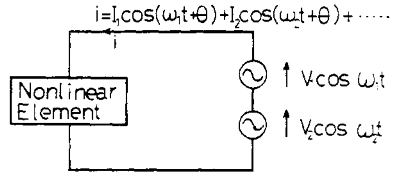


Fig. 5. Figure for the explanation of discrimination.

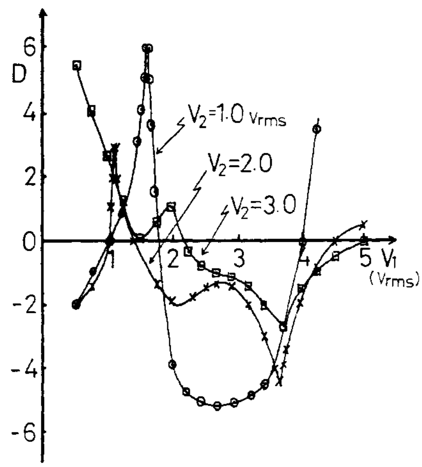


Fig. 6. Experimental results of discrimination in the nonlinear elements connected in series.

discrimination with the aid of the quantities in Fig. 5:

$$\underset{V_1>V_2}{D} = 20 \operatorname{Log}_{10} \frac{I_1/V_1}{I_2/V_2}, \quad \text{for} \quad V_1 > V_2. \tag{2}$$

The experimental results of the discrimination are shown in Fig. 6. We find that these values are negative over the wide range of the input level, although it is limited. As a result, it is suggested that as the amplitude of the small signal in the oscillator increases, both signals build up simultaneously until the equilibrium positions are reached.

## IV. Conclusion

The novel simultaneous asynchronous oscillator, constructed by two usual nonlinear elements (connected in series) and two parallel resonators, was proposed and its behavior was assured by numerical calculations and some experiments.

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# Novel Passive and Active Compensated Deboo Integrators

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*Abstract*—Two methods for compensating the well-known Deboo integrator are described. The first method is based on passive compensation and the second is based on active compensation. Both methods are equivalent and result in an improvement of many orders of magnitude in the integrator $Q$ factor.

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## I. Introduction

The Deboo noninverting integrator [1] finds wide use in many circuit applications [2]-[3]. The finite and complex gain nature of the op-amp degrades significantly the performance of this widely used positive integrator. The purpose of this letter is to introduce two methods for compensating this integrator. The first method is passive and requires only a single capacitor to be added to the network. The second method is active and requires an extra op-amp and two resistors. Both methods are equivalent; however, the second method is superior as it is not affected by the ambient conditions if matched op-amps are used.

Fig. 1 shows the well-known noninverting integrator of Deboo [1]. It uses a single op-amp, a grounded capacitor, and four resistors. Assuming an ideal op-amp, the Deboo integrator transfer function is

$$\frac{V_o}{V_i} = \frac{1 + R_3/R_4}{2sCR_1 + 1 - R_3R_1/R_4R_2}. \tag{1}$$

Hence, the condition of perfect integration is

$$R_3R_1 = R_4R_2. \tag{2}$$

Thus by taking

$$R_3 = R_4 = r \tag{3}$$

and

$$R_1 = R_2 = R \tag{4}$$

the transfer function becomes:

$$\frac{V_o}{V_i} = \frac{1}{sCR}. \tag{5}$$

Now taking into consideration the first-pole model of the op-amp which is represented by [4]

$$A(s) \simeq \frac{\omega_t}{s} \tag{6}$$

where $\omega_t$ is the gain-bandwidth product of the op-amp. The transfer function of the integrator will be

$$\frac{V_o}{V_i} = \frac{1}{sCR} \cdot \frac{1}{1 + 2\omega_0/\omega_t + 2s/\omega_t} \tag{7}$$

where

$$\omega_0 = \frac{1}{CR}. \tag{8}$$

The integrator $Q$ factor is easily obtainable from the above equation and is given by [3]

$$Q_I \simeq -\frac{1}{2}\,|A(j\omega)| = -\frac{1}{2}\,\frac{\omega_t}{\omega}, \quad \frac{\omega}{\omega_t} \ll 1. \tag{9}$$

## II. The Passive Compensated Deboo Integrator

Fig. 2(a) represents the new passive compensated Deboo integrator which uses an additional compensating capacitor $C_c$. Using the one-pole model of the op-amp as given by (6) the transfer function is given by

$$\frac{V_o}{V_i} = \frac{\omega_0}{s} \cdot \left[ \frac{1 + \dfrac{sC_cr}{2}}{\dfrac{s^2C_cr}{\omega_t} + \dfrac{s}{\omega_t}(2 + C_cr\omega_0) + \left(1 + \dfrac{2\omega_0}{\omega_t} - \dfrac{C_cr\omega_0}{2}\right)} \right] \tag{10}$$

taking

$$C_cr = \frac{4}{\omega_t}. \tag{11}$$

The transfer function becomes

$$\frac{V_o}{V_i} = \frac{\omega_0}{s} \cdot \left[ \frac{1 + s\tau}{1 + s\tau(1 + \omega_0\tau) + s^2\tau^2} \right] \tag{12}$$

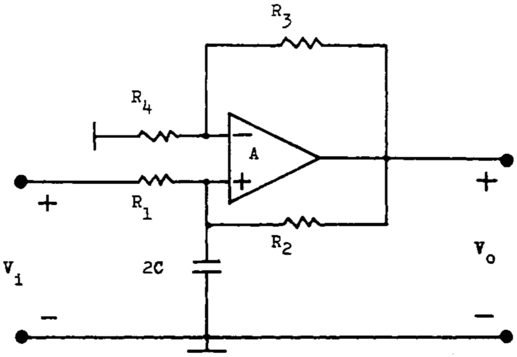


Fig. 1. Deboo noninverting integrator.

