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Missing ECG Beat Detector Design on Flexible Electronics Patch

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Abstract : *In the case of Cardio Vascular Disease patients, it is always advantageous, if missing ECG beats are detected for early warning. Ideally, this missing beat detection is required, irrespective of mobility and sleep state of the CVD patient, for providing early warning .Considering its Bio-compatible requirement, a Flexible electronic patch design has been evolved and missing ECG Beat detection, sub unit design, based on printable Thin Film Transistors (TFT) evolved has been illustrated in this publication. A non gel Epidermal ECG electrode patch provides ECG waveform, at one of the input terminals of XOR TFT logic printed on Flexible substrate like Polyamide PMDS film. The XOR logic design implemented using 8 no.s Thin Film Transistors (TFT) is fed with ECG Beat waveform, at the 2nd terminal of the XOR logic, via. a differentiator, with time constant much less than the width of the "QRS" complex of ECG waveform. The output of XOR logic goes to a Mono Shot, which generates pulses at it's output, with pulse widths more than 1500 milli seconds, at every beat instance, crossing the ECG wave or beat width. Whenever there is missing beat, the Mono Shot could generate inverted output, so that Mono Shots complementary output indicates the missing beat, on a OLED, printed on the Flexible substrate. In the conventional electronics, large values required for the time constants of Missing ECG Beat Detector would be difficult, unless 2D Wafer integration is adopted, due to large VLSI real estate sizes involved. TFTs of size 5μmx5μm for nFET and 4μmx4μm for pFET with surface energy controlled inkjet printing have been assessed in evolving the design methodology. TFT model, using printable inks and layout areas with W/L ratios, evolved at 4V, V_{DD} are illustrated. A standard available OLED stack of size 5 mm x 5mm to indicate missing of the heart beat is part of the Flexible patch.*

Keywords: *Beat Detection, ECG, Epidermal Patch, Printed OLED, QRS Complex, TFT, XOR*

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I. Introduction

There are applications, the designs of which are difficult to implement on rigid PCB substrates and other Silicon based rigid substrates. Epidermal electronic design patches for bio-sensing is one such application. In these applications the patches are wrapped around body surface, demanding flexibility of the substrate on which, electronic design is to be formed. Considering many such applications, there emerging Flexible electronics to print electronic designs on Flexible substrates printing respective active and passive components. This large area electronics is in transition with new material nano inks and methods of fast roll to roll manufacturing[1], to realize the designs on Flexible substrates. Like in matured conventional electronics on Silicon substrates and rigid PCB substrates, researchers have started, realizing the electronic functions of control, logic, sensing and information transmission, in Flexible electronics through printing processes that use conducting, dielectric, semiconducting and Poly Silicon inks. More over there in no way other than Flexible electronics processes to design the flexible electronic patch required to sense ECG beats. Over the period Thin Film Transistor (TFT) designs of various capabilities have been realized by researchers on Flexible substrates. In this design exercise, it is realizing an XOR logic used in the design and to integrate the logic in ECG beat missing detector, to indicate early warning to Cardio Vascular Patients. ECG beat acquired in the body area electronics is subjected to analog signal processing to indicate the detected missing ECG beat

II. Missing Beat Detection Design Scheme

As depicted in the building block diagram below in Fig.1, from the Body Area Electronics and the non gel based ECG electrode there in, [4][8][11] the ECG waveform is fed at the input of XOR logic, clamping ECG slightly on positive side. Realization of the XOR logic and the layout is described and depicted in the subsequent sections.

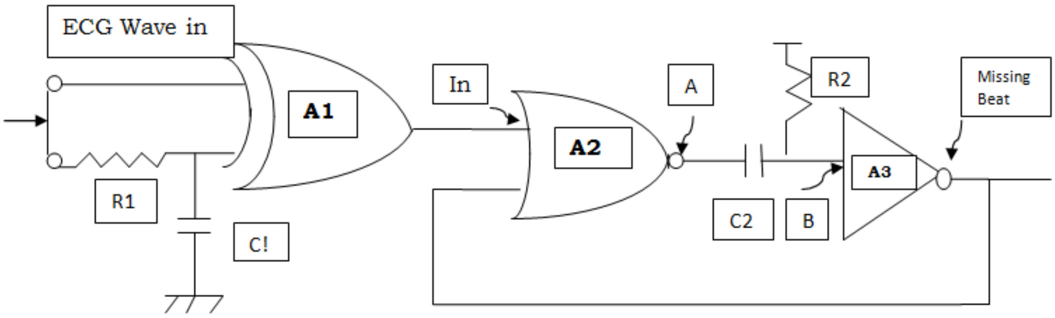

FIG 1 Missing Beat Detector - XOR Logic Design integrated with Monoshot Trigger

In the above design scheme, the output of A1 or XOR gate is fed to Missing Beat Trigger block consisting of the building blocks A2 and A3. The working of the Missing Beat Trigger block is illustrated through the wave form in Fig 2, below

