

DESIGN Third order Sinusoidal Oscillator Employing Current Differencing Cascaded Trans conductance Amplifiers

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Graphical/Tabular Abstract (Grafik Özet)

In this study, create third order oscillator using active block chip (CDCTA) with only three passive capacitors in cadence virtuoso and compare the result with experiment on a breadboard. / Bu çalışmada, kadans virtüözünde sadece üç pasif kapasitörlü aktif bir blok yongası (CDCTA) kullanarak üçüncü dereceden bir osilatör oluşturun ve sonucu bir breadboard üzerinde bir deneyle karşılaştırın.

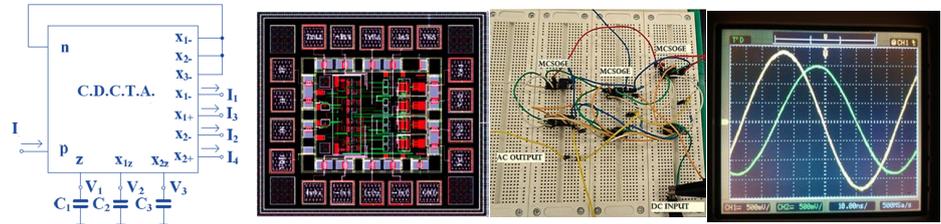


Figure A: An oscillator test breadboard and a proposed quadrature sinusoidal oscillator with experimental output waveforms / **Şekil A:** Bir osilatör test breadboard ve deneysel çıkış dalga formlarına sahip önerilen bir karesel sinüzoidal osilatör

Highlights (Önemli noktalar)

- A CDCTA active chip is created with three grounded passive capacitors. / Üç topraklanmış pasif kapasitör ile bir CDCTA aktif çip oluşturulur.
- Between two sinusoidal impulses, the oscillator under examination may offer a 90° phase difference. / İki sinüzoidal dürtü arasında, incelenen osilatör 90° faz farkı sunabilir.
- High impedance output current nodes were suited for cascading in a current-mode circuit without current buffers. / Yüksek empedanslı çıkış akımı düğümleri, akım tamponları olmayan bir akım modu devresinde basamaklama için uygundur.

Aim (Amaç): The aim of this study is to construct an active block of the CDCTA utilising the findings of an experiment on a breadboard and the 45 nm GPDK parameter data from Cadence Virtuoso. / Bu çalışmanın amacı, bir breadboard üzerindeki bir deneyin bulgularını ve Cadence Virtuoso'dan 45 nm GPDK parametre verilerini kullanarak CDCTA'nın aktif bir bloğunu oluşturmaktır.

Originality (Özgünlük): In this work, the result output was generated utilising a novel CMOS active block that used three passive capacitors and a cadence parameter of 45 nm with a chip called the MCSO6E oscillator. / Bu çalışmada, sonuç çıktısı, üç pasif kapasitör ve MCSO6E osilatörü adı verilen bir çip ile 45 nm'lik bir kadans parametresi kullanan yeni bir CMOS aktif blok kullanılarak üretildi.

Results (Bulgular): In this work, the theoretical calculation of the oscillation frequency $F_0=5.1$ MHz with low power supply voltage and the phase difference between dual-mode is 90° was performed using active block dual-mode (current and voltage) third-order. / Bu çalışmada, düşük güç kaynağı voltajı ile $F_0=5.1$ MHz salınım frekansının teorik olarak hesaplanması ve çift mod arasındaki faz farkı 90° olup aktif blok çift modlu (akım ve voltaj) üçüncü dereceden kullanılarak gerçekleştirilmiştir.

Conclusion (Sonuç): High stability, low sensitivity, and low power consumption. Considering the aforementioned benefits, the proposed sinusoidal sine oscillator can be utilised for sinusoidal signal sources in electronic measurements. / Yüksek stabilite, düşük hassasiyet ve düşük güç tüketimi. Yukarıda belirtilen faydalar göz önüne alındığında, önerilen sinüzoidal sinüs osilatörü, elektronik ölçümlerde sinüzoidal sinyal kaynakları için kullanılabilir.



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Abstract

In this study, the realization of a quadrature sinusoidal oscillator of third order was described. The Current Differencing Cascaded Transconductance Amplifier (CDCTA), a single active building block, was employed in this design in conjunction with three grounded passive capacitors. The suggested circuit's simple architecture provides it with a good candidate for inclusion in integrated circuits. The oscillator under examination may provide a 90° phase difference between two sinusoidal impulses. High impedance output current nodes made it possible to cascade them in a current-mode circuit without the need for current buffers since they were suitable for cascading. Moreover, the circuit only uses 1 mW of power, has a maximum sensitivity of 0.5, and oscillates at a frequency of up to 4.99 MHz. Additionally, both its oscillation frequency and condition may be electrically and independently adjusted. The theoretical analysis of the circuit was confirmed by the results of computer simulation using 45 nm gpdk cadence virtuoso program.

