American-Eurasian Journal of Scientific Research 12 (4): 207-212, 2017
ISSN 1818-6785

DOI: 10.5829/idosi.aejsr.2017.207.212

A Stumpy Power Oscillator Based Recite Boundary with CMUT Implementation for Biomedical Application

J. Jasmine Christina and V. Karthikeyan

Department of ECE,
Vivekanandha College of Engineering for Women, Tiruchengode, India

Abstract: A Stumpy Power Oscillator Based Recite Boundary with CMUT Implementation for Biomedical Application is presented; Capacitive micro-machined ultrasonic transducer (CMUT) is a transducer where the energy transduction is due to change in capacitance. This paper recommended an oscillator based ultrasonic sensors [1] can be mainly used to intravascular applications and other medical field applications such as liver, stomach, liver, heart, tendons, muscles and joints. The readout circuits are authorized with a capacitive micro machined ultrasonic transducer and a current-to-frequency chip. The CMOS CMUTs [2,3] are incorporated among a current amplifier circuit on the same chip and the current-to-frequency chip presents the current-to frequency readout interface [2]. Ultrasound waves [4] does not use any ionizing radiation, has no known harmful effects and presents a clear images of soft tissues that don't illustrate up well on x-ray images, thus there is no radiation exposure to the patient. The ultrasound is usually between 2 and 18MHz and also higher frequencies provide better and clear quality images. The ultrasound images are captured in real-time; they can illustrate the structure and movement of the body's interior organs, with blood flowing through blood vessels. The current amplifier is utilized and integrated with the CMUT cells to minimize the parasitic capacitance. Relaxation oscillators [5] with injection locking are utilized to attain low-power consumption. Also, the instance-based output signal can be auxiliary digitized with a time-to digital converter. Both chips are formulated in an 180nm CMOS MEMS progression technology. The CMUTs are intended with 1MHz to 4MHz cells for intravascular diagnosis applications.

Key words: CMUT · Current amplifier · Relaxation oscillator · MEMS

INTRODUCTION

An ultrasonic transducer is a device that converts the alternate current into ultrasound, in addition to reverse, sound into alternate current. The capacitive micro-machined devices are fabricated by using silicon micro-machining technology (MEMS technology), which is particularly helpful for the fabrication of transducer arrays. The oscillator based ultrasonic sensor interface [6] that can be pertained to intravascular applications. While compared to the piezoelectric transducer, CMUT has several major advantages such as a wider temperature range, superior mechanical impedance matching and the possibility of system integrations for miniature medical electronic devices. Intravascular ultrasound (IVUS) [7] is a medical imaging methodology using a particularly designed catheter with a miniaturized ultrasound probe attached to the distal end of the catheter. Thus the proximal end of the catheter is connected to computerized ultrasound equipment. It permits the application of ultrasound technology, such as piezoelectric transducer otherwise CMUT, to observe from the inside of the blood vessels out through the enveloping blood column, visualizing the interior partition of blood vessels in living individuals. The arteries of the heart (the coronary arteries) are the most frequent imaging intention for Intravascular Ultrasound. IVUS is mostly used in the coronary arteries to resolve the amount of athermanous plaque built up at any exacting point in the pericardial coronary artery. The progressive accumulation of plaque within the artery wall over decades is the group for plaque which, in rotate, leads to heart attack and stenos is

Corresponding Author: J. Jasmine Christina, PG student, Department of ECE, Vivekanandha College of Engineering for Women, Tiruchengode, India.

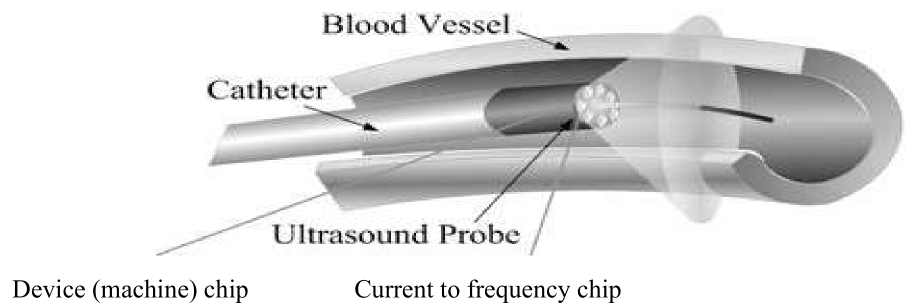

Fig. 1: Oscillator based ultrasonic sensor interface for intravascular applications

(narrowing) of the artery (called as coronary artery lesions). It can be especially helpful for conditions in which angiographic imaging is considered unreliable.

