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A DVCC Based Realization of Optimized Fractional Step Low Pass Filter

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18
Full
Text Views

Abstract

Document Sections

I. Introduction

II. Design Technique

III. Simulation Results

IV. Conclusions

Authors

Figures

References

Keywords

Metrics

More Like This

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Realization of fractional-step low-pass Butterworth filter (FSLBF) using a differential voltage current conveyor (DVCC) is presented. To approximate the FSLBF characteristic, the coefficients of three different filter transfer functions are optimally determined using the Craziness-based Particle Swarm Optimization (CRPSO) algorithm. Minimum absolute pole angle, −3 dB frequency response, squared magnitude error, etc., of the FSLBFs are evaluated. Simulations verify the efficacy of DVCC-based realizations for the designed frequency filters.

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22-23 Nov. 2024

Showing **76-100** of **161**

Testing the Accuracy of Fibonacci Retracement Levels Using Artificial Intelligence
Pratik Kodmalwar; Leena Kapse; Amol Mashankar; Kumar Mansukhani; Amruta Mahalle; Nilesh Bhosale
Publication Year: 2024 , Page(s): 399 - 404
Abstract HTML

Multi-Keywords Based Fully Homomorphic Encryption and Data Classification for Cloud Security and Privacy
Kooragayala Sukeerthi; R. Kesavan; S.A. Kalaiselvan
Publication Year: 2024 , Page(s): 405 - 411
Abstract HTML

Virtual Zone Construction for Clustering Process in Mobile Wireless Sensor Networks
B. Swathi; M. Amanullah; S.A. Kalaiselvan
Publication Year: 2024 , Page(s): 412 - 418
Abstract HTML

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Parul Dubey; Sumit Prasad; Lubhawani Tripathi; Rashmi Sharma; Sampada Mashirkar; Shilpa Ghode
Publication Year: 2024 , Page(s): 419 - 424
Abstract HTML

Spinal Column Needle with a Force Feedback: Introductory Study
Samir Morad; Kiran Hayer; Ameer. H. Morad; Taha Mehraj
Publication Year: 2024 , Page(s): 425 - 429
Abstract HTML

Source Camera Identification of Images Using Transfer Learning
Kapil Raisinghani; Yash Mohan; Kavita Jhajharia
Publication Year: 2024 , Page(s): 430 - 434
Abstract HTML

Effective Positioning of Shear Wall in Multistoried Building in Medium Soil Condition Using Response Spectrum Analysis
Vaidehi Wasalwar; Vivek Jayale

Publication Year: 2024 , Page(s): 1 - 6

Abstract HTML

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Sonia Singh; Neha Gupta
Publication Year: 2024 , Page(s): 441 - 446

Abstract HTML

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Shibendu Mahata; Soumen Mallick; Rahul Kumar Tanti; Balaram Halder; Piyush Dutta; Subhajit Hati
Publication Year: 2024 , Page(s): 447 - 452

Abstract HTML

Modelling and Synthesis of a Ring Oscillator Based True Random Number Generator using Opensource EDA Tools
Dipti Khurge; Sheetal Bhandari; Gaurav Joshi; Harshal Khairnar; Yash Meshram; Gaurav Patil
Publication Year: 2024 , Page(s): 453 - 456

Abstract HTML

Smart Water Management System for Housing Societies
Abha Marathe; Ayush Lodha; Omkar Lolage; Piyush Lodha; Leevan Herald
Publication Year: 2024 , Page(s): 457 - 461

Abstract HTML

Implementation of Web Based Intelligent System for Diabetes Prediction Using Machine Learning
Abhishek Rana; Parampreet Kaur
Publication Year: 2024 , Page(s): 462 - 467

Abstract HTML

Assessing Protection Systems for Solar PV Penetration Across Different Locations to Enhance Grid Stability and Reliability
P. S. Patil; R. M. Moharil; A. S. Lilhare
Publication Year: 2024 , Page(s): 468 - 473

Abstract HTML

Controlling Electric Switches Using IoT Devices as a Smart Switch via Android Application
Pradnyawant M. Gote; Rasika Hajare; Karan Urkude; Mohan Warbhe; Yash Pachghare; Tejas Pisal
Publication Year: 2024 , Page(s): 474 - 479