TASARIM Akım Farklılaştırıcı Basamaklı Trans iletkenlik Amplifikatörleri Kullanan Üçüncü dereceden Sinüzoidal Osilatör

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Öz

Bu çalışmada, Üçüncü dereceden bir karesel sinüzoidal osilatörün gerçekleştirilmesi tanımlanmıştır. Akım Farklılığındaki Basamaklı Transiletkenlik Amplifikatörü (CDCTA), tek bir aktif yapı taşı, Bu tasarımda üç topraklanmış pasif kapasitör ile kullanıldı. Önerilen devrenin basit mimarisi, onu entegre devrelere dahil etmek için uygun bir aday olarak sağlar. İncelenen osilatör, iki sinüzoidal impuls arasında 90° faz farkı sağlayabilir. Yüksek empedanslı çıkış akımı düşümleri. Basamaklama için uygun olduklarından, akım tamponlarına ihtiyaç duymadan bir akım modu devresinde basamaklamayı mümkün kılmıştır. Ayrıca, devre sadece 1 mW güç kullanır, maksimum 0,5 hassasiyete sahiptir ve 4.99 MHz'e kadar bir frekansta salınır. Ek olarak, hem salınım frekansı hem de durumu elektriksel ve bağımsız olarak ayarlanabilir. Devrenin teorik Analizi 45 nm gpdk kadans virtüöz programı kullanılarak bilgisayar simülasyonu sonuçları ile doğrulandı.

1. INTRODUCTION (GİRİŞ)

Sinusoidal oscillators have broad application prospects in signal processing fields such as communication, instrumentation, and automation, based on operational trans conductors (OTA), second-generation current transmitters (Second Generation Current Transducers, CCII), and current differential buffer amplifiers (Current Differential Buffer Amplifiers (Current Differential Amplifiers) Sinusoidal oscillator circuits for various voltage-mode modules such as Differentiating Buffered Amplifiers, CDBA) have been reported [1-3]. As

the requirements of integrated circuits in terms of speed, band, power consumption, etc., voltage-mode active devices have seriously affected the application of sinusoidal oscillators in the fields of high speed and high frequency. In 2003, D. Biolek first proposed a current differential trans conduction amplifier for pure current mode active devices (1~3). Current Differencing Trans Conducting Amplifier, CDCTA) Concept [4]

CDCTA has current input and current output characteristics. Compared with CCII, OTA, and CDBA, it has a lower operating voltage and a wider

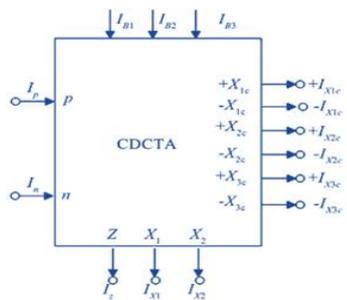
band, making up for many of the defects of previous voltage-mode active devices, and is ideal for integrated circuit design [5~10]. Current Differential Cascaded Transconductance Amplifiers (CDCTA) are the latest development of CDTA devices [11]. They combine the advantages of current differential trans conductors and computational trans conductors in terms of structure and performance. At the same time, because of their structure and performance The characteristics of the differential input structure and the fact that the internal circuit does not have a current-to-voltage conversion process make CDCTA have obvious advantages in simplifying the structure, reducing power consumption, broadening the band, and increasing reliability, especially in the oscillating circuit design based on CDCTA [12~15] This paper uses CDCTA and passive capacitors to design a low-power dual-mode (current and voltage) three-order oscillation integrated circuit.

2. MATERIALS AND METHODS (MATERİYAL VE METOD)

The methods used cadence virtuoso (45 nm gpdk parameter) program to create the various CMOS active and filter to obtain desired signal.

