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Current-mode Universal Filter using Fin type Field Effect Transistor (FinFET) - Based Multioutput Current Controlled Current Conveyor Transconductance Amplifiers

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Graphical/Tabular Abstract (Grafik Özet)

The 7nm finfet's specifications were used to replicate the finfet transistors used in the suggested design. The corresponding M.O.C.C.C.C.T.A. circuit topologies utilized in the simulations are displayed in Fig. 3. / 7nm FinFET'in özellikleri, önerilen tasarımda kullanılan FinFET transistörlerini kopyalamak için kullanıldı. Simülasyonlarda kullanılan ilgili M.O.C.C.C.C.T.A. devre topolojileri Şekil 3'te gösterilmektedir.

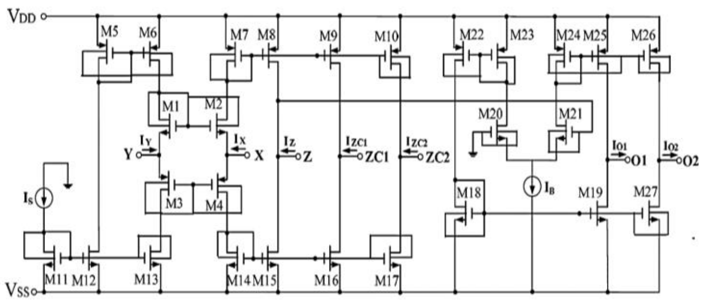

Figure A: *A potential use of CCCCTA that was employed FinFET transistor. /* ***Şekil A:*** *FinFET transistörünün kullanıldığı CCCCTA'nın potansiyel bir kullanımı.*

Highlights (Önemli noktalar)

- *For single digit nanometric dimensions, the fin type Field Effect Transistor (FinFET) transistor is a promising technology / Tek haneli nanometrik boyutlar için, FinFET transistörleri çok umut verici bir teknolojidir.*
- *FinFETs are utilized to reduce power consumption and boost performance since the two gate voltages may be regulated independently or dependently / FinFET'ler, iki kapı gerilimi bağımsız veya bağımlı olarak kontrol edilebildiği için güç tüketimini azaltmak ve performansı artırmak amacıyla kullanılır.*
- *The FinFET 7 nm PTM-MG model is used in LT-spice to simulate the suggested active filter circuit. / Önerilen aktif filtre devresini simüle etmek için LTspice'ta FinFET 7 nm PTM-MG modeli kullanılmıştır.*

Aim (Amaç): *The purpose of this study is to investigate the design of multioutput current-controlled current conveyor transconductance amplifiers (M.O.C.C.C.C.T.A.s) to perform all standard operations such as low-pass (LP), high-pass (HP), band-stop (BS), band-pass (BP), and all-pass (AP) filtering. / Bu çalışmanın amacı, tüm standart işlemleri (düşük geçiren, yüksek geçiren, bant durduran, bant geçiren ve tüm geçiren) gerçekleştirmek için çok çıkışlı akım kontrollü akım konveyör transkonduktans amplifikatörlerinin (M.O.C.C.C.C.T.A.) tasarımını araştırmaktır.*

Originality (Özgünlük): *In the study where the FinFET 7 nm PTM-MG model was used in LTspice to simulate the active filter circuit with new technology, the findings are in good agreement with the theoretical predictions. / Yeni bir teknolojiye sahip olan aktif filtre devresini simüle etmek için LTspice'ta FinFET 7 nm PTM-MG modeli kullanılan çalışmada elde edilen bulgular teorik tahminlerle iyi bir uyum içindedir.*

Results (Bulgular): *It is understood that the quality factor can be changed without adversely affecting the change in pole frequency corresponding to different bias currents./ Farklı beyz akımlarına karşılık gelen kutup frekansının değişiminde kalite faktörünün olumsuz etkilenmeden değiştirebileceği anlaşılmaktadır.*