Catheter: In medical applications, a catheter is a thin tube made from medical grade materials serving a broad range of functions. Catheters are medical devices that are able to insert to the body for treat diseases or perform a surgical procedure. By modifying the material or altering the way catheters are manufactured, it is possible to tailor catheters for intravascular, cardiovascular, urological, neurovascular and ophthalmic applications. Catheters are able to be inserted into a body cavity, duct, or blood vessel. Functionally, they permit drainage, administration of fluids or gases, approach by surgical instruments and also carry out a wide variety of other tasks depending on the type of catheter. The process of inserting a catheter is called as catheterization. In mainly uses, catheter is a slender, flexible tube ("soft" catheter) though catheters are available in varying levels of stiffness depending on the applications. A catheter is left inside the some part of the body; either temporarily or permanently, may be consigned to as an indwelling catheter (for example, a peripherally put in central catheter). A permanently inserted catheter may be consigned to as a permeate (originally a trademark).

Ultrasound imaging [6] is based on the similar principles involved in the sonar used by bats when a sound wave strikes an object; it bounces reverse, or echoes. By determining these echo waves, it is potential to establish how far away from the object is as well as the object's dimension, shape and consistency. In medicine, ultrasound is used to detect the transforms in appearance [8], size or outline of organs, tissues, as well as vessels or to sense irregular masses, such as tumors. In an ultrasound assessment, a transducer mutually conveys the sound waves and receives the echoing waves. When the transducer is pressed beside the skin, it straight the miniature pulses of muted, high-frequency sound waves keep on the body. While the sound signals bounce off interior organs, fluids and tissues, the susceptible microphone in the transducer records tiny modify in the sound's pitch and route. These signature waves are immediately measured and exhibited by a computer, which in turn generates real-time images on the monitor. One or more frames of the shifting pictures are naturally captured as still photographs and short video loops of the images can also be saved.

Doppler ultrasound is a particular application of ultrasound that measures the direction and speed of blood cells as they shift through vessels. The movements of blood cells sources a change in pitch of the reflected sound waves are described the Doppler Effect. A computer can collect and processes the sounds and constructs graphs or colour pictures that represent the flow of blood through the blood vessels. The ultrasound reflections establish the images of the blood vessel. Typically, three modes are obtainable in the ultrasonic diagnosis systems; there are A-mode, B-mode and M-mode. A-mode is the amplitude of the replicated wave, which represents the amount of the reflected ultrasound waves. B-mode shows a multiple combinations of the intensity in the A-mode, which exhibits the acoustic impedance of a two-dimensional cross-segment of the vessels. And, M-mode demonstrates the A-mode images varying with time on the horizontal axis. B-mode is clinically the mainly important diagnostic tool, because the B-mode requires converting the analog ultrasonic signals into their digital forms for further digital signal processing [9].

