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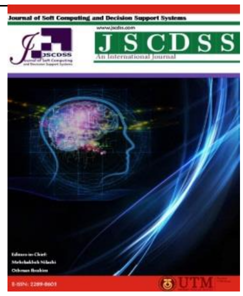

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Four-Quadrant Weak Inversion Analog Multiplier in the 180nm Technology for Biomedical Applications

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Abstract

In this paper, a current-mode four-quadrant analog multiplier circuit is proposed that utilizes MOS translinear principle. The parameters of TSMC 0.18μm technology are used to design the proposed multiplier that employs CMOS transistors operating in weak inversion region. The full combination of H-spice simulation, Monte Carlo simulation, L-edit post-layout simulation, and corner cases analysis are performed to prove its great merits of; low power consumption (1.5μW), low supply voltage (0.8V), body effect immunity, wide input range (±200nA), the bandwidth of 4.7 MHz, THD value lower than 2.8%, and the well-resistance of the proposed block against PVT (Technology Process, Supply Voltage, Temperature) non-idealises. The proposed architecture is compared with other current-mode week inversion multipliers indicating its noticeable superiorities over other ones particularly in FOM (Figure of Merits), consumed power and input range.

Keywords: Analog Multiplier, MOS Translinear, Monte Carlo, Weak Inversion

1. Introduction

Recently, the low-power low-voltage analog current-mode circuits have gained increasing attention. This attention is especially focused on the computing systems that prefer circuits with minimum consumed power and silicon area, wide dynamic range, and good linearity.

Power consumption is a subject that has been investigating by researchers in different areas of circuit designs from analog-to-digital convertors to many other parts of electronic circuits. Also, researchers try to find some signal processing approach to simplify computation, sensing, and manipulating electrical signals, particularly biomedical signals. Because for wearable biomedical sensors, we have limited power where we need both energy-efficient sensors and efficient signal processing approach. Hence designing a low power circuit may become a challenging issue. For example, recently very efficient approach for generating samples from an analog domain has been proposed based on compressive sensing (Bellasi et al., 2013). Also, in (Zanddizari et al., 2018) a post-processing method has been proposed based on Kronecker technique to accelerate the sampling phase of the analog-to-digital converters (Bellasi et al., 2013). This energy-efficient technique has been applied in two different classes of biomedical signals; electrocardiogram and magnetic resonance imaging signals (Mitra et al., 2018; Mitra et al., 2018), and the results show that both energy-efficient design and signal processing are required to achieve the ultimate goal of low power biomedical system. In (Ujan et al., 2016) they have used this idea for image enhancement, which can greatly benefit the biomedical field. The applications of such methods go beyond biomedical and to affect other fields of signal processing such as in (Khoshnevis and Ghorshi, 2019). There are also many other applications that energy-efficient circuits work along with an energy-efficient signal processing method.

Four-quadrant multiplication is one of the great important needed operations in analog computation and signal processing. It is used not only in mathematical operations but also in such applications as modulators, doublers, adaptive filters (SadoghiYazdi et al., 2010; Ndjountche et al., 1999), phase detection (Dash et al., 2012), mixers (Salama et al., 2003), neural networks (Spencer at al., 1994; Saxena et al., 1994), sensor applications (Blakiewicz et al.,2009), automatic gain controlling (Tacconi et al., 1993), fuzzy systems (Azeem et al., 2006; Afrang et al., 2010) and etc. Analog multiplier design was first reported in the work of Gilbert (Gilbert et al., 1968) which was implemented using BJT. Since then many works have been reported especially in CMOS technology (Chaisayun et al., 2012; popa et al., 2014; Al-Absi et al., 2013). The increasing demand for low voltage/low-power integrated circuits has encouraged the development of CMOS current-mode architectures. As in their voltage-mode counterparts, the operation principle of most available current-mode structures lays on drain current either deep in strong inversion (Leenaerts et al.,1996; Purushothaman et