Conclusion (Sonuç): *Due to its favorable characteristics, the proposed circuit stands out as a strong candidate for development into a monolithic chip, suitable for integration into battery-operated, portable electronic devices like components for wireless communication systems. / Olumlu özellikleri nedeniyle, önerilen devre monolitik bir çipe geliştirme için güçlü bir aday olarak öne çıkmaktadır ve kablosuz iletişim sistemleri gibi bataryalı taşınabilir elektronik cihazlara entegrasyon için uygun bir halife olarak değerlendirilebilir.*

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Abstract

For single digit nanometric dimensions, the fin type Field Effect Transistor (FinFET) transistor is a promising technology. FinFETs are utilized to reduce power consumption and boost performance since the two gate voltages may be regulated independently or dependently. This work investigates the design of multioutput current-controlled current conveyor transconductance amplifiers, or M.O.C.C.C.C.T.A.s. to carry out all standard operations, such as LP, HP, BS, BP, and AP. One of the circuit's features is its capacity to change the pole frequency electrically and independently by applying the proper input bias currents based on the quality factor. There are merely two grounded capacitors and two M.O.C.C.C.C.T.A.s in the simple circuit design. The recommended design is perfect for further development into an integrated circuit because it only contains grounded components and does not require any external resistors. The FinFET 7 nm PTM-MG model is used in LT-spice to simulate the suggested active filter circuit. The obtained findings are in good agreement with the theoretical prediction.

Fin tipi Alan Etkili Transistör (FinFET) Tabanlı Çok Çıkışlı Akım Kontrollü Akım Konveyörü Transiletkenlik Amplifikatörlerini kullanan Akım Modlu Evrensel Filtre

Makale Bilgisi

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Anahtar Kelimeler

fin type Field Effect Transistor (FinFET)
M.O.C.C.C.C.T.A.
current-mode
filter.

Öz

Tek haneli nanometrik boyutlar için, FinFET transistörleri çok umut verici bir teknolojidir. FinFET'ler, iki kapı gerilimi bağımsız veya bağımlı olarak kontrol edilebildiği için güç tüketimini azaltmak ve performansı artırmak amacıyla kullanılır. Bu çalışma, tüm standart işlemleri (düşük geçiren, yüksek geçiren, bant durduran, bant geçiren ve tüm geçiren) gerçekleştirmek için çok çıkışlı akım kontrollü akım konveyör transkonduktans amplifikatörlerinin (M.O.C.C.C.C.T.A.) tasarımını araştırmaktadır. Devrenin temel özelliklerinden biri, kutup frekansını elektriksel olarak ve kalite faktörüne göre bağımsız olarak uygun giriş akımlarını uygulayarak değiştirebilme kapasitesidir. Basit devre tasarımı yalnızca iki topraklanmış kapasitör ve iki M.O.C.C.C.C.T.A. içermektedir. Önerilen tasarım, sadece topraklanmış bileşenler içerdiğinden ve harici direnç gerektirmediğinden, entegre devre olarak daha fazla geliştirme için idealdir. Önerilen aktif filtre devresini simüle etmek için LTspice'ta FinFET 7 nm PTM-MG modeli kullanılmıştır. Elde edilen bulgular teorik tahminlerle iyi bir uyum içindedir.

1. INTRODUCTION (GİRİŞ)

Analogue filters are now crucial building elements that are frequently used in real-time signal processing. They are used in a variety of industries, including control systems, electronics measurement, and communication. Among the most often used analogue filters is the universal biquadratic filter, which performs many tasks at once without changing the circuit design. These days, voltage-mode universal filters are becoming less common than current-mode ones. Over the past 20 years, a lot of work has gone towards, lowering the supply voltage. This is because there is a need for equipment that is battery-operated and portable. When low-voltage operational circuits are required, the current-mode approach serves as a suitable substitute [1-6]. A circuit that employs the current-mode approach can provide more benefits, such as reduced power consumption, increased linearity,