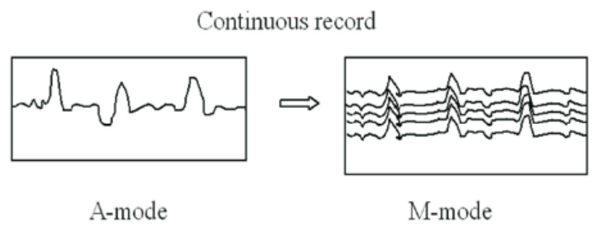

Fig. 2: The images of A-mode and M-mode

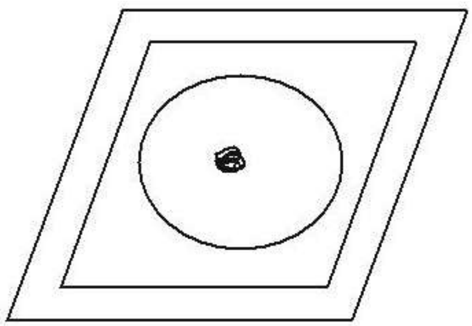

Fig. 3: Image of B-mode

CMUT STRUCTURE

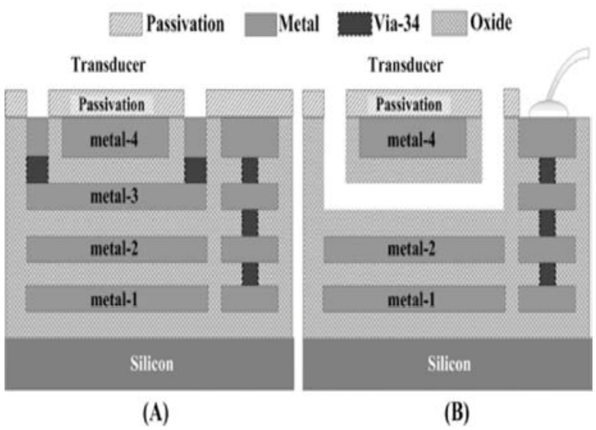

Fig. 4: The cross section view of the CMUT structure, (A) Before post Processing (B) After post processing

The detailed cross section plots of the CMUT structure is shown in Figure 4. In this work, the membrane is created with the metal-4 and metal-2 layers, which function as the superior and bottom electrodes. Moreover, the metal-3 forms the sacrifice layer to constitute the suspended structure. The passivation layer would be enclosed on the top of the die except for the openings for the etchant holes. The etchant holes are collected of the metal-4, via-34 and metal-3. The air hole will be formed after metal-3 was removed.

The Proposed Readout Circuit

System Architecture: The overview of the recommended system is improving the bandwidth for creating the clear image of blood vessel. The CMOS CMUTs are included with a current amplifier on the equivalent chip and the current-to-frequency chip presents [2,10] the current-to frequency readout interface. Relaxation oscillators with inoculation locking are employed to realize the low-power consumption [5]. The represented block diagram of system architecture is shown in Figure 5.

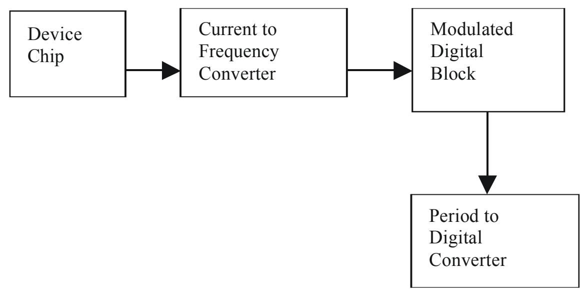

Fig. 5: Block diagram of system architecture

Also, the time-based output signal may be auxiliary digitized with a time-to digital converter. Both the chips are fabricated in an 180nm CMOS MEMS development technology.

MEMS Process: Micro-Electro-Mechanical Systems or MEMS, is a technology that is most universal form can be defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and constructions) that are finished employing the techniques of micro fabrication. The stable physical dimensions of MEMS devices may differ from well below one micron on the lower end of the dimensional spectrum, all the way to several millimetres. The types of MEMS devices can vary from relatively simple structures having no moving elements, to greatly complex electromechanical systems with several moving elements under the control of integrated microelectronics.

The one major condition of MEMS is that there are at least some elements having some kind of mechanical functionality whether or not these elements can shift. The term exercised to describe MEMS varies in different divisions of the world. In the United States they are prevalently called MEMS, while the some other division of the world they are described “Microsystems Technology” or “micro machined devices”. Whereas the functional components of MEMS are miniaturized constructions, sensors, actuators and microelectronics, the mainly notable (perhaps generally interesting) elements are the micro sensors [11] and micro actuators. Micro sensors also micro actuators are properly categorized as "transducers", which are described as devices that exchange the energy from one structure to another. In the case of micro sensors, the machine usually exchanges a measured mechanical signal into an electrical signal.

The fabrication of MEMS develop from the process technology in semiconductor device fabrication, i.e. the essential techniques are deposition of material layers, modelling by photolithography and etching to produce the required shapes. Even though MEMS and Nanotechnology are sometimes cited as split and distinct technologies, in actuality the distinction among the two is not so obvious-cut. The well-known checking tunnelling-tip microscope (STM) which is utilized to sense individual atoms and particle on the nanometre range is a MEMS mechanism. Similarly the atomic force microscope (AFM) which is employed to control the placement and location of individual atoms and molecules on the surface of a substrate is a MEMS device as well. In fact, selections of MEMS technologies are needed in order to interface with the nano-scale domain.