2.1 CDCTA and Its CMOS Circuit (CDCTA ve CMOS Devresi)

CDCTA is a pure current mode active device with current input and current output. Its circuit symbol and equivalent circuit are shown in Figure 1. P is the positive current input terminal of CDCTA, n is the negative current input terminal, and Z, Xi, and ±Xic are the high impedance current output terminals. Its port voltammetry characteristics are:



$V_p=V_n=0, I_z=I_p-I_n$ (1)

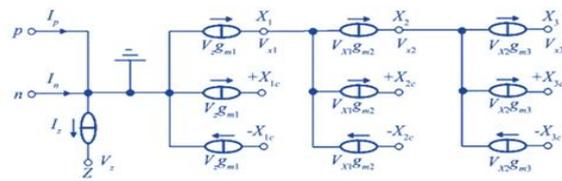
$\pm I_{x1c}=I_{x1}=g_{m1} \cdot V_z$ (2)

$\pm I_{x2c}=I_{x2}=g_{m2} \cdot V_{x1}$ (3)

$\pm I_{x3c}=I_{x3}=g_{m3} \cdot V_{x2}$ (4)

In the above equation, $V_p, V_n, V_z,$ and V_{xi} respectively indicate the voltage drop at the p, n, Z, and X_i ends of the CDCTA; $I_p, I_n, I_z, I_{xi},$ and I_{xic} respectively indicate the current flowing through the p, n, Z, $X_i,$ and X_{ic} ends; g_{mi} is the transconduction gain and can be adjusted by the

external bias current I_{BI} . By the formula (1) ~ (4) As can be seen, the voltage drop at the input end of CDCTA is constant to zero, and there is no voltage drop at the p and n ends. The input end of the current differential cascade transconductor amplifier uses this structure, so that it can obtain very low input impedance and a fairly wide band in some functional application circuits. As shown in Figure 2, the entire circuit consists of two parts: a current differential circuit and a multi-output transconduction amplification circuit [11]. The input stage achieves differential current input function and zero input characteristics through two sets of negative feedback current mirrors composed of CMOS tubes M_1 to M_{15} ; the output stage achieves multiple output transconduction amplification functions and high output impedance characteristics through a multi-level cross-coupling transconductor circuit composed of CMOS tubes M_{16} to M_{17} and an offset current source I_{BI} . Furthermore, the transconductivity gain G_{MI} value is related to the external bias current I_{BI} as shown in Equation (5), K is The fixed coefficient of the CMOS tube. All CMOS tubes M_p are equivalent to a stable offset current source. All CMOS tubes use the same DC power supply to ensure that the entire circuit works in a normal working state.



$g_m = \sqrt{KI_{BI}}$ (5)

Figure 1. Electrical symbol & Equivalent circuit of CDCTA (CDCTA'nın elektrik sembolü ve eşdeğer devresi)

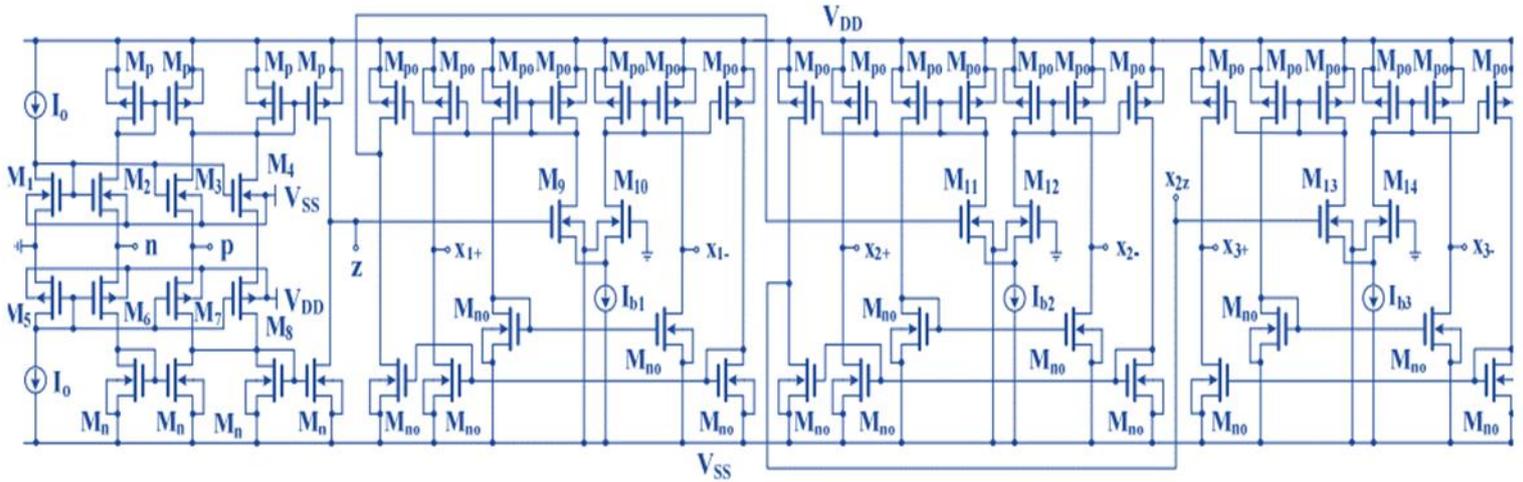


Figure 2. Implementation of CDCTA using CMOS transistor (CMOS transistör kullanarak CDCTA uygulaması)

