

**Testing report for MOSIS Educational Program  
(Research)**

Project Title

Integrated Circuit for Implantable Sensor

**Prepared by:** F.C. Jain<sup>1</sup>, Mo Zhang<sup>2</sup>, and S.K. Islam<sup>2</sup>

**Institution:**

<sup>1</sup>Department of Electrical and Computer Engineering, University  
of Connecticut, Storrs, CT 06269

<sup>2</sup>Department of Electrical and Computer Engineering, University  
of Tennessee, Knoxville, TN 37996-2100

**Date of Submission:** 12/04/2005

**Mosis Fab-ID: T55ZAT**

## Project Description

Two main issues for implantable sensors are long-term biocompatibility and power management. Electronic circuit using CMOS technology is one of the best candidates for designing the signal processing part due to its low power consumption and small size. The power will be transferred through inductive coupled links, therefore wire connections are eliminated and long-term stability of the device is significantly enhanced. In figure 1, we present a generic implantable sensor that transforms the signals in biology environments in term current levels. The electronic circuit integrated with the chemical part of the sensor will convert the sensed current to voltage, which can be transmitted outside the body through a RF (radio frequency) link. To be powered up by wireless connections, the most important requirement of the electronic part is capability of operating with very low power consumption in order of microwatt or smaller.

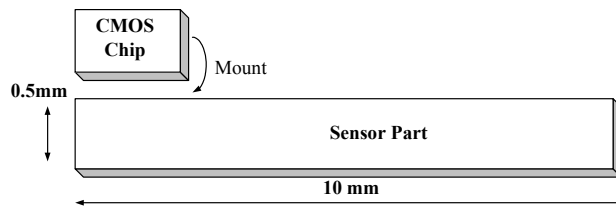


Figure 1. Simplification of an implantable sensor

## Fabrication Process

We chose CMOS TSMC 0.35 $\mu$ m process for this design because of its capability to implement low voltage supply, low power and reasonable cost designs. In this submit, we will include the light power source using Silicon solar cells and the design (except the sensor) in the same chip. *The chip is designed in TSMC 0.35  $\mu$ m process and is targeted for May 2005 run.*

## Simulation and Layout Plans

The circuits are simulated using Synopsys' Hspice and Cadence's Spectre. Hspice is used for most of the time domain simulations.

Layout is done using Cadence Virtuoso and the LVS clean layout is extracted with resistive and capacitive parasitics. The extracted netlist is simulated and compared with the simulation results from the schematic netlist. Both the schematic and post-layout simulations are done across all process corners and a temperature range of -40 to 120 degree C. A brief description of the schematics, simulation waveforms and performance is given below.

## Implantable sensor

The block diagram of implantable sensor is shown in figure 2 and the simulation results are given in figure 3. This circuit is designed to be powered by itself and send ASK signal, which can be received and demodulated by a commercial radio. The sensor current is generated by the implantable chemical sensor part. The current level is about  $0.2\text{-}2\mu\text{A}$ . The frequency out of the current sensor block is proportional to the sensor current. The square wave signal out of the carrier frequency generator is about 1MHz. The NAND gate will modulate the current sensor signal with the carrier frequency to create the ASK signal. A driver will be used to drive the antenna. Since the whole circuit is powered by on-chip solar cell. Every component is designed to consume very small power. A voltage regulator is designed to supply a stable  $V_{DD}$  for the circuit. Which is very important to create stable frequency for both current sensor block and carrier frequency generator, with a given sensor current.