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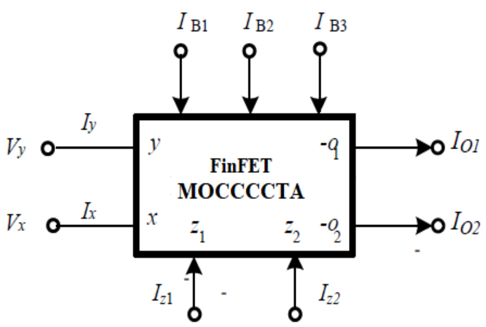
better bandwidth, bigger dynamic range, and simpler circuitry. A reported active element with five terminals, the current conveyor transconductance amplifier, was presented in 2005. It appears to be a flexible part that may be used to realize a variety of circuits for processing analogue signals, particularly systems that are current-mode or voltage-mode. Furthermore, it is possible to control the output current gain. Nevertheless, it's crucial to emphasize that the current-controlled transconductance amplifier (CCTA) remains unaffected by parasitic resistances at the current input port [7-15]. The updated version of the C.C.T.A was recently introduced by Jaikla and Siripruchyanun. It could be controlled by an input bias current (IB). It has two current input ports with adjustable parasitic resistances. The new name for it is the C.C.C.C.T.A. A C.C.C.C.T.A. appears to be a valuable foundational active block as it can serve as a basis for the development of various circuits and systems. According to literature assessments, many suggested current-mode universal filters need many active and passive components, necessitating changes to the circuit architecture to accomplish several goals. A lot of floating capacitors are used in some of them, which is inappropriate for use as a monolithic device. Additionally, many circuits that are provided only offer BP, HP, and LP transfer functions. This paper's goal is to suggest a current-mode (C.M) universal biquadratic active filter with a focus on using Finfet transistors that are based on M.O.C.C.C.C.C.T.A.s. The following are the characteristics of the suggested circuit: supplying all common transfer functions, including BP, BR, LP, and HP. Because the circuit architecture is so straightforward and only uses grounded capacitors as passive parts, it may be manufactured as a monolithic chip. Electronic modification of the pole frequency and quality factor is achievable. The LT-SPICE 7nm transistor simulations demonstrate the characteristics of the suggested circuits and demonstrate a strong conformance with the theoretical presumptions [15-27].

2. MATERIALS AND METHODS (MATERYAL VE METOD)

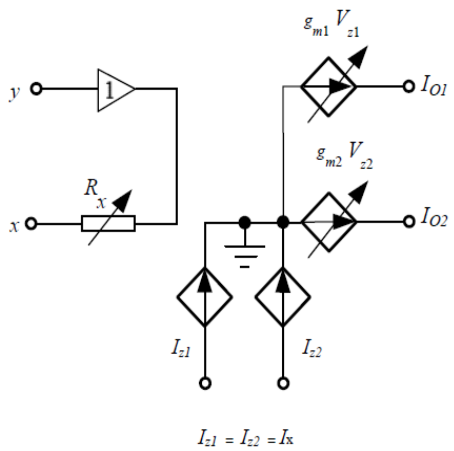
2.1. Active Filter (M.O.C.C.C.C.T.A.) (Aktif Filtre)

A M.O.C.C.T.A. with multiple outputs (M.O.C.C.T.A.) is an analog active component featuring six terminals. The symbols for the input and output terminal names are x, y, z1, z2, o, and o2. The y terminal is the voltage input port with the highest impedance. The current input port, usually known as the x terminal, has a controlled parasitic resistance (Rx). The parasitic resistance is tuned electronically (Rx). These terminals are the high-impedance equivalents of the current output port, designated as z1, z2, o1, and o2. It is optimal for the current to be equal at the z and x terminals. The M.O.C.C.C.C.T.A.'s equivalent circuit and symbol are illustrated in Fig. 1. The matrix below can be used to describe the qualities of the idea M.O.C.C.C.C.T.A [28].

$$\begin{bmatrix} I_y \\ V_x \\ I_{z1}, I_{z2}, I_{zc} \\ I_{01} \\ I_{o2} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ Rx & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \pm g_{m1} & 0 \\ 0 & 0 & 0 & 0 & \pm g_{m2} \end{bmatrix} \begin{bmatrix} Ix \\ Vy \\ V_{z1} \\ V_{01} \\ V_{o2} \end{bmatrix} \quad (1)$$



a) Symbol



b) Equivalent circuit

Figure 1. FinFET M.O.C.C.C.C.T.A.'s corresponding circuit and symbol (FinFET M.O.C.C.C.C.T.A. karşılık gelen devre ve sembol)