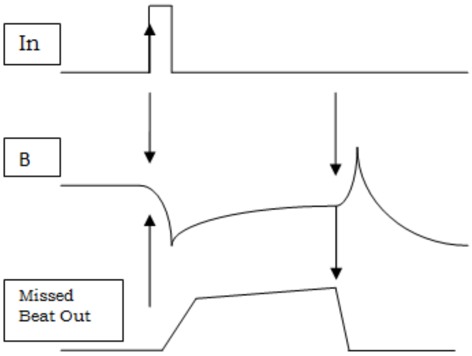

FIG 2 Monoshot Trigger Circuit Waveforms

At the front end, the ECG Waveform is fed to both terminals of XOR logic, with a phase difference of the order of 1 µs, approximately, depending on the tolerance of components in the printed design values of R1 and C1. Normally ECG beat exists through out. Till the time, ECG or Heart Beat exists, the XOR logic generates a narrow pulse for R1 = 10K and C1 = 10 nF in Fig 2, as shown, at signal 'In' waveform in the above Fig 2. The narrow width I µs, 'In' signal is routed to one of the inputs of OR gate A2 of subsequent trigger circuit.

III. Thin Film Transistor Logic Design of XOR Gate

XOR Logic design implementation is the heart of this design methodology. As the design has to be printed, on a rigid flexible substrate printable Thin Film Transistors (TFTs) are used in the methodology. It has 4 No.s of P-MOS transistors and 4 No.s of N-MOS transistors as shown in Fig 3

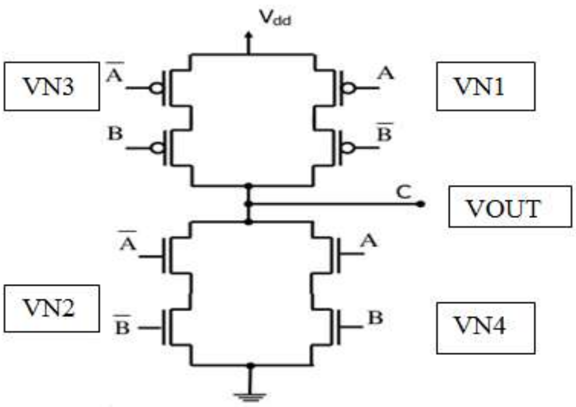

FIG 3 XOR Logic

The XOR logic is made up of two AND gates and one OR gate. VN1 and VN2 are inputs of AND gate 1 and VN3 and VN4 are inputs of AND gate 2. When outputs of the two gates are joined, it has wired OR effect and at VOUT, XOR logic is realized. The printing areas for the XOR layout of the design is indicated below in Fig 4. TFTs [3][6][7][19][20] of size 5µx5µ for nFET and 4µx4µ for pFET have been employed in evolving the design[22]. Printing is an emerging approach for low cost, large area manufacturing of electronic circuits, but has the disadvantage of poor resolution, large overlap capacitances and oxide film thickness achieving limitations, resulting in slow circuit speeds and relatively high operating voltages, which are not disadvantages for this design.

The realization of NOR gate A2 in Fig 1 is using 3 NAND gates derived from above AND gates in XOR logic and an inverter equivalent to A3, whose design using TFTs given below in Fig 4.