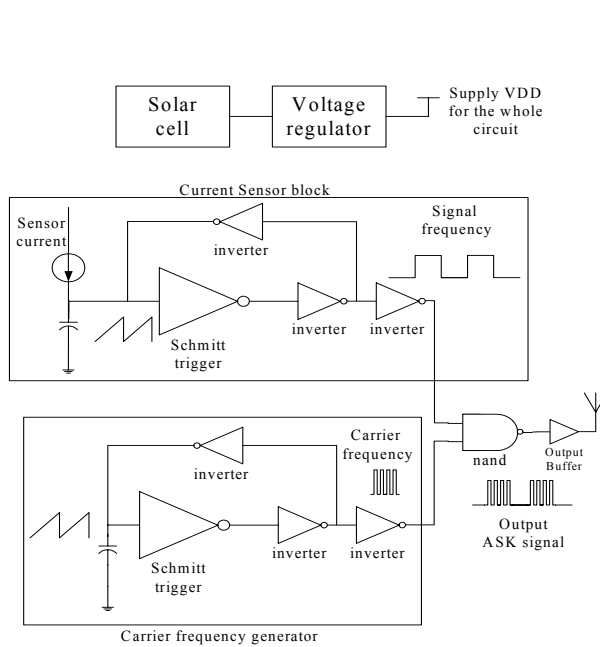


Figure 2--- Implantable sensor design

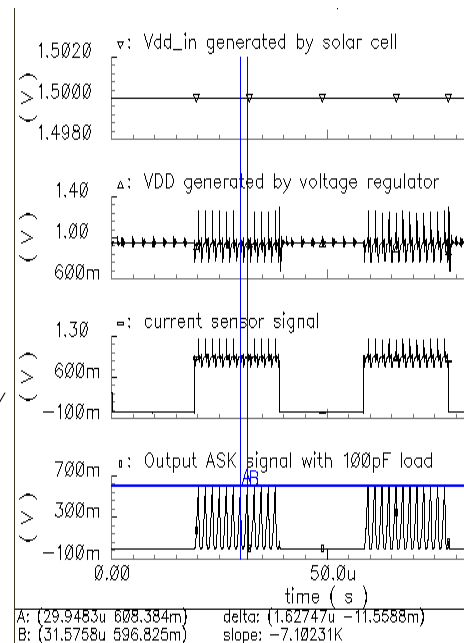


Figure 3--- Simulation results for the implantable glucose sensor

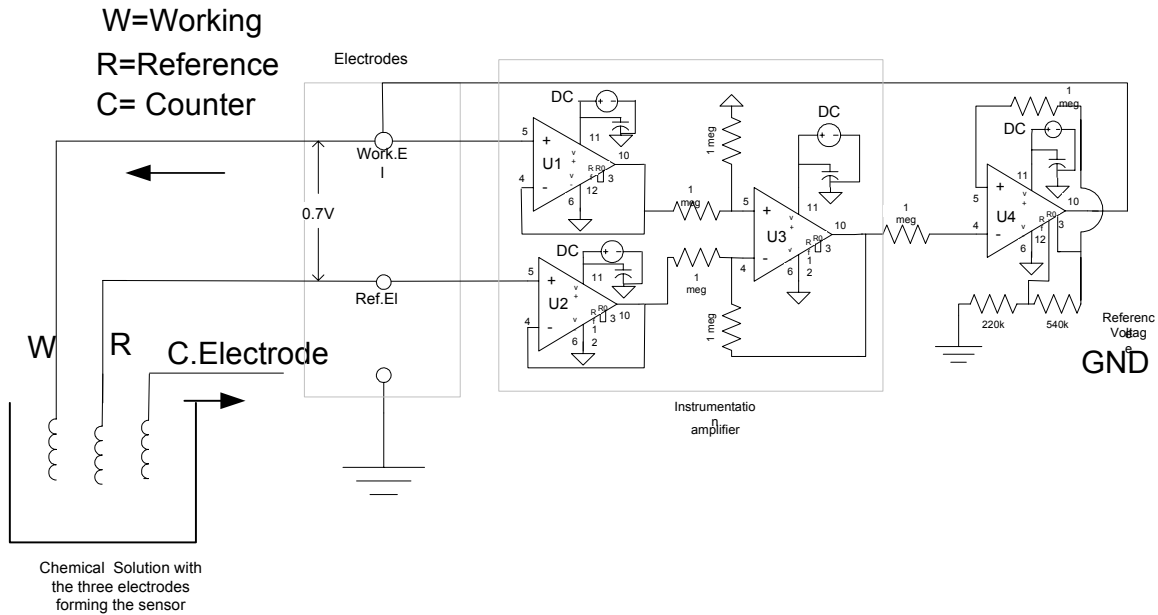


Figure 4--- Schematic of potentiostat circuit

Figure 4 shows the schematic of potentiostat circuit. It will generate the current that need to be processed by the other part of the sensor. The voltage difference between “Working” electrode and “Reference” electrode should always be about 0.7V. The current level out of the “Counter” electrode will be transferred to the frequency of the square wave output of the sensor circuit.

### Test Results

The fabricated chip will be tested in the Analog VLSI and Devices Laboratory. Tektronix TDS two-channel digital real-time oscilloscope are used to test the glucose sensor circuit.