Abstract HTML

Determination of Properties of Soil with Ultrasonic Pulse Velocity
Jayant Manohar Raut; Kashisha Prabhakar Kapse; Sonal Bhagwan Dhanvijay; Kamlesh Prashant Thawkar; Pawan Keshaorao Hinge; Tejaswi Ajay Sahare; Tanushree Damodhar Ramteke; Rahul Parasaram Rathod
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Abstract HTML

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A DVCC based Realization of Optimized Fractional Step Low Pass Filter

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***Abstract*—Realization of fractional-step low-pass Butterworth filter (FSLBF) using a differential voltage current conveyor (DVCC) is presented. To approximate the FSLBF characteristic, the coefficients of three different filter transfer functions are optimally determined using the Craziness-based Particle Swarm Optimization (CRPSO) algorithm. Minimum absolute pole angle, –3 dB frequency response, squared magnitude error, etc., of the FSLBFs are evaluated. Simulations verify the efficacy of DVCC-based realizations for the designed frequency filters.**

***Index Terms*—fractional order circuits, fractional step filter, Butterworth filter, craziness-based particle swarm optimization, differential voltage current conveyor**

I. Introduction

Fractional-order systems are governed by fractional differential equations, which use derivatives and integrals of non-integer order as core operators [1]. This mathematical framework, known as fractional calculus, has diverse applications [2]–[4].

A fundamental element in building fractional-order analog circuits is the constant phase component, such as a fractional-order capacitor (FOC) [5]. Given the lack of commercially available FOCs, researchers have developed approximations using R-C ladder networks; one notable approach is the Foster-II network, illustrated in Fig. 1 [6]. Realization of fractional filters that employ the FOC [7], FOC emulator [8], and rational approximation technique [9] have been published in the literature.

FSLBFs offer a gradual stopband attenuation of $-20(n+\alpha)$ dB/dec, where α ranges between 0 and 1 [10]–[13]. For filters of order $1+\alpha$, with a pole-frequency ω_0, approximation can be achieved as described in equations (1)-(3).

$$H_A^{1+\alpha}(s) = \frac{1}{(s/\omega_0)^{1+\alpha} + k_{1A}(s/\omega_0)^{\alpha} + k_{2A}} \tag{1}$$

$$H_B^{1+\alpha}(s) = \frac{1}{(s/\omega_0)^{1+\alpha} + k_{1B}(s/\omega_0) + k_{2B}} \tag{2}$$

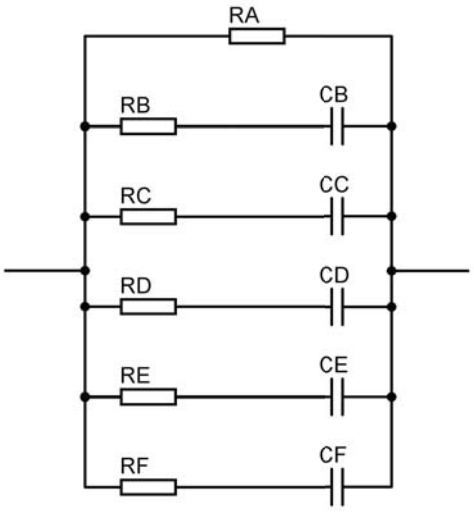

Fig. 1. A Foster-II network.

$$H_C^{1+\alpha}(s) = \frac{1}{(s/\omega_0)^{1+\alpha} + k_{1C}(s/\omega_0)^{(1+\alpha)/2} + k_{2C}} \tag{3}$$

where k_{1A}, k_{2A}, k_{1B}, k_{2B}, k_{1C}, and k_{2C} are the coefficients of the filter functions.

This study introduces the application of the CRPSO algorithm [14] to optimize filter design coefficients, specifically k_{1A}, k_{2A}, k_{1B}, k_{2B}, k_{1C}, and k_{2C}, for the first time. The goal is to reduce the discrepancy between the theoretical and actual magnitude responses of the proposed FSLBFs. Evaluation criteria include stability margin, error within the design frequency band, –3 dB cutoff frequency, and roll-off characteristics. The designs for orders 1.1, 1.5, and 1.9 are realized using DVCCs. Monte Carlo simulations further assess the impact of component tolerances on circuit performance.

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