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Low power sensitivity and Temperature stability relaxation oscillator for biomedical systems

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***Abstract*—Nowadays, the increasing concern of people about health has boosted researches on devices and circuits for biomedical systems. The design of low power sensitivity and temperature stability relaxation oscillator for biomedical system has been presented. This oscillator can be applied in any monitoring devices used in biomedical systems. The existing relaxation oscillators have less impacton frequency stability. In order to achieve the high stability in relaxation oscillator, the proposed method employs dynamic switching threshold (DST) technique and limited field (LF) technique. DST technique eis proposed to improve thestability of an oscillator frequency against supply voltage. The proposed LFconcept is aimedat making the oscillation frequency insensitive to temperature variations. The proposed system was designed in 0.18μm CMOS process with 1.84 V power supply. The oscillator In this paperex hi bi ts acompetitive performance on frequency stability against both supply voltage and temperature variations by reducing the phase noise and jitter.**

***IndexTerms*—**
Biomedicalsystems,frequencystability,dynamic switching threshold (DST),relaxationoscillator,limited field (LF), jitter.

I. INTRODUCTION

The biomedical devices are those that save the most lives and help to improve the patient health, quality of the life of an individual's, effectiveness and delivery of clinical medicine. As medical practice became more technologically based, a progressive shift is occurring in industry to meet the demand [1]-[3]. A self-chopped relaxation oscillator with adaptive supply generation provides the stable output clock against variations in temperature and supply voltages. The cost is less but power consumption is high [4]. Biomedicalarmamentaria withwide workingtemperaturerangearemoreattractive forbetterreliabilityin biologicalapplications underharshconditions.Inaddition,operating withwiderangeofsupplyvoltage isalsoappreciated toextendthe workingtimewhenpoweredbysourceswithfiniteenergy. The crystaloscillators are very stable versus temperature and supply voltage variations they cannot be integrated. In a CMOS a high performanceinphasenoise, jitters andalsoin frequencystabilityagainstenvironmentvariations,sucha sprocess, supplyvoltage,andtemperature. Theexternaldevices cause excessive cost and integration problems. In biomedical applications such as the collection of life parameters and the check of functioning of living organism more concern is focused on the stability of oscillators against PVT variations rather than jitters or phase noise [5],[6]. Relaxationoscillatorsaremorevaluableas on-chipclockgeneratorsembeddedinbiomedicalsystems. Manyresearchactivitieshavebeencarriedoutonhigh-stability relaxation oscillators. Simple resistive and capacitive temperature compensation techniques for relaxation oscillators acceptable high temperatureperformance particularly, for applications operating below 200°C such as the target application of this work that is monitoringenvironmental

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variables (e.g., temperature and pressure) insidea pulp and paper digester where the temperature can go ashigh as 180°C[7]. In a 1.1-MHz sub microwatt current-mode relaxation oscillator the current-starving inverters are biased by using the current sources with positive and negative temperature coefficients. It relaxes the temperature variations. The transistors in the sub threshold region, the current-mode comparator, and the current starving inverters are used to reduce the power of the relaxation oscillator. The current-starving inverters are biased by using the PTAT and CTAT current sources to release the temperature variations. The parallel/series composite resistor and the PTAT/CTAT current sources are also used to further reduce the temperature coefficient [8].

Recently, a relaxation oscillator that utilizes electron mobility as a time reference has been reported [9], which, as opposed to mixing resistors. This is less suffered from process variations at the cost of degraded temperature stability.

In this brief, a low power sensitivity and temperature stability relaxation oscillator for biomedical system was presented. The concept of dynamic switching threshold (DST) technique and limited field (LF) technique was employed to attain a high stability in relaxation oscillator.

This brief is organized as follows. Section II describes the related works. Section III describes circuit description. Section IV presents the experimental results. The conclusions are given in Section V.

II. RELATED WORKS

Dynamic threshold(DT)isusedto enhancethefrequencystabilityofaoscillatoragainstsupply voltage.TheSRisproposedtomitigatethefrequency driftoftheoscillator whentemperaturechanges.Temperaturedependenceoffrequency ismainlycausedbythe largeTCofresistorsappliedinthecircuit. Themaindrawofthis workisthatphasenoiseandjitterishigh[13]. Inorderto handlelowcommon-modeinputs,aPMOS-inputdesignisusedandsaturationoftheinput pairisensuredbysub-threshold operation.Transconductanceefficiencyisalsomaximized, hencebythereducing power. Themaindrawbackinthiswork isthatvoltagedrop ishigh[14]. On-chiposcillatorsarestrongly demandedfortheexternal-XO replacementbylow-costandsingle-chipsystems. Anoscillatorwithfrequencytrackingloopinprovidesastableoutputclockunder widesupplyandtemperaturevariations, butitrequiresaBGRcircuits withhigh-precision, whichinducescosts [4].