Both potentiostat and sensor work. The voltage between ref\_el and work\_el is about 0.6V. The sensor's squarewave output frequency is proportional to the current flows between ref\_el and work\_el of the potentiostat.

There are two kinds of sensor circuit. Both of them work. Channel B only creates square wave output. Channel A consumes less power with low VDD and send out ASK signal, which has carrier frequency of 1MHz. The power consumption of channel A can be about 1mW. Channel B's power consumption is about 5mW.

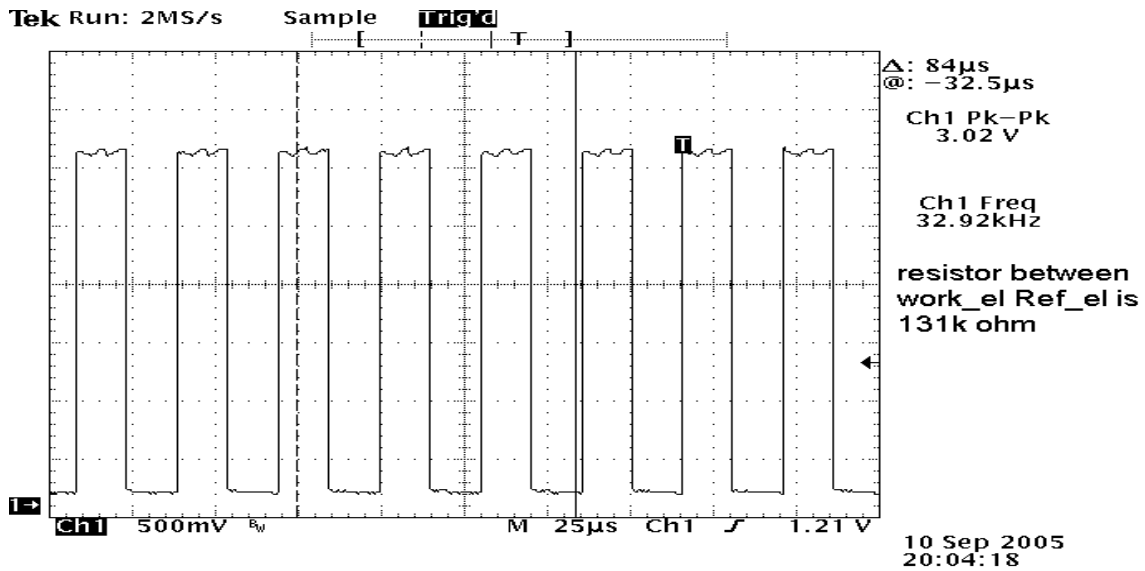


Figure 5---Channel B, resistor between work\_el and Ref\_el is 131k ohm. Square wave output frequency is 32.92kHz.