Current Amplifier: Since the sensed biomedical signals are naturally with miniature magnitudes and the operation environment is potentially noisy. If the sensing elements are attached to the amplifier using wire bonding, the parasitic capacitances as of the bond pads and the bonding wires boost the total input capacitance, which disgraces the noise performance significantly [12]. The current amplifier is exploiting and integrated with the CMUT cells to minimize the parasitic capacitance and enhance the sensitivity of the overall ultrasonic system. In this work, the early capacitance of the CMUT cells is 270 fF. The induced current with the pressure from 0.10 MPa to 0.50 MPa ranges from 3 μA to 11 μA. The persuaded current will then be amplified by the current amplifier to improve the sensitivity of the readout circuit [13]. It adopted a simple architecture for the current amplifier to lower the flicker noise from the transistors [8].

$$Iinj = ICMUT \times (r01 \,//\, r02) \times \frac{g_{m4\ 03}}{1+g_{m4}R} \times Rout \qquad (1)$$

The structural design of current amplifier is shown in Figure 4. M_1 and M_2 provided an equivalent resistance r_0 to convert I_{CMUT} to influence the gate voltage of M_4 Accordingly, this gate voltage of M_4 will be further amplified by the common-source amplifier. The output current I_{inj} of the current amplifier can be expressed in (1). A current amplifier is somewhat alike to a voltage buffer but the difference is that an ideal voltage buffer will make on effort to deliver whatever current required by the load while remaining the input and output voltages same, where a current amplifier provides the succeeding stage with a current that is a fixed multiple of the input current. A current amplifier can be recognized using transistors.

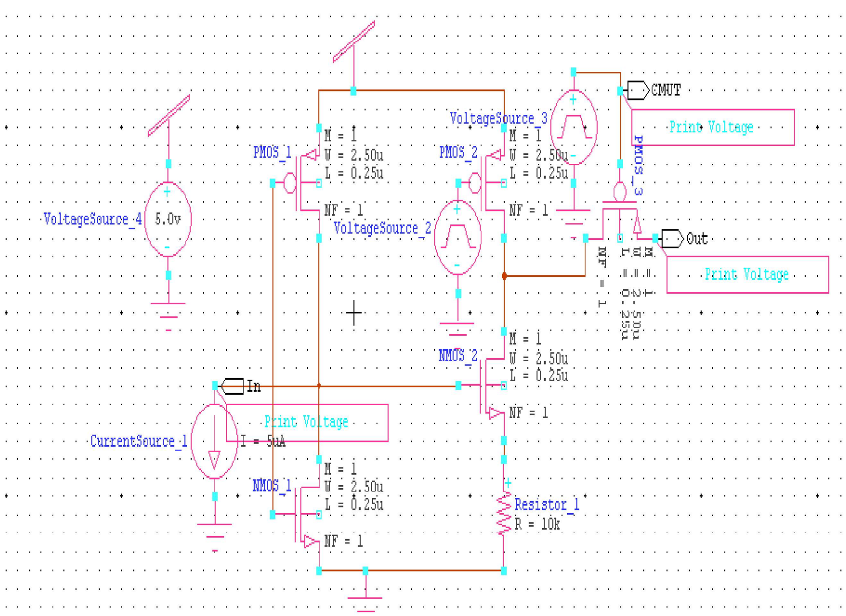

Fig. 6: The Simulated Diagram of current amplifier

In this work, the current amplifier provides a gain of 52dB to satisfy the overall system constraints. The induced current from CMUTs after the current amplifier, I_{inj}, will be in the range of 90.1 µA to 100.43 µA.

Relaxation Oscillator: The relaxation oscillator is further classified into two categories. There are

- Sensing relaxation oscillator
- Reference relaxation oscillator

Relaxation oscillators are generally used to create a low frequency signals for such applications as flashing lights and electronic beepers and clock signals in some digital circuits. The term relaxation oscillator is also applied to dynamical systems in many diverse areas of science that produce a nonlinear oscillations [14] that produces a non sinusoidal repetitive output signal and can be analyzed using the same mathematical model as electronic relaxation oscillators. Relaxation oscillations are described by two alternating processes on different time scales; a long relaxation period during which the system structure approaches an equilibrium point, exchanging with a short impulsive period in which the equilibrium point transfers. The period of a relaxation oscillator is mostly determined by the relaxation time constant. Relaxation oscillations are a category of limit cycle and are deliberate in nonlinear control theory.

