# ABSTRACT

This Ph.D thesis investigates the design, realization and performance of low-voltage low-power signal processing applications in the fractional domain. Fractional calculus is about 300 years old, branch of mathematics that deals with the hypothesis of differentiation and integration of non integer orders. Components which exhibit properties of fractional impedance are called Fractional Order Elements (FOEs). However, these FOEs are not available in the market. Therefore, as far as commercial FOEs become accessible to realize circuits of $s^{\alpha}$, integer-order approximations must be utilized. The Continued Fraction Expansions (CFEs) and rational approximation methods are most commonly used methods to approximate $s^{\alpha\cdot}$ Investigation of analog filter circuits using FOEs enhances the design functionality and proves that the integer-order performance is a very narrow subset of the fractional-order. Therefore, it is always challenging to design the analog filters in the fractional domain.

In general, an extensive variety of Fractional Order Filters (n+$\alpha$) are available that utilize two techniques to realize the fractional transfer functions (FTFs) where n is the integer order and α is the fractional step of filter, which essentially utilize two techniques to realize the FTFs. In the first technique FSFs are realized by using fractional order element having admittance $s^{\alpha}C$ instead of traditional capacitor having admittance sC. Whereas in second technique, the design of FSFs is based on the approximation of fractional step filters by using an appropriate integer order transfer function.

In this thesis, the design, realization and performance of second order filter in the fractional domain based on first techniques offering: (i) operate on low-voltage, (ii) provide low sensitivity and (iii) suitable for IC-implementation, is investigated as a first step. Moreover there is no component matching constraints.

Next, the fractional order filters with 3 degrees of freedom offering following benefits: (i) circuit can be used to realize third order FLP, FHP and FBP responses in fractional domain from the same topology (ii) minimal number of active and passive components (iii) uses three fractional capacitors of different orders (α+β+γ) which enhances the design flexibility, is introduced for the first time in literature.

Furthermore, the filters of order (1+ α) based on the second technique providing interesting features namely: (i) grounded capacitors are used to realize all the filters, which is the significant advantage for practical design because it is easy to fabricate grounded capacitors, (ii) no constraints of component matching and (iii) this approach is very simple and provides design adaptability. Signal Flow graph (SFG) approach is used for the realization Fractional step Filters of order (1+α) which eliminates the utilization of FOEs. The evaluation of the realized fractional step filters are also performed through the AC analysis and Corner Analysis

It is worth noting that Current Mode circuits (CMCs) find usefulness in the design of fractional order filters because they provide one or more of the following advantages higher bandwidth, better signal linearity range, higher slew rates, lower power consumption, and better accuracy. In addition, CMCs are often less complex than the voltage-mode circuits, which may lead to save in chip area. The analog building blocks (ABBs) utilized in this thesis are Current Differencing Buffered Amplifiers (CDBAs) and Operational Transresistance Amplifiers (OTRAs).

At the end of this thesis, a compact design of fractional filter is proposed. This filter is realized by FOEs that are obtained using single RC parallel network and offering the following benefits: (i) Low active and passive sensitivities and (ii) The reduced complexity in design of fractional filters is to save in chip area.

Finally, the signal processing applications are presented using FOEs verifying the requirement of fractional calculus, especially when compared with the corresponding integer-order counterparts.

**Keywords:** Fractional calculus, fractional order elements (FOEs), fractional order capacitor(FOC), fractional order filters, critical frequencies, stability, sensitivity, Total Harmonic Distortion(THD), noise, analog building blocks.