$ and $Y = \cosh P$,

$P = \sqrt{sRC}$, R and C are the values of total resistance and capacitance of the URC respectively. Ans s is the complex angular frequency variable.

3. HPF USING URC

3.1 HPF WITH NOTCH CHARACTERISTICS

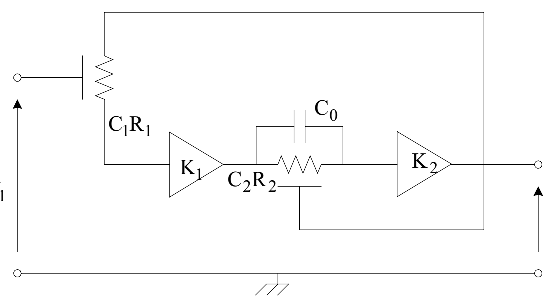


Fig. 2 Active distributed RC HPF.

The proposed active distributed RC HPF circuit is shown in Fig. 2. The voltage transfer function T(p) = V_2/V_1 of the circuit is given as follow:

$$\frac{V_2}{V_1} = \frac{-(Y_1-1)(sC_0+X_2)K_1K_2}{(sC_0+X_2)K_1K_2 - Y_1\{-X_2(Y_1-1)K_2 + (sC_0+X_2Y_2)\}} \qquad (2)$$

Where

$$\left.\begin{array}{l} Y_1 = \cosh P_1, \quad Y_2 = \cosh P_2, \\ X_1 = \dfrac{P_1}{R_1 \sinh P_1}, \quad X_2 = \dfrac{P_2}{R_2 \sinh P_2}, \\ P_1 = \sqrt{sR_1C_1}, \quad P_2 = \sqrt{sR_2C_2}, \\ \dfrac{P_2}{sC_0R_2} = \dfrac{1}{P_2}.\beta, \quad \beta = \dfrac{C_2}{C_0} \end{array}\right\} \quad (3)$$

K_1, K_2 are positive gain amplifier.

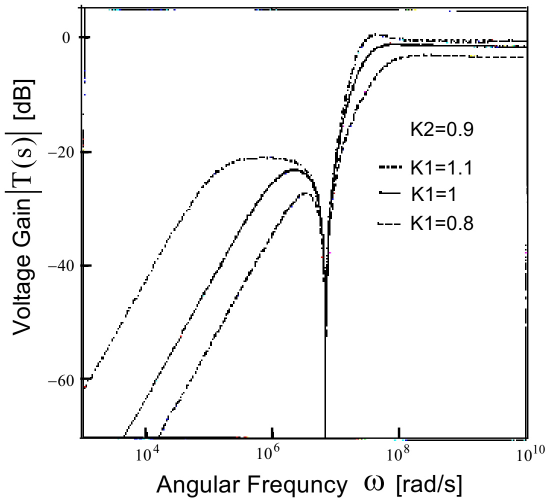
Eq. (2) is reduced to the following expression:

$$\frac{V_2}{V_1} = \frac{-(\cosh P_1 - 1)(P_2 \sinh P_2 + \beta)K_1K_2}{(P_2 \sinh P_2 + \beta)K_1K_2 + \cosh P_1 \{\chi - \beta K_2 - P_2 \sinh P_2\}} \quad (4)$$

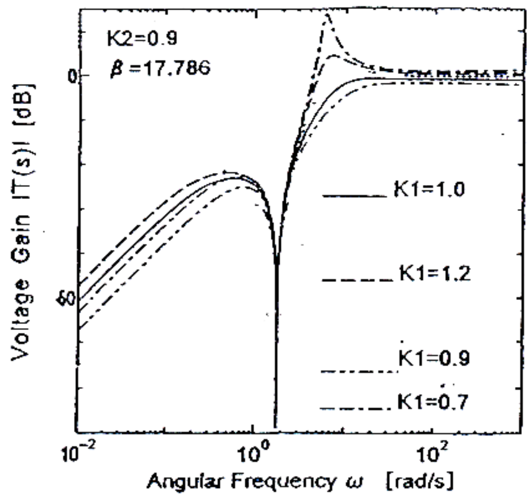
Where $\chi = \beta \cosh P_2 (K_2 - 1)$

3.2 Frequency response

Frequency response of Eq. (4) for the values of K_1, K_2 are plotted in Fig. 3(a), 3(b). The frequency response are favorable for HPF.



(a)



(b)

Fig. 3(a), (b) Magnitude frequency response.

From Fig. 3(a), 3(b) it is seen that for $K_2 = 0.9$, $\beta = 17.786$ and $K_1 = 1$ will give a high pass filter with steeper slope at the pass band without producing pass band peak.

3.3 Example

Herein, we consider a high pass transfer function. Let $K_1 = 1$, $K_2 = 0.9$ for an experiment, we choose the values of the circuit parameters as follows:

$$\left.\begin{array}{l} R_1 = 10\mathrm{K\Omega}, \quad R_2 = 100\mathrm{K\Omega}, \\ C_1 = 10\mathrm{pF}, \quad C_2 = 100\mathrm{pF}, \\ C_0 = 5.622\mathrm{pF} \end{array}\right\} \quad (5)$$

The experimential results for the frequency charecteristics is shown in Fig. 4. The results gives good agreement with theoretical values.

