Optimal design of second generation current conveyor using craziness-based particle swarm optimisation

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Abstract: In this paper, a population-based meta-heuristic search algorithm called craziness-based particle swarm optimisation (CRPSO) has been employed for the optimal design of positive second-generation current conveyor based on a trans-linear loop ($CCII^+$). CRPSO accepts several random variables for encompassing improved and quicker search and utilisation in multidimensional search space. The main goal of this work is to optimally size the $CCII^+$ building block to attain the suitable aspect ratios of the MOS transistors. To enhance the performance of a $CCII^+$ design, it needs to increase the higher cut-off frequency of the current signal (f_{CI}) as well as to decrease the input X-port parasitic resistance (R_X). Accordingly, the optimisation problem is developed as a bi-objective problem of minimisation to obtain the least value of R_X and the superior value of f_{CI}. The current conveyor is simulated and validated using UMC 180 nm CMOS technology with a power supply of ±2.5 V in Cadence Virtuoso XL Design Environment.

Keywords: CMOS; circuit sizing; second generation current conveyor; trans-linear loop; CRPSO; evolutionary optimisation techniques; X-port parasitic resistance; higher cut-off frequency.

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1 Introduction

The three main steps of analogue circuit design topology selection, sizing of the circuits and circuit layouts continue to draw attention of analogue circuit designers (Graeb and Antreich, 2007). The sizing and design of the high-performance analogue system are done by expert designers (Tlelo-Cuautle and Duarte-Villaseñor, 2008). The ever-increasing circuit density builds the design process extravagantly monotonous for the expert designers to achieve the best possible design constraints. Actually, the best possible analogue building block design is a hindrance in the entire design path. Programmed optimisation technique for analogue building block sizing is an essential stuff towards the capability to rapidly design the superior performance building blocks are shown in Toumazou et al. (1990) and Conn et al. (1996). In analogue CMOS integrated circuit (IC) design method, the MOS transistors' aspect ratios guarantee that the search area and optimisation method are even and trustworthy. For the automation of the optimal design of analogue CMOS IC, efficient optimisation algorithms are very crucial.

Classical deterministic techniques are relevant for small size problems. The classical statistical techniques are initiated by setting up of a proper DC quiescent point given by the expert designer and then a simulation-based method is employed. On the other hand, these statistical techniques are time-taking and do not assure the convergence in the direction of the optimal global solution is proposed in Talbi (2002). Therefore, classical optimisation techniques are very complex, extremely constrained and nonlinear procedure and hence are not suitable for handling the large size problems. This is the primary inspiration to accept the heuristic-based evolutionary algorithms (EAs) to explain the modern composite nonlinear problems.

Generally, the analogue circuit is formulated with different types of performance parameters, variables and objective/cost functions to design optimally. Therefore, when the design problem becomes much complex, the methods above for optimisation usually require extensive computational time as well as occupy larger space for searching. In Bonabeau et al. (1999), a novel set of bio-inspired-based meta-heuristic algorithms is proposed to overcome the shortcomings associated with those optimisation algorithms. The thought process after those of the algorithms is inspired by the combined behaviour of self-organised and decentralised systems.

Nowadays, most of the new algorithms developed are nature-inspired. The majority of the nature-inspired optimisation algorithms are derived from several biological systems and bio-inspired. Among the bio-inspired algorithms, a particular group of algorithms has been developed by drawing inspiration from swarm intelligence. The thought process at the rear of those algorithms above is inspired by the collective behaviour of decentralised, self-organised systems. Some of the well known nature-inspired algorithms are particle swarm optimisation (PSO) (Kennedy and Eberhart, 1995; Eberhart and Shi, 1998; Clerc and Kennedy, 2002), ant colony optimisation (ACO) (Dorigo et al., 1999) and artificial bee colony (ABC) (Karaboga and Basturk, 2008), etc. PSO is highly recognised by the researchers because of its enormously well performing characteristics in various areas of application (Banks et al., 2007). In Guerra-Gomez et al. (2009), HPSICE-based multi-objective EA is employed to optimise the second-generation current conveyors (CCII) is proposed. Without the help of circuit evaluator, a multi-objective heuristic (Salem et al., 2006) and PSO (Cooren et al., 2007; Fakhfakh et al., 2009, 2010) techniques are used to obtain the optimal sizing of high-performance CMOS current conveyors (CCs). The design of CCII using bacterial foraging optimisation (BFO) and differential evolution (DE) is proposed in Chatterjee et al. (2010) and the same is designed using the multi-swarm PSO–2S in Dor et al. (2014). Detailed analysis of the application of EAs for the synthesis and sizing of analogue ICs can be found in Tlelo-Cuautle et al. (2010). Social-emotional optimisation algorithm (SEOA) is employed for the optimal sizing of analogue CMOS amplifier circuits is proposed in Mallick et al. (2017). A hybrid GSA-GA algorithm for constrained optimisation problems is proposed in Garg (2019). In Garg (2016), a hybrid PSO-GA algorithm for constrained optimisation problems s proposed. A hybrid GA-GSA algorithm for optimising the performance of an industrial system by utilising uncertain data is proposed in Garg (2015) and an efficient biogeography-based optimisation algorithm for solving reliability optimisation problems can be found in Garg (2014).

PSO is flexible, robust, population-based stochastic search algorithm with attractive features of simplicity in implementation and ability to quickly converge to a reasonably good solution. Additionally, it has the capability to handle larger search space and non-differential objective function (OF), unlike traditional optimisation methods. But to enhance the overall performance of the basic PSO, a craziness factor in introduced and the proposed optimisation algorithm is called CRPSO. To increase the performance of optimisation algorithm in global search as well as local search, the authors are motivated to adopt CRPSO technique for the optimal design of positive second-generation CC based on a trans-linear loop. Integration of craziness factor in the basic velocity expression of PSO brings multiplicity in particles as well as confirms convergence to optimal solution. The proposed CRPSO-based approach has