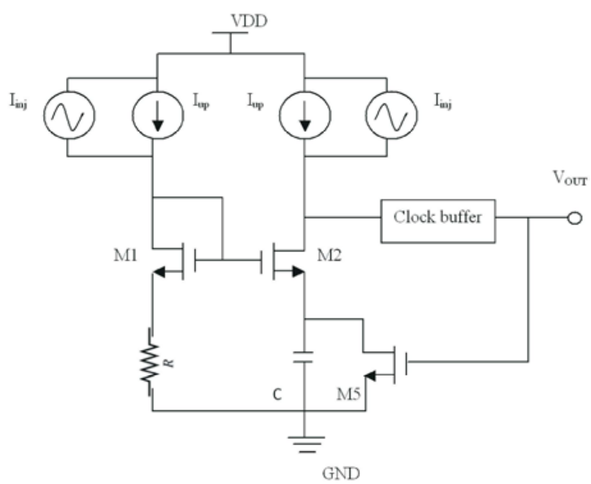

Fig. 7: Circuit diagram of current-mode relaxation oscillator

The oscillation frequency of a relaxation oscillator can be expressed in (2).

$$F = \frac{I_{UP}}{V_{TH}.C} = \frac{1}{R.C + T} \qquad (2)$$

Where τ is the delay introduced by the clock buffer and the switches. V_{TH} is the reference voltage and I_{UP} is the dc charging current.

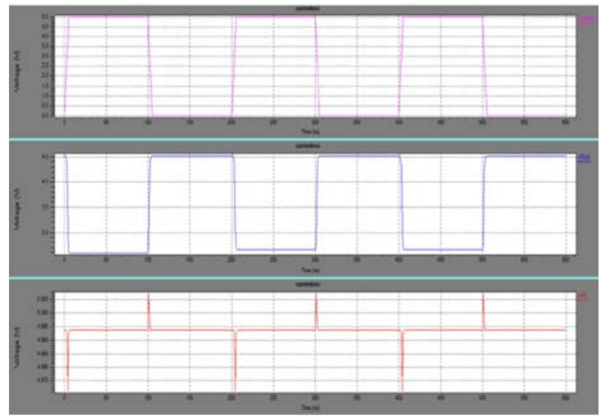

Fig. 8: Output waveform of current amplifier

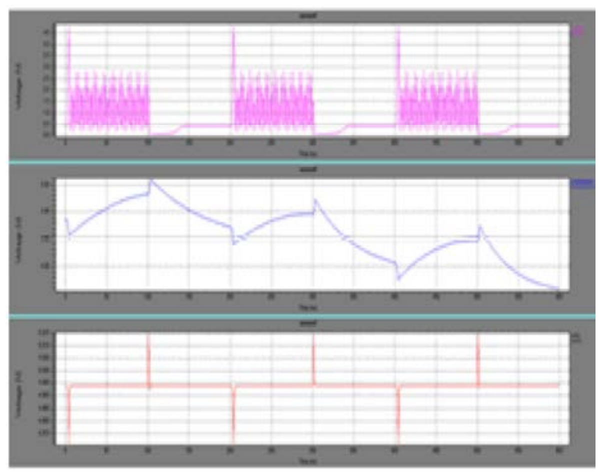

Fig. 9: Output waveform for relaxation oscillator

Measurement Result: We inflict a waterproof package for CMUT chip and measured in the underwater environment. JSR DPR300 ultrasonic pulsar is employed as the ultrasound emission source and measured by a 2.25MHz probe. The output waveform shows the measurement results that the ultrasonic signal increases the output frequency and generates the modulation pulse width. Figure 8. Shows the output signal of the current amplifier. The ultrasonic current received from the CMUTs is around 3 µA to 11 µA. After the current amplifier, the injection ac current is about 90.1 µA to 100.43 µA. Figure 9. shows that the simulation output waveform of the relaxation oscillator. Thus the relaxation oscillator consumes the power is 1.452mW to 5.823mW at the input supply current is 5µA to the current amplifier circuit. The delay factor is obtained in 1.89993e-010 at the relaxation oscillator circuit.