Where:

$$Vx = IxRx + Vy, I_{z1} = Ix = I_{z2} = I_{zc}$$
$$I_{o1} = g_{m1}.V_{z1}, I_{o2} = g_{m2}.V_{z2} \tag{2}$$
$$Rx = \frac{V_T}{2I_{B1}}, g_{m1} = \frac{I_{B2}}{2V_T}, g_{m2} = \frac{I_{B3}}{2V_T}$$

The thermal voltage of 26 mV is called VT [29]. IB2 and IB3 govern the transconductance gain of the gm in a line, while IB1 controls the parameter Rx, according to Eq. (2).

A universal filter with current mode proposed.
(Akım moduyla önerilen evrensel bir filtre)

Fig. 2 depicts the suggested current-mode universal active filter., where IB1, IB2, and IB3 represent the bias currents of M.O.C.C.C.C.T.A.1 and M.O.C.C.C.C.T.A.2, respectively [5]. A simple study of the circuit in Fig. 2 using the characteristics of M.O.C.C.C.C.T.A. in Sections 2.1 results in the transfer functions listed below.

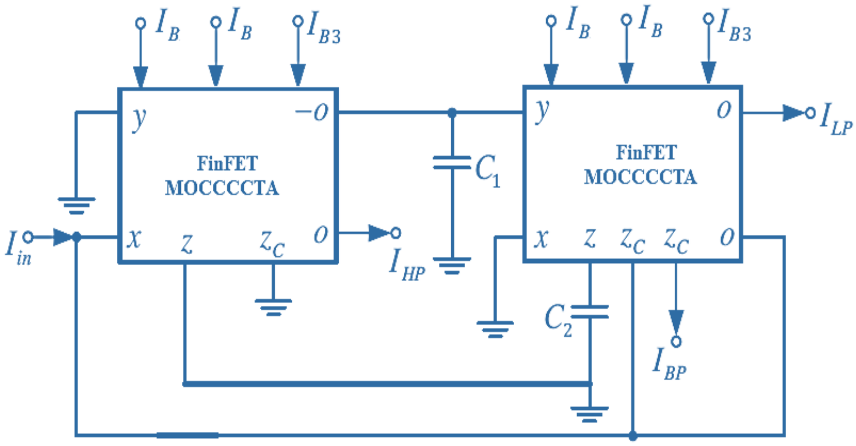


Figure 2. A universal filter with current mode proposed (Akım moduyla önerilen evrensel bir devre)

$$\frac{I_{HP}}{I_{in}} = \frac{Ks^2}{s^2 + s\dfrac{K}{R_{x2}C_1} + \dfrac{Kg_{m2}}{R_{x2}C_1C_2}} \tag{3}$$

$$\frac{I_{BP}}{I_{in}} = \frac{\dfrac{K}{R_{x2}C_1}s}{s^2 + s\dfrac{K}{R_{x2}C_1} + \dfrac{Kg_{m2}}{R_{x2}C_1C_2}} \tag{4}$$

$$\frac{I_{LP}}{I_{in}} = \frac{\dfrac{Kg_{m2}}{R_{x2}C_1C_2}s}{s^2 + s\dfrac{K}{R_{x2}C_1} + \dfrac{Kg_{m2}}{R_{x2}C_1C_2}} \tag{5}$$

where K=0. 5gm1.Rx1 Moreover, by combining the currents IBS==ILP+IHP and IAP==IBPS-IBR, the BS and AP functions may be obtained, respectively,

where,

$$\frac{I_{BS}}{I_{in}} = \frac{K(\dfrac{g_{m2}}{R_{x2}C_1C_2} + s^2)}{s^2 + s\dfrac{K}{R_{x2}C_1} + \dfrac{Kg_{m2}}{R_{x2}C_1C_2}} \tag{6}$$

$$\frac{I_{AP}}{I_{in}} = \frac{K(\dfrac{g_{m2}}{R_{x2}C_1C_2} - \dfrac{1}{R_{x2}C}s + s^2)}{s^2 + s\dfrac{K}{R_{x2}C_1} + \dfrac{Kg_{m2}}{R_{x2}C_1C_2}} \tag{7}$$