III. CIRCUITS DESCRIPTION

The block diagram ofrelaxationoscillator c o n s i s t s of twocomparators, a effectivecapacitorandalatch,asdepictedin[10]. ThecapacitorisalternatelychargedtoV$_{OH}$anddischargedtoV$_{OL}$byaconstantcurrentI$_{C}$dependingonthestateoftheRSlatch. The period of the relaxation oscillator can be expressed as

$$\Phi=2^{Cf(VOH_{Ic}-VOL)}+2t_p \quad (1)$$

Where C_f,V_{OH},V_{OL}, I_C and t_p are the effective capacitance, high threshold voltage, low threshold voltage, charge and discharge current and delays of comparators and latch.

In order to increase the stability of an oscillator to the supply voltage variation, BGR or current reference is usually employed [5],[6]. These techniques minimize the frequency drift caused by supply variation as well as by temperature changes. In this brief, DST and LF techniques are proposed to improve the stability of an oscillator frequency against supply voltage and temperature changes.

A. DST Technique

The DST technique is proposed to mitigate the frequency drift of an oscillator against supply voltage. The circuit implementation of DST technique is shown in Fig.1. The circuit consists of a timing capacitor, one comparator, a timing resistor, some batches of current.

- When voltage at node B (V_B) is greater voltage at node A (V_A), the comparator output will be V_{OH} and turns the switches S_C and S_G on. In this period the capacitor will gets discharged and results in a decrease of voltage at node B (V_B).
- When voltage at node A (V_A) is greater

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voltage at node B (V_B), the comparator output will be V_{OL} and turns the switches S_C and S_G off. In this period the capacitor will gets charged and changes the state of oscillator to the charging phase.

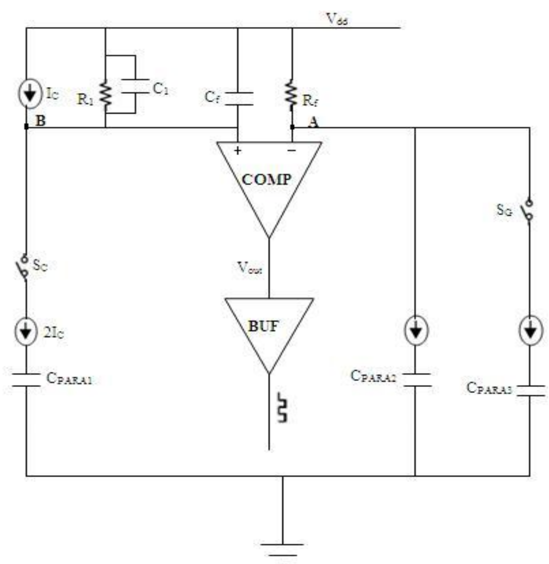

Fig. 1. Circuit schematic of proposed DST technique

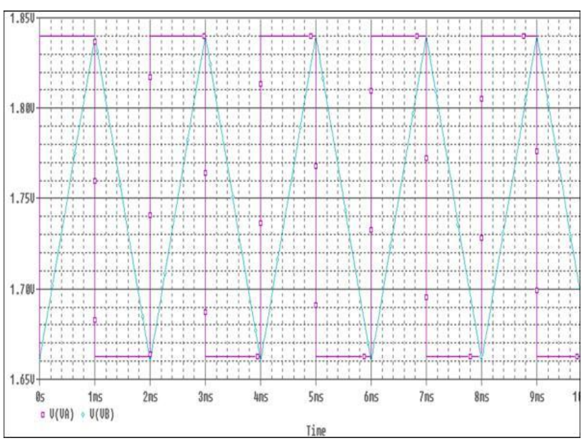

Fig. 2. Simulation waveforms of V_A and V_B.

By observing the above operating mechanism, both high and low threshold voltages are dynamic and temporal. According to DST technique, the oscillation period can be written as

$$\Phi = 2\frac{C_f(V_{OH}-V_{OL})}{\,} + 2t_{p+}Cpara \qquad (2)$$

where C_f, I_C, t_p are effective capacitance, charging currents ~~and~~ delays of comparators.

$\Phi=2R_fC_fI^2_{Ic}+4tp + Cpara(3)$

In several MHZ applications, t_p is negligible with sufficient gains of the comparator, the reason is that it is a primary contributor to power consumption and might consume hundreds of µA currents at frequency bands of MHz.

B. LF Technique

The circuit schematic of the proposed LF technique is shown in Fig. 2. TheproposedLFconcept is aimedatmaking the oscillationfrequencyinsensitivetotemperature in a process providing at least two types of resistors with different TC_S. In addition, a three parasitic capacitor is added in series to the circuit. Control signals are derived from the output of the comparator. The selection of V_{OUT+} / V_{OUT-} is determined by the polarity of TC_S of R_1 and R_2.