CONCLUSION

In this paper a low-power oscillator-based ultrasonic sensor [1] interface for intravascular medical applications [1,12] is obtained. The proposed system incorporates the CMUTs with the current amplifier and the current-to frequency converter on two chips. Both of them were fabricated in TSMC 180nm CMOS process. The low-power design of battery-powered devices such as portable medical equipment is an essential objective to reduce the system cost as an increased energy demand has to be covered by a higher battery capacity. In future work we can use Frequency Divider (FD) and multiplexer to reduce the power consumption. The Frequency Divider component produces an output that is the clock input divided by the specified value. They can be used for improving the presentations of electronic counter measures equipment, communications systems and laboratory instruments.

REFERENCES

1. Cheng, T.C., C.W. Hsu, H.C. Wang, B. Parviz and T.H. Tsai, 2016. A Low-Power Oscillator-Based Readout Interface for Medical Ultrasonic Sensors, IEEE, April.2016.
2. Gurunet, G., P. Hasler and F.L. Degertekin, 2011. Front-End Receiver Electronics for High-Frequency Monolithic CMUTon-CMOS Imaging Arrays, IEEE Trans. Ultrason. Ferroelectr. Freq. Control., 58(8): 1658-1668.
3. Hwang, C., S. Bibyk, M. Ismail and B. Lohiser, 1995. A very low frequency, micropower, low voltage CMOS oscillator for noncardiac pacemakers, IEEE Trans. Circuits Syst. I, Reg. Papers, 42(11): 962-966.
4. Kim, I., H. Kim, F. Griggio, R.L. Tutwiler, T.N. Jackson, S. Trolier-Mc Kinstry and K. Choi, 2009. CMOS Ultrasound Transceiver Chip for High-Resolution Ultrasonic Imaging Systems, IEEE Trans. Biomed. Circuits Syst., 3(5): 293-303.
5. Denier, U., Analysis and design of an ultralow-power CMOS relaxation oscillator, IEEE Trans. Circuits Syst. I, Reg. Papers, 57(8): 1973-1982.
6. Przybyla, R., S. Shelton, A. Guedes, R. Krigel, D. Horsley and B. Boser, 2012. In-air ultrasonic rangefinding and angle estimation using an array of aln micromachined transducers, in Hilton Head Solid-State Sensors, Actuators and Microsystems Workshop, pp: 50-53.
7. Kuratli, C., and Q. Huang, 2000. A CMOS ultrasound range-finder microsystem, IEEE J. Solid-State Circuits, 35(12): 2005-2017.
8. Huang, S.W., S.L. Chen, T. Ling, A. Maxwell, M. O'Donnell, L.J. Cuo and S. Ashkenazi, 2008. Low-noise wideband ultrasound detection using polymer microring resonators, Appl. Phys. Lett., 92: 193509.
9. Bracke, W., P. Merken, R. Puers and C.V. Hoof, 2007. Ultra-low-power interface chip for autonomous capacitive sensor systems, IEEE Trans. Circuits Syst. I, Reg. Papers, 54(1): 130-140.
10. Mina, I.G., H. Kim, I. Kim, S.K. Park, K. Choi, T.N. Jackson, R.L. Tutwiler and S. Trolier-McKinstry, 2007. High frequency piezoelectric MEMS ultrasound transducers, IEEE Trans. Ultrason., Ferroelectr., Freq. Control, 54(12): 2422-2430.
11. Shenghua, Z. and W. Nanjian, 2007. A novel ultra low power temperature sensor for UHF RFID tag chip, in Proc. IEEE Asian Solid-State Circuits Conf., pp: 464-467.
12. Foster, F.S., C.J. Pavlin, J.A. Harasiewicz, D.A. Christopher and D.H. Turnbull, 2000. Advances in ultrasound biomicroscopy, Ultrasound Med. Biol., 26(1): 1-27.
13. De Vita, G., F. Marraccini and G. Iannaccone, 2007. Low-voltage low-power CMOS oscillator with low temperature and process sensitivity, in Proc. IEEE Int. Symp. Circuits Syst., pp: 2152-2155.
14. Chiang, Y.H. and S.I. Liu, 2013. A Submicrowatt 1.1-MHz CMOS Relaxation Oscillator With Temperature Compensation," IEEE Trans. Circuits Syst. II, Exp. Briefs, 60(12): 837-841.