2.2 Design of a 3rd Order Oscillator (3. Dereceden Bir Osilatör Tasarımı)

Figure 3 shows a third-order sinusoidal oscillator circuit based on CDCTA. It uses only a single CDCTA and three ground capacitors to achieve two sets of sinusoidal current signals (I_{o1}, I_{o2} and -I_{o1}, -I_{o2}) and a set of sinusoidal voltage signals (V₁, V₂ and V₃). Combining Figure 3 with Equations (1) to (4) for conventional circuit analysis, the circuit output

equations are as follows:

$$I_{o1} = I_{x2c} = g_{m2} V_{x1} = g_{m2} (I_{x1} / sC_2) \tag{6}$$

$$I_{x1} = g_{m1} * V_z = g_{m1} (I_z / sC_1) \tag{7}$$

$$I_z = I_p - I_n = -I_{x1c} - I_{x2c} - I_{x3c} \tag{8}$$

$$I_{o1} (s^2 C_1 C_2 + s C_2 g_{m1}) + g_{m1} * g_{m2} (I_{o1} + I_{o2}) = 0 \tag{9}$$

$$s^3 C_1 C_2 C_3 + s^2 C_2 C_3 g_{m1} + s C_3 g_{m1} g_{m2} + g_{m1} g_{m2} g_{m3} = 0 \tag{10}$$

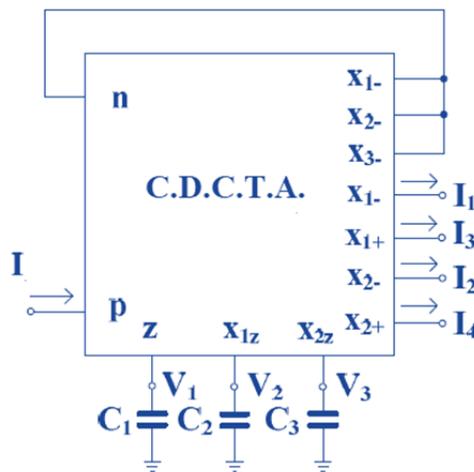


Figure 3. Proposed 3rd Order Using CDCTA (CDCTA kullanılarak önerilen üçüncü derecede)

Equation (10) shows that a sinusoidal oscillator based on CDCTA has a stable closed-loop gain, as shown below:

$$AF = \frac{(s^3 C_1 C_2 C_3 + s^2 C_2 C_3 g_{m1} + s C_3 g_{m1} g_{m2})}{(g_{m1} g_{m2} g_{m3})} = -1 \tag{11}$$

According to conventional circuit analysis methods, a sinusoidal oscillating circuit should meet the following conditions for stable oscillation. It can be seen from the equation (11).

$$A(\omega) = \frac{1}{(g_{m1}g_{m2}g_{m3})} = 1 \tag{12}$$

$$F(\omega) = \{ (j\omega)^3 C_1 C_2 C_3 + (j\omega)^2 C_2 C_3 g_{m1} + (j\omega) C_3 g_{m1} g_{m2} - \omega^2 C_2 C_3 g_{m1} + j(\omega C_3 g_{m1} g_{m2} - \omega^3 C_1 C_2 C_3) \} \tag{13}$$

It can be seen from equations (12) and (13) that the proposed oscillator basically amplifies the large circuit gain A and the feedback circuit gain F, and the difference between the proposed oscillator is as follows:

$$|F(\omega)| = \frac{1}{\sqrt{(-\omega^2 C_2 C_3 g_{m1})^2 + (\omega C_3 g_{m1} g_{m2} - \omega^3 C_1 C_2 C_3)^2}} \tag{14}$$

Thus, when $n = 1$ is taken for the combined equation (12) and equation (14) analysis, we have:

$$|A(\omega)||F(\omega)| = \frac{\omega^2 C_2 C_3 g_{m1}}{g_{m1} g_{m2} g_{m3}} = 1 \tag{15}$$

Using Equation (5) and substituting Equation (15) analysis respectively, it can be obtained that the oscillation conditions and oscillation frequency of the proposed sinusoidal oscillator are classified as follows:

$$\frac{g_{m3}}{g_{m1}} = \frac{\sqrt{I_{B3}}}{\sqrt{I_{B1}}} = \frac{C_3}{C_1} \tag{16}$$

$$W = K * \sqrt{\frac{g_{m1} * g_{m2}}{C_1 * C_2}} = \sqrt{\frac{I_{B1} * I_{B2}}{C_1 * C_2}} \tag{17}$$

