SSRG International Journal of Electronics and Communication Engineering
ISSN: 2348 – 8549 /doi:10.14445/23488549/IJECE-V8I3P101

Volume 8 Issue 3, 1-2, March, 2021

Novel Current-Mode Amplitude Equalizers

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Received Date: 24 January 2021
Revised Date: 05 March 2021
Accepted Date: 09 March 2021

Abstract - *Novel current mode amplitude equalizers with only one active device and two grounded passive elements (one capacitor and one resistance) are proposed. The variable resistance can be kept within the physical range by using one negative impedance converter.*

Keywords - *Amplitude equalizer, Current-Mode, CDBA, MO-DXCC*

I. INTRODUCTION

Many voltage-mode (VM) amplitude equalizers (AEs) [1]-[14] have been proposed in the past. Rathore [14] has given a comprehensive review of several types of AEs and their design. Broadly, the single Op-Amp-based AEs can be grouped into two categories; (i) with negative resistance and (ii) without negative resistance. In the second category, it is shown [8][14] that there are many possible AEs. Also, it is possible to realize AEs with a specified range of variable resistance $R_v = R_r$ and the value of $R_v = R_f$ for flat response. AEs shown in [6][7][13] are the special cases. Some of the reported AEs either use more than one active device and/or more than two passive elements. All these elements may not be grounded.

AEs using an Op-Amp, due to the finite gain-bandwidth product have limited frequency range of operation. AEs using current conveyor [11] and current feedback operational amplifiers [13] have been suggested to increase the frequency range. Rathore [14] has suggested AEs using other devices such as FTFN, CFA, CDBA.

Some of the AEs are obtained by inverse network transformation [13], and some are using VM-CV transformation [21].

Current-mode (CM) circuits are attractive because of their wider bandwidth, wider dynamic range, and lower power consumption compared to VM counterparts [16]-[19].

In this paper, we propose two CM AEs which use only one capacitor and one resistor; both are grounded, and only one active device.

II. Transfer Function of Amplitude Equalizers

The amplitude equalizers (AEs) are used in many systems to compensate for the deviations produced in the loss-gain response. Bode [1] suggested, for realizing AE, the transfer function

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

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.

$$T(s) = \begin{cases} 1/H(s) \text{ for } R_v = R_{v1} = 0 \\ H(s) \text{ for } R_v = R_{v2} = \infty \\ 1 \text{ for } R_v = R_f \end{cases} \qquad (2)$$

From Eqn. (1), the following properties are noted.

1) It has symmetry around 0 dB line and has the flat response for $R_v = R_f$.
2) As x varies from 0 to∞, $T(s)$ varies from $1/H(s)$ to $H(s)$.
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 $1/T(s)$. It is possible to convert one into the other using inverse transformation [20].
5) A flat response, $T(s) = 1$, is obtained when $x = 1$. The corresponding value of R_v will be designated as R_f.

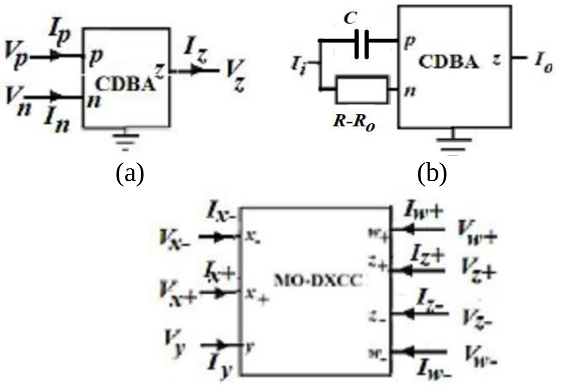
III. PROPOSED CM CIRCUITS

The proposed CM AEs are shown in Fig. 1, where active devices CDBA and MO-DXCC have the symbolic representations as shown in Figs. (a) and (c). Their terminal characteristics are

$$\begin{bmatrix} V_p \\ V_n \\ I_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & -1 & 0 \end{bmatrix} \begin{bmatrix} I_p \\ I_n \\ V_z \end{bmatrix} \qquad (3)$$

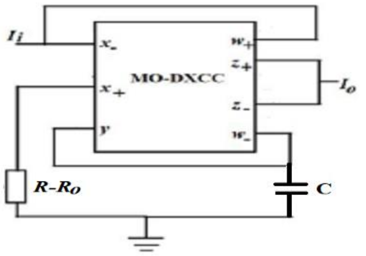
and

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



(a) (b)

(c)



(d)

Fig. 1 (a) and (c) Models of CDBA and MO-DXCC, (b) and (d) CM AEs

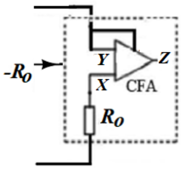


Fig. 2 Simulation of -*Ro***

Analysis of both the circuits leads to

$$T(s) = \frac{I_o}{I_i} = \frac{1 + \left(\frac{R}{R - 2R_o}\right)\left(\frac{R - Ro - \frac{1}{sC}}{R - Ro + \frac{1}{sC}}\right)}{\left(\frac{R}{R - 2R_o}\right) + \left(\frac{R - Ro - \frac{1}{sC}}{R - Ro + \frac{1}{sC}}\right)} \tag{5}$$

Comparing with Eq (1), we get

$$x = \left(\frac{R}{R - 2R_o}\right) \tag{6}$$

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

Now

$$T(s)|_{R=0} = \frac{R_o - 1/sC}{R_o + 1/sC_o} \tag{8}$$

and

$$T(s)|_{R=2R_o} = \frac{R_o + 1/sC}{R_o - 1/sC_o} = \frac{1}{T(s)|_{R=0}} \tag{9}$$

Thus,

$$R_r = 2R_0. \tag{10}$$

When $R = R_o$,

$$T(s) = 1. \tag{11}$$

Thus, R_o is defined as the value of $R = R_f$ for flat response.

Both the AEs use 1*R* and 1*C* and one active device. The passive elements are virtually (CDBA) or actually ((MO-DXCC) are grounded. Thus, they are superior to all those AEs appeared in [1]-[14] which use either a greater number of passive elements and/or a greater number of active devices, and some or all floating passive elements.

A practical resistance cannot have a negative value. Therefore, a negative impedance converter shown in Fig. 2 can be used to replace -R_o. Thus, $R_r = 2R_o$.

IV. CONCLUSION

Two novel CM AEs using one active device, 1*R*, and 1*C* which are either virtually (CDBA) or actually (MO-DXCC) grounded, are introduced. The range of the variable resistance is brought within the physical limit using one negative impedance converter. All other known AEs either have more than one active device and/or more than two passive elements, some or all of which are floating.

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