# DESIGN OF NOISE INJECTOR USING INSTRUMENTATION AMPLIFIER FOR HIGH EFFICIENCY SENSOR APPLICATIONS

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***ABSTRACT:*** In this paper, issues related to noise sensor application of instrumentation amplifier through substrate coupling are described and established with the physical phenomenon responsible for its formation, coupling transmission method and media, factor affecting coupling strengths and its impact on mixed signal integrated circuits. Basic aim is to find out magnitude of interference happening when analog and digital circuit is placed nearby on a common substrate. It has been design to have a broad bandwidth (1 KHz to 1MHz) with very high CMRR to cancel out the unwanted noise at its both inputs and deliver single output. MOSFET capacitors are used for the picking of substrate interference. Advantages and disadvantages of the design are also discussed.
***Keywords:*** CMOS, noise sensor, Substrate Coupling, Guard Banding.

## Introduction

The wireless sensor network is applicable in abundant life saving vital field because of low cost long battery life sensors. A sensor network comprises of sensors and routers to choose the supervisor host that is called the controller [AA12]. A wireless sensor network is easy to use in the preferred surroundings [***08], and the information can be collected then processed and sent to a desired location. Recent break trough in wireless communication and micro-electro-mechanical systems (MEMS) [K+13, Est02, E+08] provides large scale, low power, multi-functional, and low cost network

A wireless sensor network can be composed of a large number of nodes, constituting a multi-hop network, where vicinity nodes communicate with each other, with routing responsibilities.. As a wireless sensor network able to have more than one sensing nodes so increase spatial coverage and become more fault tolerance. [K+13, Est02, E+08, ***08, S+00, B+12]

Analog circuits contain extremely sensitive circuits e.g. opamp and comparator which can take a few µvolt of signal at their input and convert them to several volts at their outputs. Digital circuits on the other hand operate with rapidly switching waveforms with swings of several volts.

Hence when we put analog & digital circuits on the same substrate which is increasingly the case in modern VLSI and if a minute fraction of digital swing is coupled to sensitive analog nodes the result can be disastrous for the affected analog circuit and hence it will degrade the performance of the entire VLSI system. Any unwanted coupling happening between generation section (digital circuit) and reception section (analog circuit) on the same substrate can be seen as Mixed Signal Interference. [AA12, K+13, B+12]

In analog circuits the substrate is, as in digital circuits, biased via substrate contacts. Consequently, noise is received via the substrate contacts in analog circuits in a similar way as noise is injected via substrate contacts in digital circuits. Furthermore, if the analog ground is used to bias the substrate, noise can couple directly to the ground making the performance degradation of the analog circuit. [MYB94]

In addition to it some design guidelines and techniques to reduce or avoid the substrate noise problem need to be developed which requires measures to both make the transmitter (digital circuitry) to increase the transmission impedance between transmitter and receiver to desensitize the receiver (analog circuitry). Some of these measures can be executed at technology level others at circuit design level or at the layout level.

### 1. Demonstration circuit implementation of Noise Sensor

The Noise sensor circuit one is for the observation and measurement of displacement current using a CMOS inverter in different 1.2 um, 0.8 um and 0.35 um technology with different sizes and load capacitor in each technology. The drain current fluctuates due to substrate noise voltage that is resistively coupled to the back-gate region and capacitive coupled from there to the detector. Here an arbitrary Substrate circuit is introduced, where substrate resistance is also chosen arbitrarily in the range of 50 Ω and 1 KΩ.

### 1.1. NMOS Amplifier

A common source (nMOS) amplifier is designed with W = It has been design to have a broad bandwidth (1 KHz to 1MHz) with very high CMRR to cancel out the unwanted noise at its both inputs and deliver single output. The coupling capacitors C1 and C2 are implemented as MOS capacitor. 30 um, L = 3 um and resistor value 7 KΩ. The input of amplifier is 1.77 V and output is 2.4 V. This setup is used to analyze the effects of coupling through the substrate It is assumed that coupling occurs mainly through the transistor back gates and direct substrate contacts. This circuit is then simulated in Spice to simulate two versions of the circuit, with and without the substrate model. The ring oscillator is run freely, and the analog transistor is biased to deliver a constant current in the absence of substrate noise. After that analog transistor's body terminal is monitored.