As can be seen from equations (16) and (17), the oscillation condition and oscillation frequency of the CDCTA are related to the transconductive g_{mi} of CDCTA, so the oscillation condition and oscillation frequency of the circuit can be changed by adjusting the external bias current i_{Bi} . Further more, when other parameters are kept unchanged, the oscillation conditions of the circuit can be changed without changing the oscillation frequency; similarly, when only g_{m2} is electronically regulated, the oscillation frequency of the circuit can be changed. Oscillation conditions are not affected. Therefore, the oscillation conditions and oscillation frequency of this third-order sinusoidal oscillator can be

electronically controlled and tuned independently of each other. Further analysis of the output current and voltage transmission characteristics of the

proposed circuit results in the following relationships:

$$I_{o1}(s)/I_{o2}(s) = sC_3/g_{m3} \tag{18}$$

$$V_{o1}(s)/V_{o2}(s) = sC_3/g_{m2} \tag{19}$$

Obviously, equations (18) and (19) show that the phase difference between I_{o1} and I_{o2} is 90° , and the phase difference between V_{o1} and V_{o2} is 90° . Therefore, the proposed circuit can simultaneously achieve sinusoidal current signals and sinusoidal voltage signals in the same Circuit. Furthermore, assuming that CDCTA has the same trans conductivity parameters and uses the same passive capacitor, that is,

$g_{m1} = g_{m2} = g_{m3} = g_m, C_1 = C_2 = C_3 = C$, further analysis of transmission. The amplitude characteristics of the output signal can be obtained:

$$\left| \frac{I_{o1}(j\omega)}{I_{o2}(j\omega)} \right| = \frac{C_3}{g_{m3}} \sqrt{\frac{g_{m1} g_{m2}}{C_1 C_2}} = \frac{C}{g} \sqrt{\frac{g^2}{C^2}} = 1 \tag{20}$$

$$\left| \frac{V_{o1}(j\omega)}{V_{o2}(j\omega)} \right| = \frac{C_3}{g_{m3}} \sqrt{\frac{g_{m1} g_{m2}}{C_1 C_2}} = \frac{C}{g} \sqrt{\frac{g^2}{C^2}} = 1 \tag{21}$$

It can be seen that the two sets of sinusoidal current signals of the proposed n th-order sinusoidal oscillator have the same amplitude characteristics as a set of sinusoidal voltage signals. Furthermore, it can also be seen from the above equation that the amplitude of the output signal of the sinusoidal oscillator can also be adjusted by changing the size of the external bias current I_{Bn} according to actual application conditions.

2.3 Sensitivity Analysis (Hassasiyet Analizi)

Since the proposed circuit is affected by the non-ideal characteristics of the active device, there will be a certain deviation from the ideal value in actual application. Therefore, for a complete circuit analysis, it is necessary to further analyze and explore the non-ideal characteristics of the circuit. Assume that α_p ($\alpha_p = 1 -$

$\epsilon_p, |\epsilon_p| < 1$) and α_n ($\alpha_n = 1 - \epsilon_n, |\epsilon_n| < 1$) are the biological transmissions of CDCTA from p and n end to Z end, respectively Current transfer gain, β ($\beta = 1 - \epsilon_b, |\epsilon_b| < 1$) is the output trans conduction error of z, xi to $x_1, x_{(i+1)}$ end, and γ ($\gamma = 1 - \epsilon_c, |\epsilon_c| < 1$) is the xi end Since in a non-ideal situation, the values of the parameters $\alpha, \beta,$ and

gamma are infinitely close to 1 but not equal to 1, the parasitic conductors Gz, Gz1, and Gx2 are infinitely close to 0 but not equal to 0, and C'1, C'2, C3. As can be seen from equation (26), the oscillation frequency of the proposed sinusoidal oscillator is small compared to the theoretical value. Therefore, in order to make up for the non-ideal characteristics of the oscillation frequency Effects, gm1 and gm2 values should be adjusted to compensate in the actual circuit. According Parasitic current transmission gain to the XIC end. Furthermore, under non-ideal circumstances, there are parasitic impedance Rp and Rn at the p and n ends, and there are also ground parasitic resistors Rz, Rxi, Rxic, and parasitic capacitors Cz, Cxi, and Cxic at the Z, Xi, and Xic terminals respectively. When the oscillator frequency is less than 1/ (Cxc * Rn) or 1/ (Cxi * Rp), a non-ideal CDCTA circuit is used to recreate the proposed third-order sinusoidal oscillator The analysis is as follows:

$$I_z = \alpha_p \cdot I_p - \alpha_n \cdot I_n \tag{22}$$

$$I_{x1} = \beta_1 g_{m1} V_z \tag{23}$$

$$I_{xi} = \beta_n g_{mi} V_{x(n-1)} \quad (i=2,3) \tag{24}$$

$$I_{xi} = \gamma_n I_{xi} \quad (n=1,2,3) \tag{25}$$

Combine Figure 3 with the above equation to recalculate the characteristic equations of a third-order sinusoidal oscillator under non-ideal conditions:

$$\omega_0 = \sqrt{\frac{(G_z \cdot G_{x2} \cdot C'2 + G_{x1} \cdot G_{x2} \cdot C'1 + G_z \cdot G_{x1} \cdot C'3 + \beta_1 \cdot \gamma_1 \cdot \gamma_2 \cdot \alpha_p \cdot g_{m1} (G_z \cdot G_{x1} \cdot C'3 + G_z \cdot G_{x2} \cdot C'2 + \beta_2 \cdot g_{m2} \cdot G_z \cdot G_{x1} \cdot C'3))}{C_1 C_2 C_3}} \tag{26}$$

The values are very low, and their absolute values are not greater than 0.5. As a result, the proposed circuit has a high degree of stability. to the sensitivity formula $S_y^x = (x/y) \cdot \frac{\partial y}{\partial x}$, the active and passive sensitivity values of an sinusoidal oscillator can be obtained by equation (26)

$$S_{\beta_1, \beta_2, \alpha_p, \gamma_1, \gamma_2}^{\omega_0} = 0.499 \quad , \quad S_{C_1, C_2, C_3}^{\omega_0} = 0.499$$

$$S_{g_{m1}, g_{m2}}^{\omega_0} = 0.499 \quad S_{\beta_3, \alpha_3, \gamma_3, g_{m3}}^{\omega_0} = 0 \tag{27}$$

As can be seen from equation (27), the oscillator is passive and active sensitive. Table 1 contrasts the performance of the proposed CDCTA with the main results of the cited [15] CDCTA. In terms of voltage of supply, input spectrum, bandwidth, and consumption of power, Table 1 shows that the recommended circuit outperforms the CDCTA while keeping acceptable both its input and output impedance characteristics. It is also clear that the recommended circuit consumes 1 mW of power. The test bread board for the MCS06E oscillator is shown in Figure 8, together with the results of the measured experiments. The average OF approximates 321.1 kHz,

Table 1. Compares of the reference [15] CDCTA with the proposed CDCTA's performance

(Tablo 1. Referans [15] CDCTA'nın önerilen CDCTA'nın performansı ile karşılaştırılması)

Performances	[15]	This work
Process	0.5 μm	45 nm
Adjustable feature for tranconductance (mS).	0.8–138	130–20
Voltage of supply (V)	1.25 V	0.9 V
Consumption of power	2.48 mW	1 mW
Input spectrum (GHz)	0.95, 0.95, 0.93	0.049
Input and output impedance characteristics (V)	7.03, 15.18	22
Technology programs	Ltspice	Cadence virtuoso

3. RESULTS AND DISCUSSION (BULGULAR VE TARTIŞMA)

In order to verify the accuracy of the above theoretical analysis, CADENCE virtuoso 45 nm gpdk simulations were performed on the proposed dual-mode (current and voltage) third-order sinusoidal oscillator. The simulation process model used the TSMC 45 nm CMOS process and the W/L width-to-length ratio settings for the CMOS tube are shown in Table 2. The power supply voltage $V_{DD} = -V_{SS} = 0.9$ V, $I_0 = 25\mu\text{A}$. The offset current and passive capacitance values are respectively $I_{B1} = 58 \mu\text{A}$, $I_{B2} = 59 \mu\text{A}$, $I_{B3} = 57 \mu\text{A}$, $C_1 = C_2 = C_3 = 12$ pF, the theoretical calculation of the oscillation frequency $F_0=5.1$ MHz. The output sinusoidal current and voltage signal simulations results are shown in Figure 4 and Figure 5, respectively. Actual spectrum of current outputs of the oscillator measurements in Figure 6.

The phase difference between I_{o1} and I_{o2} is 90° , the phase difference between V_{o1} and V_{o2} is 90° , the simulation results are in line with theoretical derivation. Furthermore, the power consumption of the third-order sinusoidal oscillator circuit was measured to be 1 mW. In order to meet actual application requirements, the proposed circuit was implemented using a 45 nm CMOS process flow sheet. The micrograph of the chip is shown in Figure 7. The total area of the chip is only about $03 \times 03 \text{mm}^2$ shown below is an image of the output sinusoidal voltage signal measured at the end points of the V_{o1} and V_{o2} chips, and the measured phase difference is 90.00° . The simulation and experimental results show the proposed 3rd order shown in Figure 8 with output signal. The oscillator circuit is correct and effective, and has practical application significance.