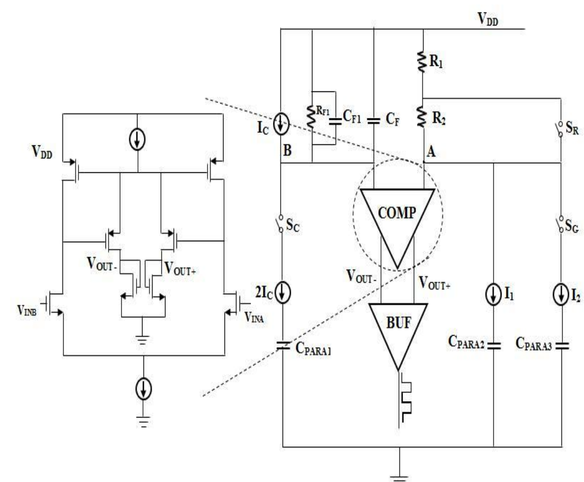

Fig. 3. Circuit of the proposed LF technique.

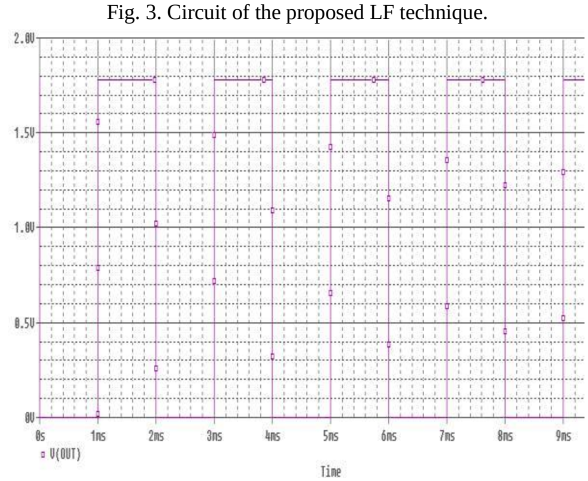

Fig. 4. Output waveform of buffer

- *TC_S of R_1 and R_2 have the same polarity:* In this case, S_R and S_G must have the same steering signals. With $t_p$being ignored, the expression of oscillation period in (2), (3) should be modified correspondingly a

$$\Phi = 2C_f(\overline{V_{OH}-V_{OL}})/I_c + C_{para} \quad (4)$$

$$\Phi = \frac{2C_f}{I_c}(I_2R_1 - I_1R_2) + C_{para} \quad (5)$$

AsTCsofcapacitorandthesecond-orderTCsofresistorsare ignorablewithrespecttothefirst-orderTCsofresistors,theoscillation periodintermsoftemperaturecanapproximatelybe

$$\Phi = \frac{2C_f}{I_c} I_2R_{10}(1+TC_1R_1\Delta_t) - I_1R_{20}(1+TC_1R_2\Delta_t) + C_{para} \quad (6)$$

The above expression is for the first-order TC_S of resistors at room temperature.

- *TC_S of R_1 and R_2 have the different polarity:* In this case, to ensure proper charging and dischargingtiming,SGmust becontrolledby*V*out+.

IV.EXPERIMENTALRESULTS

The oscillator was designed and implemented with a standard 0.18-μm CMOS process with the supply voltage of 1.84V. The previous system suffers from large area and high cost. Though our proposed system occupies less area and less cost. Mostly the biomedical systems have embedded memory arrays for critical information and data storage, which can be utilized for frequency calibration by digitally tuning I_C, I_1, I_2 rather than resistors and capacitors for area saving. Inthepresentdesign,registerswereemployedasmemories tostore thecalibrationinformationforthesakeofflexibility intesting.In addition,thecurrents I_C, $I1$,and $I2$ arebinarycoded. The variationofresistorsTCscausedbythatofprocessisanotherbreakertotemperature stability ofthe oscillator. However,theimpactisnegligibleasTCsofresistors are almostconstantagainstprocessvariation[11],[12]. The oscillator inthispaperex hib its aco mp etitive performanc e onfrequencystabilityagainstbothsupplyvoltageandtemperature variations by reducing the phase noise and jitter. Further the area can be reduced by eliminating the decoders and registers.

V.CONCLUSION

This paper has proposed a new concept of DST and LF technique for relaxation oscillator and analytically explained its immunity against power supply and temperature variations. The minimum achievable sensitivity was generalized to be independent of oscillation frequency. The noise reduction mechanism of DST and LF technique was explained. A system was designed in a 0.18μm standard CMOSprocess with 1.84V power supply. A performance comparison with recent works resulted that our work achieved small area and low power with competitive low sensitivity to voltage and temperature. This oscillator can be applied in any monitoring devices used in biomedical systems.

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