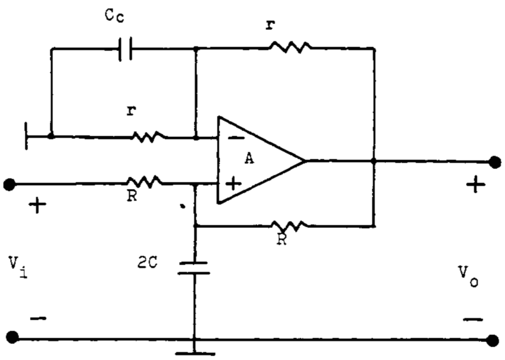


Fig. 2. Passive compensated Deboo integrator.

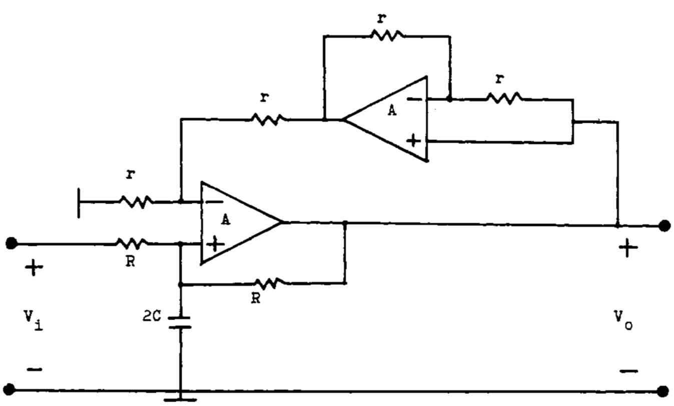


Fig. 3. Active compensated Deboo integrator.

where

$$\tau = \frac{2}{\omega_t}. \tag{13}$$

From (12) the compensated integrator $Q$ factor is given by

$$Q_I \simeq -\frac{1}{8} \cdot |A(j\omega)|^3 = -\frac{1}{8} \cdot \frac{\omega_t^3}{\omega^3}, \quad \frac{\omega}{\omega_t} \ll 1 \tag{14}$$

Comparison of this value of the compensated $Q$ factor with that of (9) shows that an improvement of many orders of magnitude is obtained.

### III. The Active Compensated Deboo Integrator

Fig. 3 represents the novel active compensated noninverting Deboo integrator. It is required for compensation that the two op-amps used must have identical unity-gain-bandwidths $\omega_t$ (op-amps are available in a dual package). This new active compensated circuit is equivalent to the passive compensated one as it has the same transfer function given by (12). The compensated $Q$ factor is given by (14).

Practically this active compensated circuit is better than the passive compensated one, in which the compensating capacitor $C_c$ must be adjusted according to (11) which depends on the op-amp unity-gain bandwidth. It is well known that $\omega_t$ is sensitive to variations in temperature or power supply voltage [3]. So if these conditions are changed the passive compensation will no longer be a satisfactory solution.

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## A Modified Canonic Active-*RC* Bandpass Filter with Reduced Sensitivity to Amplifier Gain-Bandwidth Product

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***Abstract*—A new configuration for activating a passive-*RC* bandpass building block to realize an inverting selective bandpass filter is described. The proposed network has the advantages of being canonic, is always stable, and has reduced sensitivity to the amplifier gain-bandwidth product.**

Recently an inverting bandpass filter has been introduced [1]. The network is based on activating a passive-*RC* bandpass building block and has reduced sensitivity to the amplifier gain-bandwidth product (*GB*).

In this letter the circuit is slightly modified such that the fractional shifts in $\omega_0$ and $Q$ due to the finite *GB* of the operational amplifier (OA) are reduced to $\frac{2}{3}$ of their previous values [1]. Moreover, the gain can be independently controlled by tuning a single resistor in the circuit.

The proposed structure is shown in Fig. 1 and is different from the circuit in [1] in two respects. First the voltage follower at the output is replaced by a noninverting voltage controlled voltage source of gain $\beta$, secondly the feedback is taken from the noninverting terminal of $A_2$ instead of the output terminal of $A_2$.

The voltage transfer function for the network in Fig. 1 is given by:

$$G(s) = \frac{V_0}{V_i} = \frac{-\alpha\beta T}{\left[1 + \frac{\beta}{A_2}\right]\left[1 - (\alpha + 1)\left(T - \frac{1}{A_1}\right)\right]} \tag{1}$$

where $T$ is the open-circuit voltage transfer function of the passive-*RC* bandpass network, which is given by:

$$T(s) = \frac{sC_1R_1}{s^2C_1C_2R_1R_2 + s(C_1R_1 + C_2R_2 + C_1R_2) + 1}. \tag{2}$$

From (1) and (2) and as $A_i$ approaches infinity ($i = 1, 2$) the transfer function reduces to:

$$G(s) = \frac{-s\alpha\beta\, C_1R_2}{s^2C_1C_2R_1R_2 + s(C_2R_2 + C_1R_2 - \alpha C_1R_1) + 1} \tag{3}$$

which realizes an inverting bandpass characteristics having:

$$\omega_0 = \frac{1}{\sqrt{C_1C_2R_1R_2}} \tag{4}$$

$$Q = \frac{\sqrt{C_1C_2R_1R_2}}{C_2R_2 + C_1R_2 - \alpha C_1R_1} \tag{5}$$

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