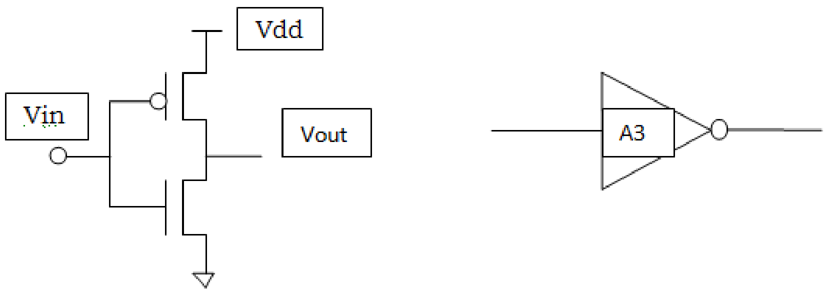

FIG 4. NOT Gate

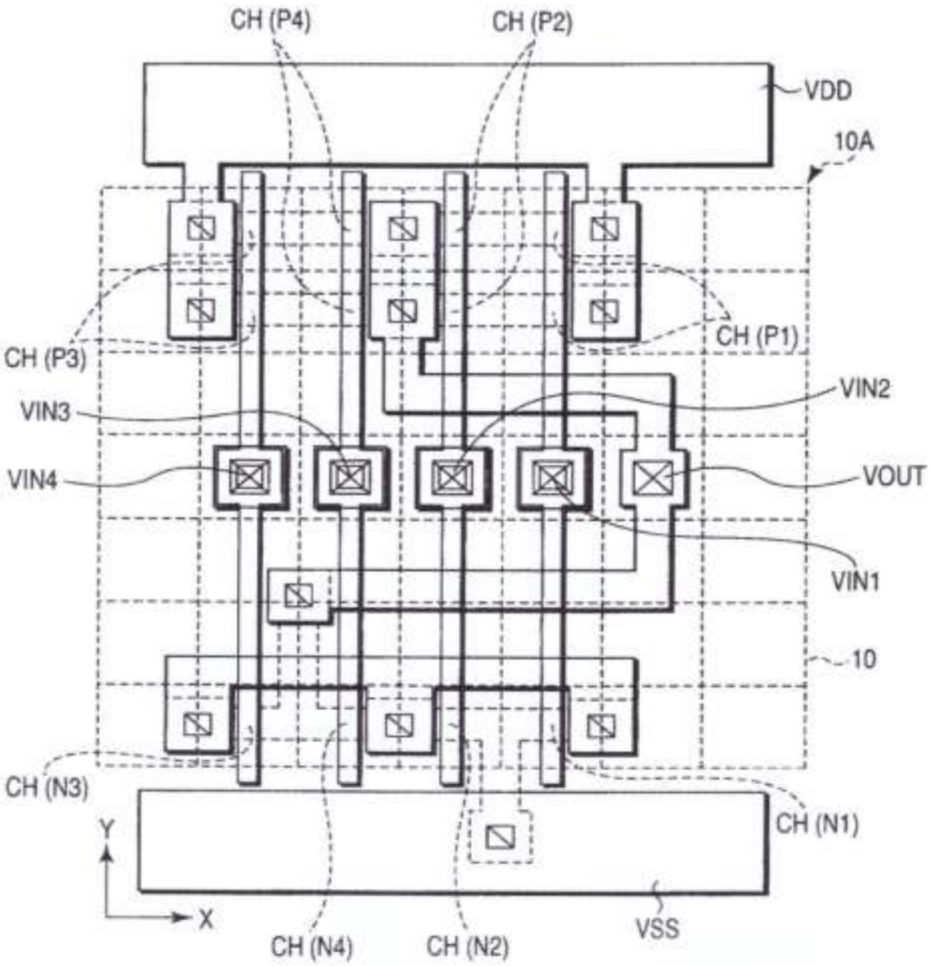

FIG. 5 - Layout areas of the TFT XOR Design using Flexible Electronic printing methods

IV. ECG BEAT Missing Detector Bio-Sensor patch

In this ECG Biosensor making, the typical process flow involve, attaching a rigid handler substrate, to facilitate handling flexible substrate material such as PMDS with very good mechanical and bendable characteristics. The rigid handler facilitate subsequent processing steps, followed by deposition of the Thin Film Device Layer via. available solution processes, spin coating, dip-coating and other transfer printing processes, using printable nano inks. The technology drivers for this potential area are the inherently novel electronic and mechanical properties of these sheets; their flexibility, conformability, biocompatibility and transferability of designs to other hosts; the ability to introduce strain and thus novel properties associated with strain in ways not possible with bulk materials and the ability to integrate membranes of different materials because of the much better bondability of membranes than bulk materials. Also the current nano ink based, electronic design printing processes evolved, allow heterogeneous integration of dissimilar materials. It is not only this specific design possibility for early warning of missing ECG beat, but also, Inorganic crystalline semiconductor Nano material sheets with nanometer to sub-micrometer scale thickness have in the last several years, demonstrated great potential to become a disruptive technology, driven primarily by the successes shown with Group IV Crystalline Nano Materials transferred and tracked on to foreign substrates, including both rigid such as Silicon and Glass substrates and Flexible substrates such as plastics and polymers, which have also lead to optoelectronics[16] flexible biosensors by researchers.

The method evolved, after printing the entire Missing Beat Detection circuit in Fig 1 with associated analog signal processing and associated TFT devices, drives a standard available multi layer printable OLED device stack, of size 5 mm x 5mm, or a speaker for providing visual or audio [2][5] indication of any missed ECG beat.

V. Conclusion

The TFT device architecture and method used minimizes, contact resistance effects, enabling scaling of transistor current with channel length. Self aligned gate configuration in TFT transistors minimizes parasitic overlap capacitances at higher speeds and slew rates required in Flexible and printable electronics, but this specific application for Missing Beat Detection, does not require higher speeds. More over large capacitance [24] areas and resistance areas required for large time constants of the order of 1500 ms in this design are better realizable in Large Area electronics than conventional VLSI Designs. Self aligned printing approach allows, down scaling of printed Thin Film Transistors to channel lengths of the order of 100 – 400 nm[7][9][10], at operating voltages of 4V.

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