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Conversion of First Order All-Pass Filters into Variable Amplitude Equalizers

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Abstract – *It is shown that a class of first-order all-pass filters that do not require matching of the passive elements involved in the time constant RC can be converted into variable amplitude equalizers when the fixed resistance R is replaced by a variable one.*

I. INTRODUCTION

Many voltage modes (VM) and current mode (CM) amplitude equalizers (AEs) have been proposed in the past (see [1][2] and the references cited therein). Some of the VM AEs use one or more active devices. VM AE, suggested by Rathore and Khot [3], uses only one active device and one variable resistance R_v. It has the facility of accommodating the desired range R_r and the desired value R_f (for flat response) of R_v. CM circuits are preferred to VM as they have several advantages.

In this paper, we show that a class of first-order all-pass filters (FO APF) acts as a variable amplitude equalizer when the fixed resistance is replaced by a variable resistance.

II. TRANSFER FUNCTION OF AN AMPLITUDE EQUALIZERS

Bode [4] suggested, for realizing AE, the transfer function

$$T(s)=\frac{1+xH(s)}{x+H(s)} \tag{1}$$

Where x is a function of a single variable resistor R_v and is dimensionless, for any AE, $T(s)$ should satisfy the following relations.

$$T(s)=\begin{cases} 1/H(s) & \text{for} \quad R_\upsilon = R_{\upsilon 1}=0 \\ H(s) & \text{for} \quad R_\upsilon = R_{\upsilon 2}=\infty \\ 1 & \text{for} \quad R_\upsilon = R_f \end{cases} \tag{2}$$

From (1), the following properties are noted.

1) It has symmetry around 0 dB line and has a flat response for $R_v = R_f$.
2) As x varies from 0 to ∞, $T(s)$ varies from $1/H(s)$ to $H(s)$. Thus, the total range of variable resistance is $R_r = \infty$.
3) The x and $H(s)$ are interchangeable.
4) When $H(s)$ is replaced by $1/H(s)$, $T(s)$ becomes $1/T(s)$. Hence, one has to consider the realization of either $T(s)$ or $1/T(s)$.
5) A flat response, $T(s) = 1$, is obtained when $x = 1$. The corresponding value of R_v will be designated as R_f.

III. All-pass filter

The transfer function of a FO APF can be expressed as

$$T(s)=\left(\frac{1-\frac{1}{sCR_v}}{1+\frac{1}{sCR_v}}\right), \tag{3}$$

Where CR_v is called the time constant (TC) of the filter. $T(s)$ may be a voltage or current transfer function. As examples of an APF for voltage transfer function is shown in Fig. 1, and for a current transfer function is shown in Fig. 2 [6], where MO-DXCCII is an active device with the terminal characteristics given by

$$\begin{bmatrix} \pm V_y \\ I_y \\ I_{z\pm} \\ I_{w\pm} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} V_{x\pm} \\ V_w \\ I_{x\pm} \\ I_{x\pm} \end{bmatrix} \tag{4}$$

Adding and subtracting $\left(\frac{R}{sC}-R_o^2\right)$ and $\left(\frac{R}{sC}+R_o^2\right)$ in the numerator and denominator, respectively, of (3) and then dividing the numerator and denominator by

$$(R-R_o)\left(R_o+\frac{1}{sC}\right)$$

and rearranging, we get

$$T(s)=\frac{1+\left(\frac{R_v+R_o}{R_v-R_o}\right)\left(\frac{1-\frac{1}{sCR_v}}{1+\frac{1}{sCR_v}}\right)}{\left(\frac{R_v+R_o}{R_v-R_o}\right)+\left(\frac{1-\frac{1}{sCR_v}}{1+\frac{1}{sCR_v}}\right)} \tag{5}$$

Comparing (5) with (1), we get

$$x=\left(\frac{R_v+R_o}{R_v-R_o}\right) \tag{6}$$

and

$$H(s)=\left(\frac{1-\frac{1}{sCR_v}}{1+\frac{1}{sCR_v}}\right) \tag{7}$$

Thus, the transfer function of FO APF becomes that of a variable AE. We, therefore, conclude that any FO APF can be converted into a variable amplitude equalizer by changing the fixed resistance in TC into a variable one.

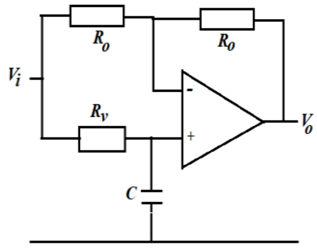

Fig. 1 APF using Op-Amp

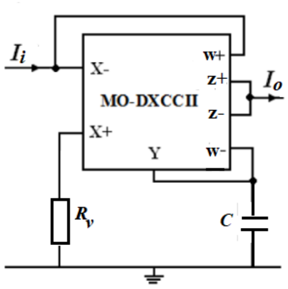

Fig. 2 APF using MO-DXCCII [6][12]

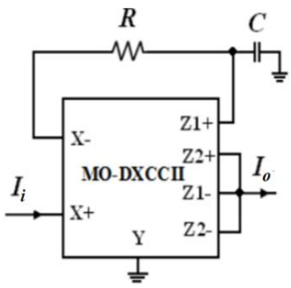

Fig. 3 APF using MO-DXCCII [7]

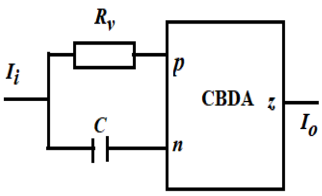

Fig. 4 APF using CBDA [5][12]

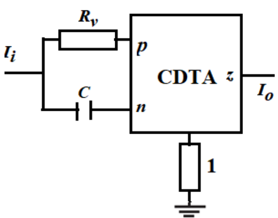

Fig. 5 APF using CDTA

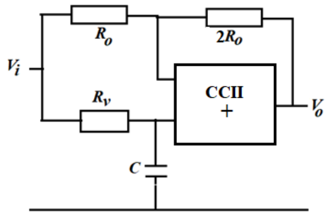

Fig. 6APF using CCII

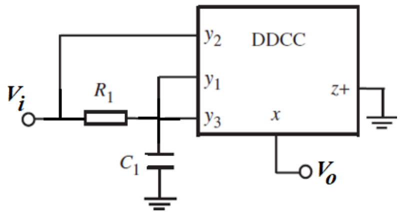

Fig. 7 APF using DDCC [8]

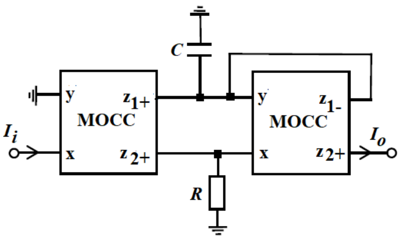

Fig. 8 APF using MOCC [9]

Now R_o may be defined as the value of the variable resistance $R_v = R_f$ corresponding to a flat response, i.e., $T(s) = 1$. When $R_v = -R_0$, $T(s) = 1/H(s)$ and when $R_v = R_0$, $T(s) = H(s)$. Hence, the spread in values of variable resistance, R_v, is $2R_0$. A physical resistance cannot have a negative value of $-R_0$. To overcome this problem, a negative impedance converter may be used.

Typical FO APFs which can be converted into variable AEs are shown in Figs. 1-8 [5]-[12]. APFs which impose matching of the passive elements that appear in the time constant, such as those reported in [14][15], are not suitable for AEs.

IV. CONCLUSION

It is shown that a class of FO APFs, which do not require the matching of those passive elements which appear in the filter time constant, act as AEs when fixed resistance in time constant is replaced by a variable resistance.

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