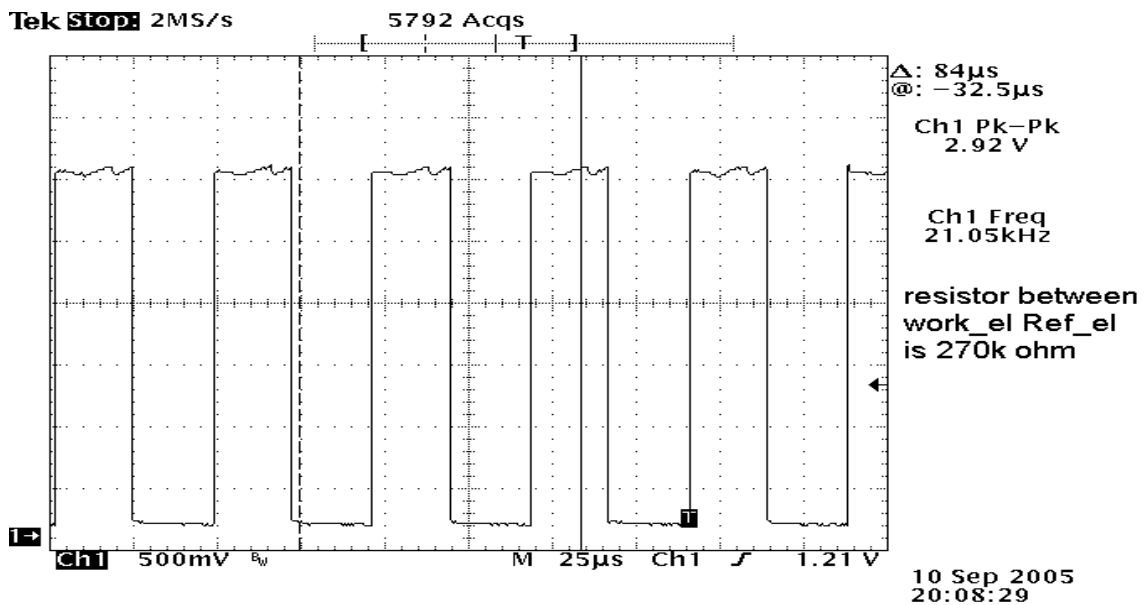


Figure 6---Channel B, resistor between work\_el and Ref\_el is 270k ohm. Square wave output frequency is 21.05kHz.

$$f \propto I \propto \frac{V_{work\_el} - V_{Ref\_el}}{R}, \text{ so we should have } \frac{f_1}{f_2} = \frac{R_2}{R_1}$$

$$\frac{f_{131k\Omega}}{f_{270k\Omega}} = \frac{32.92kHz}{21.05kHz} = 1.56, \quad \frac{R_{270k\Omega}}{R_{131k\Omega}} = \frac{270k}{131k} = 2.06$$