The quality of factor (Qo) and pole of frequency (wo), respectively, are given by the formulae.

$$wo = \sqrt{\frac{Kg_{m2}}{R_{x2}C_1C_2}} \tag{8}$$

$$Q_0 = \sqrt{\frac{C_1R_{x2}g_{m2}}{KC_2}} \tag{9}$$

If Rxi==VT. (2. Ibi)-1and gmi==IB/2.VT from Equ. 8 and 9 can obtain.

$$wo = \frac{1}{V_T}\sqrt{\frac{I_{B2}I_{B3}}{8C_1C_2}}$$
(10)

$$Q_0 = I_{BQ}\sqrt{\frac{4C_1}{C_2 I_{B2} I_{B3}}} \quad (11)$$

2.3. Sensitivities of the Finfet active filter (Finfet aktif filtrenin hassasiyetleri)

The suggested circuit's sensitivities may be determined using Eqs. (10)– (11).

$$S^{wo}_{I_{B2},I_{B3}} = 0.5; \quad S^{wo}_{C_1,C_2,I_{B1}} = -0.5; \quad S^{wo}_{V_T} = -1 \quad (12)$$

$$S^{Qo}_{I_{B2},I_{B3}} = 0.5, \quad S^{Qo}_{I_{B2},I_{B3},C_2} = -0.5 \quad (13)$$

$$S^{BW}_{I_{B2},I_{B3}} = 1, \quad S^{BW}_{V_T,C_1,I_{B1}} = -0.5 \quad (14)$$

As a result, the circuit exhibits commendable sensitivity, where all passive and active sensitivities are equal to or smaller than unity. Simulation of the active filter and its outcomes are presented.

An analysis of the suggested circuit's performance was done using an LT-SPICE simulation [30-31]. The 7nm finfet's specifications were used to replicate the finfet transistors used in the suggested design. The corresponding M.O.C.C.C.C.C.T.A. circuit topologies utilized in the simulations are displayed in Fig. 3. The circuits were biased with voltages supply (VEE) of ±0.1V, C1=C2=1pF, IB1=170nA, IB2=172nA, and IB3=175nA. This resulted in a pole frequency of 406kHz, which is different from the theoretical value of 532kHz (deviated by 5.31%) obtained from Eq. (11). This variation is brought about by the parasitic elements of the active devices that are utilised in the circuit. Figure 4 depicts the simulated gain frequency responses of the universal filter proposed in Figure 3. It vividly illustrates the circuit's capability to deliver concurrent functionality. transfer functionalities without altering the circuit design, such as BP, HP, and LP.

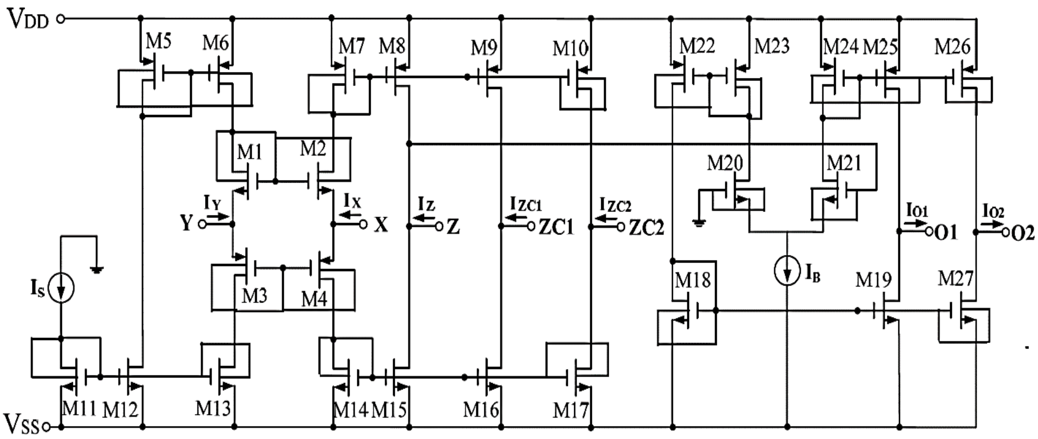


Figure 3. A potential use of CCCCTA that was employed FinFET transistor. (FinFET transistörünün kullanıldığı CCCCTA'nın potansiyel bir kullanımı)

The band-pass function's gain responses are displayed in Fig. 5 when I_B is set to 50 nA, 100 nA, and 400 nA, respectively. As indicated by Eqs. (10) and (11), This outcome shows that it is possible to alter the pole frequency without sacrificing the quality factor.