Table 2. CMOS tube parameters (CMOS tüp parametreleri)

COMSTRANSISTORS	W(µm)/L(µm)
M1, M2, M3, M4, Mn	25/1
M5, M6, M6, M8, Mp	1/1
M9, M10	50/1
Mop	70/0.9
Mon	25/0.9

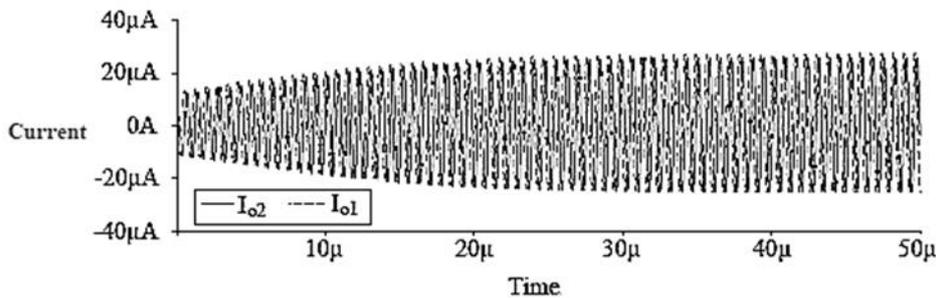


Figure 4. Current outputs of the proposed oscillator (Önerilen osilatörün akım çıkışları)

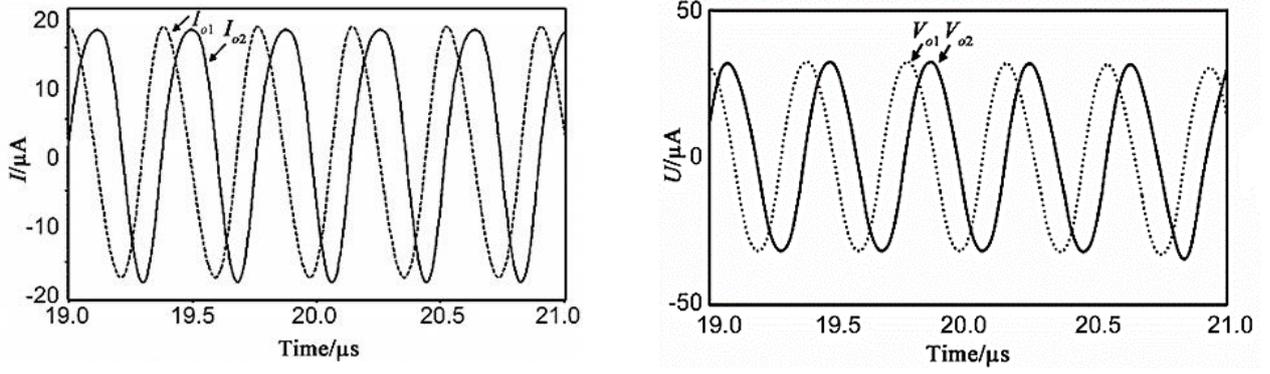


Figure 5. Dual-mode (Current and voltage) outputs of the proposed oscillator (Önerilen osilatörün çift modlu (Akım ve voltaj) çıkışları)

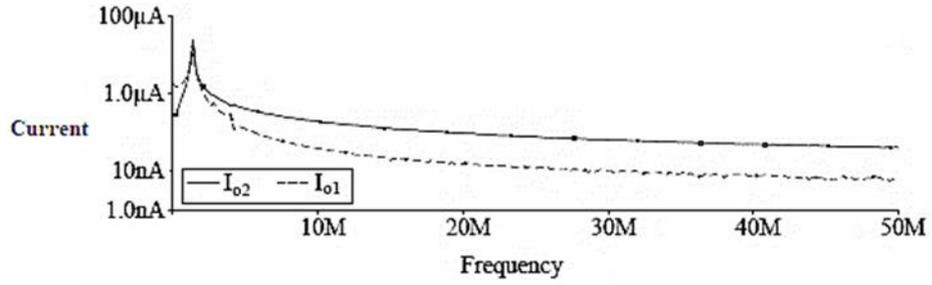


Figure 6. Spectrum of current outputs of the oscillator (Osilatörün akım çıkışlarının spektrumu)