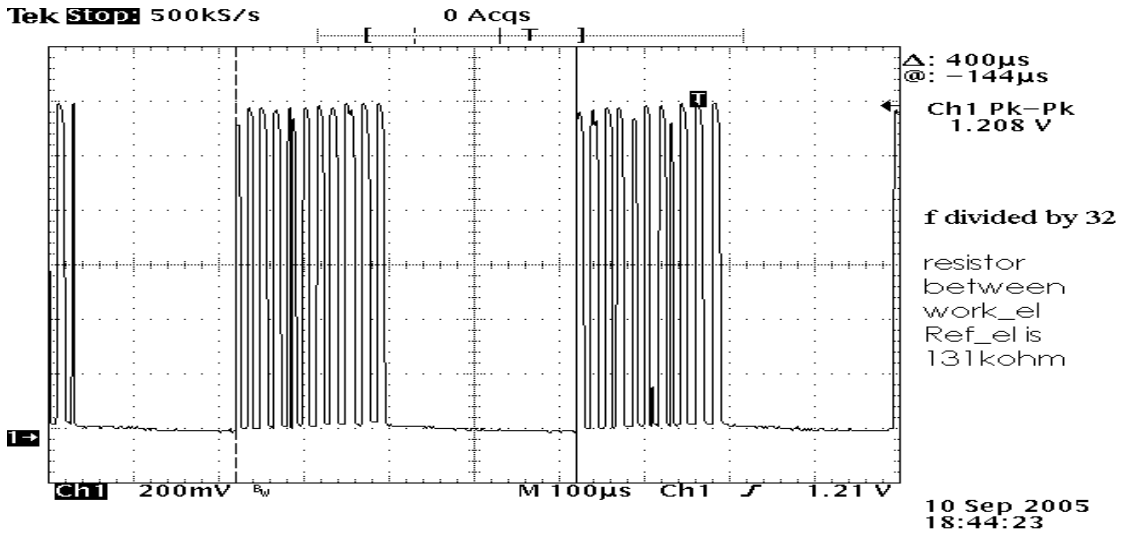


Figure 7---Channel A, resistor between work\_el and Ref\_el is 131k ohm. Square wave output frequency is  $1/400\mu s = 2.5\text{kHz}$ . Output frequency has been divided by 32 with an on-chip programmable frequency divider. ASK signal's carrier frequency is about 1MHz.

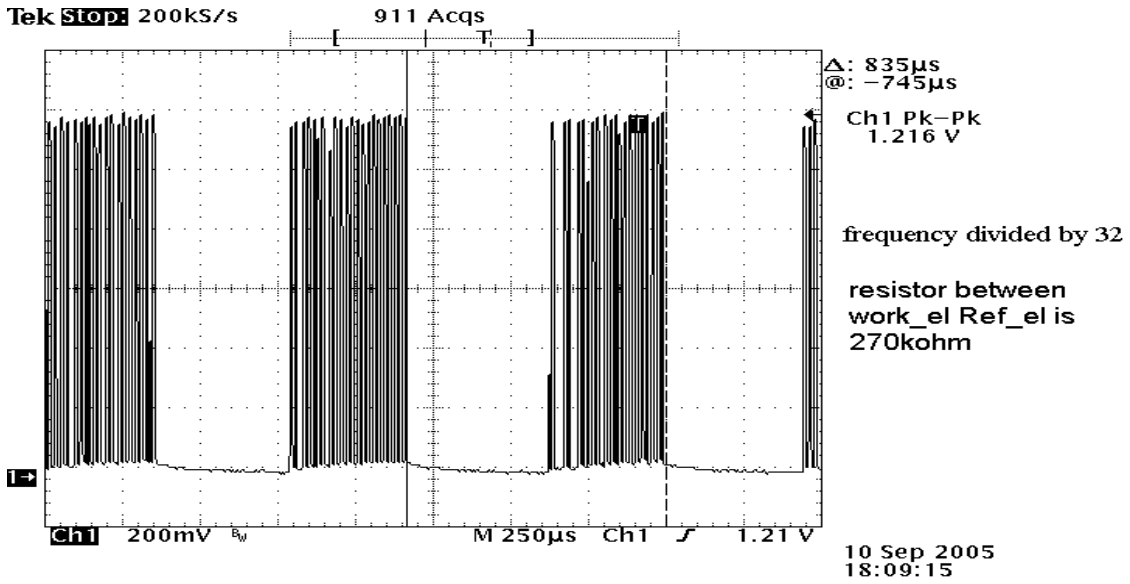


Figure 8---Channel A, resistor between work\_el and Ref\_el is 270k ohm. Square wave output frequency is  $1/835\mu s = 1.2\text{kHz}$ . Output frequency has been divided by 32 with an on-chip programmable frequency divider. ASK signal's carrier frequency is about 1MHz.

$$\frac{f_{131k\Omega}}{f_{270k\Omega}} = \frac{2.5\text{kHz}}{1.2\text{kHz}} = 2.08, \quad \frac{R_{270k\Omega}}{R_{131k\Omega}} = \frac{270k}{131k} = 2.06$$