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A study of fractional order circuits and Systems

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ABSTRACT

This work provides a study to expand the continuous time filter design into the domain of fractional orders, based on fractional calculus techniques. Fractional calculus is a mathematical field, that investigates how non-integer order differential and integral operators affect system modeling and control.

Because it offers additional degrees of freedom that the integer order subspace does not, fractional calculus has been shown in multiple articles to be superior in describing non-local and physical processes.

In this study, all filter responses are recovered using inverting and non-inverting filters based on Sallen-key voltage mode architecture, follow-the-leader-feedback (FLF), inversefollow-the-leader multi-feedback (IFLF) topologies. The study presents generalized formulas for each response's transfer function with various fractional orders.

The additional degree of freedom offered by the fractional order parameters allows the fractional order filters to improve the design flexibility and controllability. Two approaches are studied in the design of fractional order filter: converting to equivalent integer order transfer function using syntheses transformation techniques, getting the coefficients of the fractional transfer function over a certain frequency band using filters specifications parameters ($\omega cutoff$,$\omega stopband$, passband ripples,...).

A new third approach is introduced to get the optimal coefficients of the fully fractional transfer function over all bands of the approximation based on a metaheuristic algorithm, the generated transfer function approximated the magnitude response of the filter type.

This work also investigates the fundamentals of fractional calculus, fractional differential equations, and some of its engineering applications, such as control, signal processing, and fluid mechanic application.

Various numerical solutions are introduced including solving frictional order differential equations and fractional order filter design.

In addition, a discussion of stability is provided for several fractional-order cases. The Spice circuit simulation results are constantly compared to Matlab numerical simulation of the transfer functions to demonstrate the validity of the created methods. All filters are implemented using passive circuits, active circuits, or both.