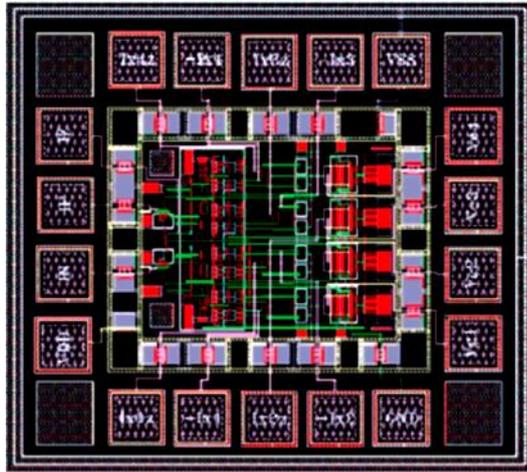


Figure 7. Layout of the Active filter (CDCTA) (Aktif filtrenin düzeni (CDCTA))

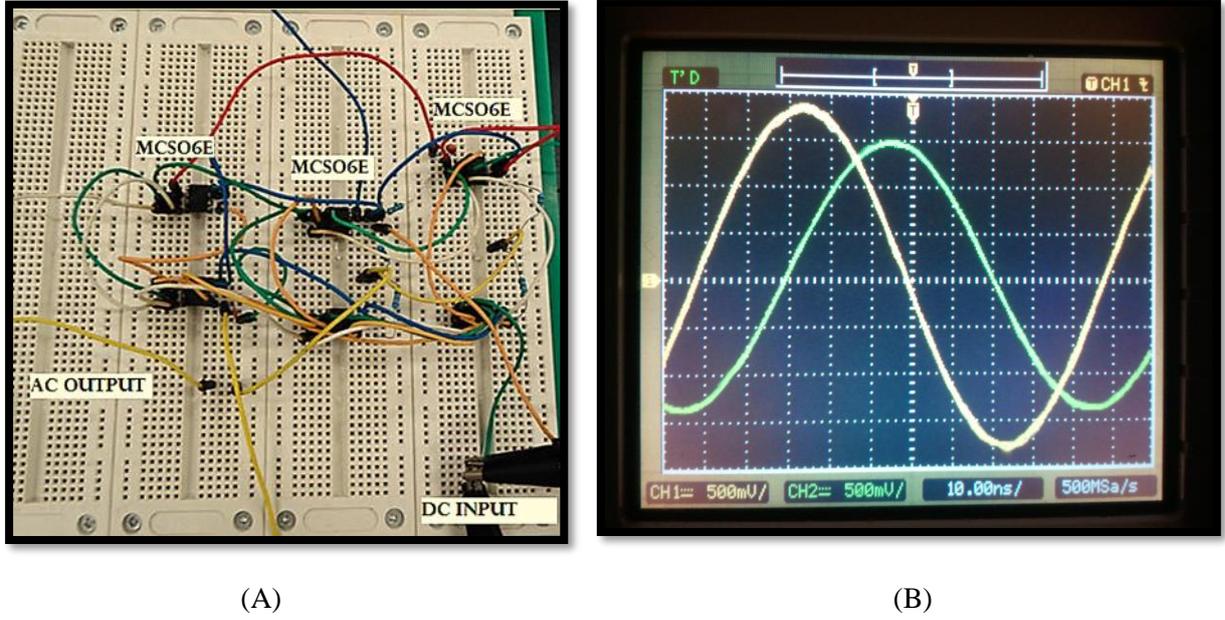


Figure 8. Experimentally, the oscillator response was determined. **A** and **B** are the experimental output waveforms and the oscillator test breadboard (Deneysel olarak osilatör yanıtı belirlendi. **A** ve **B** deneysel çıkış dalga formları ve osilatör test devre tahtasıdır)

4. CONCLUSION (SONUÇLAR)

Suggest a dual-mode (current and voltage) analog integrated third-order sinusoidal oscillator circuit. The proposed circuit has the following characteristics: (1) there are few active and passive components and the structure is simple; (2) there are no resistors, all capacitors are connected, and are easy to integrate; (3) It is versatile and can generate sinusoidal current and sinusoidal voltage signals at the same time; (4) The oscillation frequency is high, making it easy to apply in the high frequency field ; (5) The oscillation frequency and oscillation conditions can interact with each other Independent electronic control and regulation, flexible application; (6) Low power consumption, low sensitivity, and high stability. Based on the above advantages, the proposed sinusoidal sine oscillator can be used for sinusoidal signal sources in electronic measurements, carrier signals in wireless transmitters, clock signal sources in digital systems, and everything else requiring sinusoidal current signals. the results of the active filter simulation using 45 nm gpdk cadence virtuoso program.

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 ederler.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

Arsen Ahmed MOHAMMED: He conducted the experiments, analyzed the results and performed the writing process.

Deneyleri yapmış, sonuçlarını analiz etmiş ve maklenin yazım işlemini gerçekleştirmiştir.

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

Deneyleri yapmış, sonuçlarını analiz etmiş ve maklenin yazım işlemini gerçekleştirmiştir.

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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