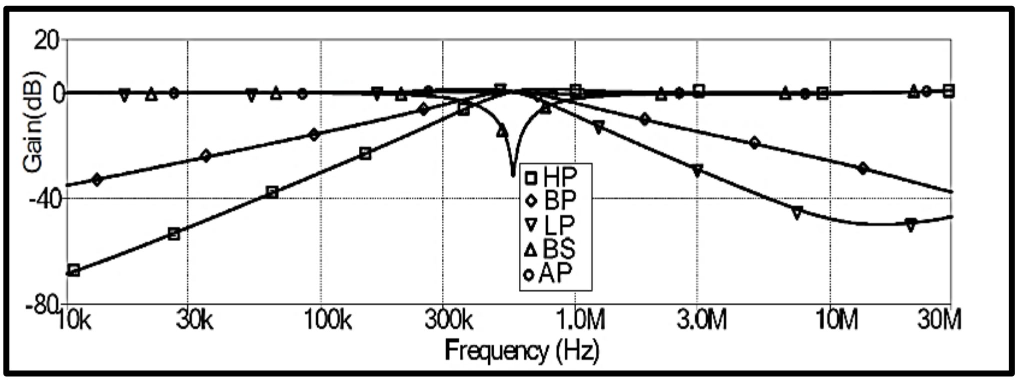


Figure 4. Proposed active circuit responses gain.

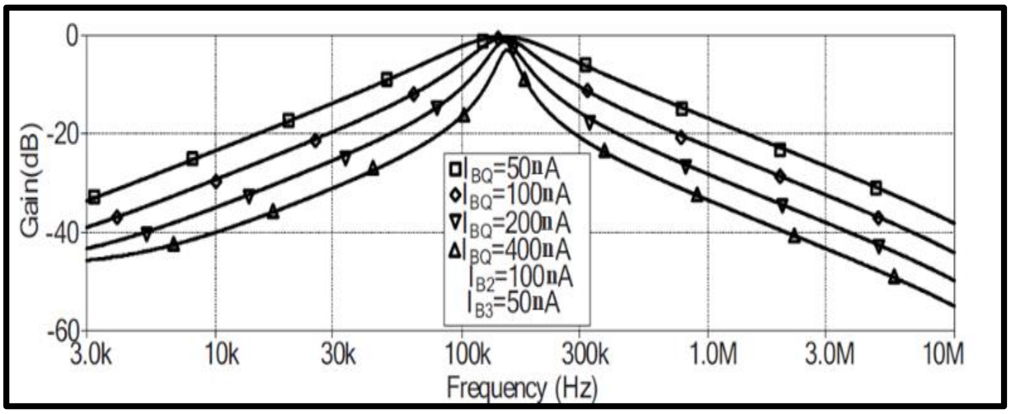


Figure 5. Responses on band passes for varying I_{BQ} levels.

3. CONCLUSIONS (SONUÇLAR)

The Finfet active filter M.O.C.C.C.C.T.A.s-based current-mode universal biquadratic active filter has been introduced. The following are the planned circuit's benefits: The distinct circuit arrangement can yield the whole set of conventional transfer functions. A microcontroller may be used to readily modify the quality factor, but it is also possible to electronically tune the pole frequency using bias currents. The circuit layout is appealing for IC implementation since it just has two grounded capacitors and two M.O.C.C.C.C.T.A. Due to its favorable characteristics, the proposed circuit stands out as a strong candidate for development into a monolithic chip, suitable for integration into battery-operated, portable electronic devices like components for wireless communication systems.

DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The author of this article declares that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan eder.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

***Hüseyin DEMİREL*:** He conducted the analyzed the results and performed the writing process.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

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