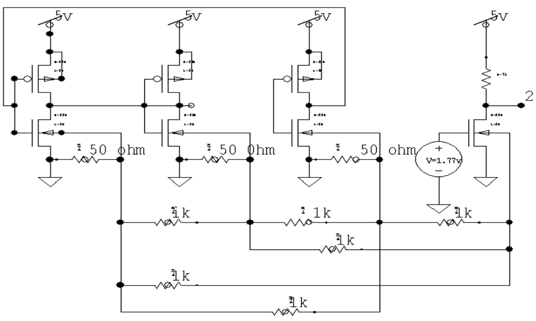


**Fig.1 Ring oscillator and common source amplifier circuit to evaluate the interference at the amplifier output**

When substrate coupling is not accounted for, the analog transistor's body terminal has a constant voltage and the amplifier output remains constant at 2.4V. However, when the substrate circuit is inserted in the circuit, the voltage at the body terminal oscillates rapidly with significant amplitude. The peaks in the body terminal of the analog transistor's It has been design to have a broad bandwidth (1 KHz to 1MHz) with very high CMRR to cancel out the unwanted noise at its both inputs and deliver single output. The coupling capacitors C1 and C2 are implemented as MOS capacitor. Waveform corresponds to the time periods during which the oscillator output nodes change more rapidly. These oscillations cause threshold-voltage changes, which can degrade the transistor's performance considerably. For correct circuit verification, therefore, we have to generate substrate models and must be included in any simulation.

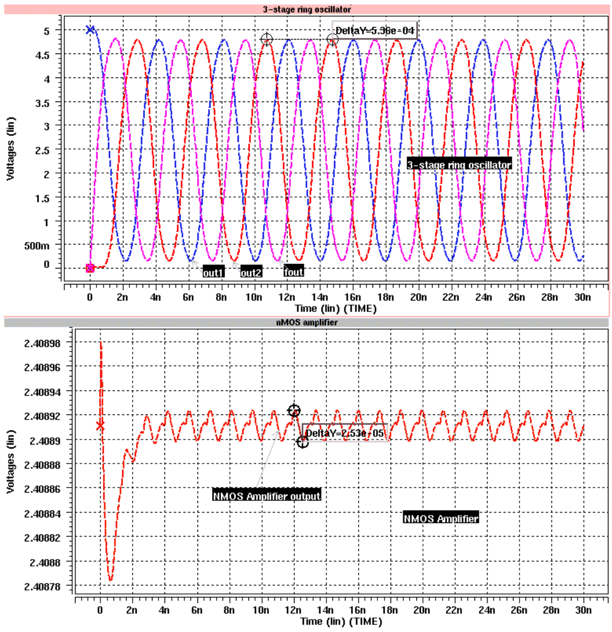


**Fig.2 Ring oscillator waveform and its coupling at nMOS amplifier output node**

### 1.2. PGIA Specifications (Noise Sensor)

- Power Supply
  - $V_{DD}$ = + 5 V
  - $V_{SS}$ = 0 V.
- Temperature Range = -40°C to +85°C.
- Dynamic Response
  - Bandwidth = 1 KHz – 1 MHz
  - Nominal Gain = 50 v/v – 10 v/v
- Reference Input = 2.5 v.
- Input
  - Operating Voltage Range = 0.7v to 3.3v.
  - Impedance = 100 MΩ.
- Output Voltage Swing = 0.5 to 4.5.
- Input Noise = 25 µv
- Output Noise = 35 µv

Because it must be able to handle very low level input voltages, an in-amp must not add its own noise to that of the signal. Micro power in-amp is optimized for the lowest possible input stage current and, therefore, typically has higher noise levels than their higher current cousins.

### 1.3. Instrumentation Amplifier Simulation

Test circuits for Instrumentation Amplifier:

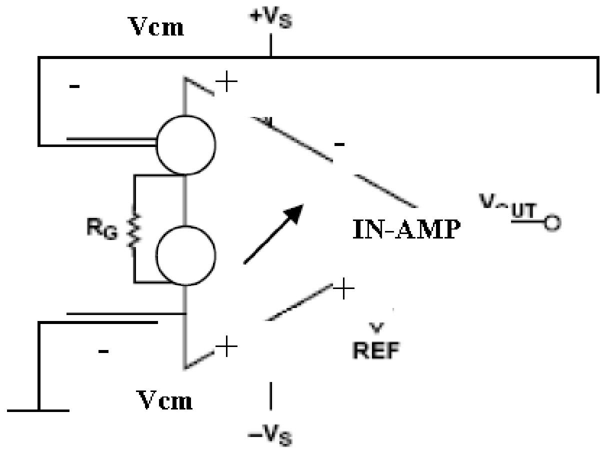


**Fig.3 IA Gain 30 (magnitude) at 27°C, 5V supply and $C_L$=20 fF**

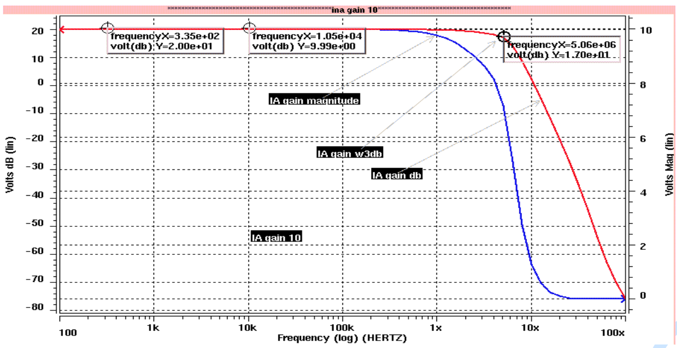


**Fig. 4 IA Gain 10 (magnitude) at 27°C, 5V supply and $C_L$=20 fF**

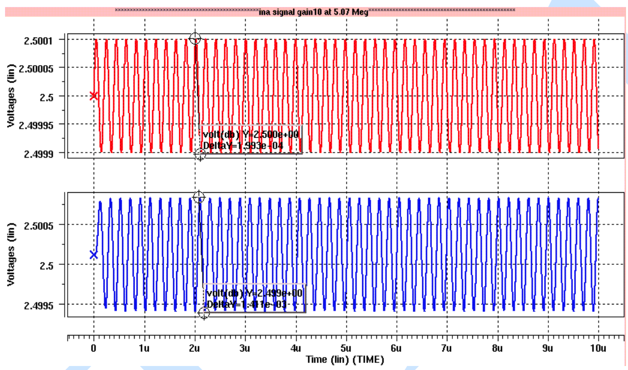


**Fig.5 IA 100 UV Signal amplification at 5.07 MHz, 27oC, 5V supply, CL=20 fF**

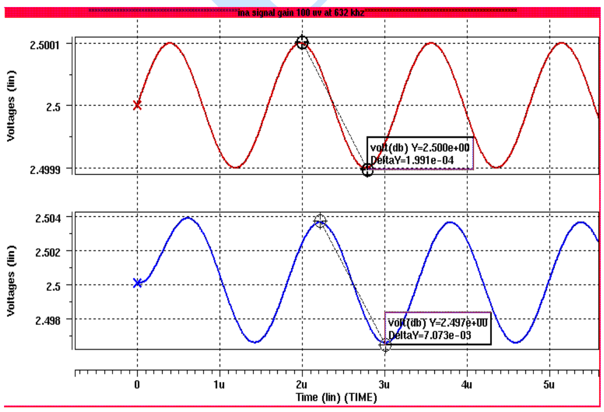


**Fig.6 IA 100 UV Signal amplification at 632 KHz, 27°C, 5V supply and $C_L$=20 fF**

## 2. Simulation

Resolution versus Frequency Capabilities of INA Substrate Noise Sensor (Biasing mechanism of Instrumentation amplifier inputs). The instrumentation amplifier is substrate Noise sensor with one input connected to a quiet ground and the other input connected to the substrate. It has been design to have a broad bandwidth (1 KHz to 1MHz) with very high CMRR to cancel out the unwanted noise at its both inputs and deliver single output. The coupling capacitors C1 and C2 are implemented as MOS capacitor.

## Conclusion

A novel method of measuring substrate coupling has been presented. An instrumentation amplifier (IA) with a broad bandwidth has been used to allow the measurement of substrate noise in time and frequency domain. Time and frequency domain measurement, using this substrate noise sensor, is planned to perform with programmable array of inverter string. All the circuit blocks are designed using the 0.8 µm design and process parameters. The obtained results for circuit blocks show a fair comparison between the targeted and the achieved values.

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