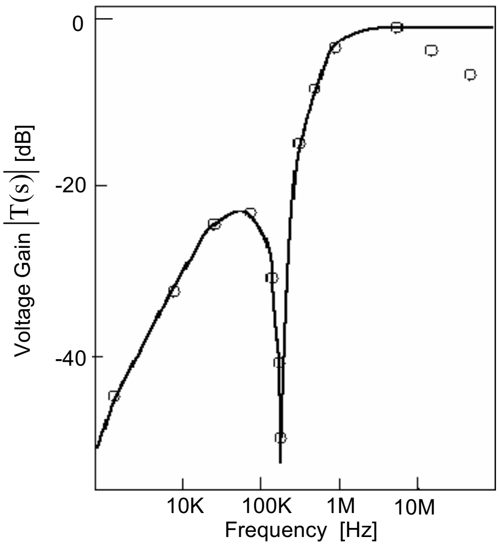


Fig. 4 Frequency response.

3.4 Sensitivity

The sensitivity $S_{X_j}^{T}$ is defined as the ration of the normalized incremental change of the transfer function $T(p)$, due to the normalized change of the circuit parameter X_j.

$$S_{X_j}^{T} = d\frac{T(p)}{dX_j}.\frac{X_j}{T(p)} \quad (6)$$

Magnitude sensitivity is defined as follow:

$$S_{X_j}^{|T|} = \mathrm{Re}\, S_{X_j}^{T} \quad (7)$$

We can calcuation the magnitude sensitivity for the change of K_1, K_2. The sensitivity $S_{K_1}^{T}$ for the voltage gain K_1 is shownas follow:

$$S_{K_1}^{|T|} = \frac{\cosh P_1 \{\chi - \beta K_2 - \beta P_2 \sinh P_2\}}{(P_2 \sinh P_2 + \beta) K_1 K_2 + \cosh P_1 \{\chi - \beta K_2 - \beta P_2 \sinh P_2\}} \quad (8)$$

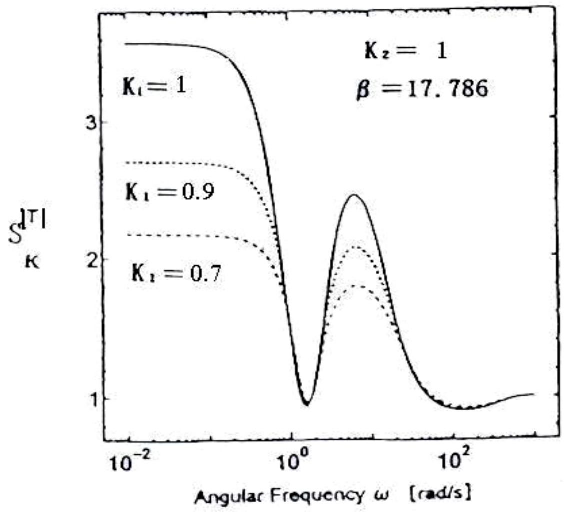
Where $\chi = \beta \cosh P_2 (K_2 - 1)$

The sensitivity $S_{K_2}^{T}$ for the voltage gain K_2 is shown as follow:

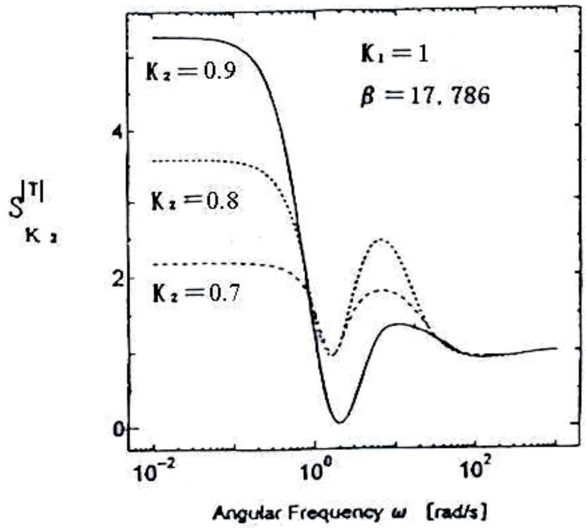
$$S_{K_2}^{|T|} = \frac{-\cosh P_1 \{\beta \cosh P_2 + P_2 \sinh P_2\}}{(P_2 \sinh P_2 + \beta) K_1 K_2 + \cosh P_1 \{\chi - \beta K_2 - \beta P_2 \sinh P_2\}} \quad (9)$$

Where $\chi = \beta \cosh P_2 (K_2 - 1)$

Fig. 5(a), (b) shown magnitude sensitivity of $T(j\omega)$ for amplifier K_1 ,K_2 .



(a)



(b)

Fig. 5(a), (b) Magnitude sensitivities for The active element K_1 , K_2

From Fig. 5(a) and 5(b) , it is seen that the sensitivities of positive gain K_1 are sensible than does the positive gain K_2 at the pass band.

4. CONCLUSIONS

The novel active distributed RC HPF using URC elements are proposed and discussed. The experimental results of the frequency characteristics and the simulation by H-SPICE showed good agreements with theoretical.

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