

Design for MOSIS Educational Program (Research)

Project Title

Design of Implantable Sensors for Biomedical Applications

Design No:71951 Fab_ID:T4CU-AS

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Date of Submission: May 5, 2005

Project Description

We designed a circuit, which is suitable for biomedical implantable applications or remote sensor systems. The circuit could be used to monitor glucose density of human blood, neural signals in human brain or heart blood pressure. The sensor will be implanted inside the human body, so it is necessary to design a circuit, which can operate well at low voltage supply and consume a very small amount of power. The power sources for the system can be a light source using on-chip photodiode or a power source converting from RF signals (Radio Frequency). Two versions of design will be included in the chip.

Fabrication Process

We chose CMOS TSMC 0.35 μ 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 μ m process and is targeted for December 13 run.*

Simulation and Layout

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 °C. A brief description of the schematics, simulation waveforms and performance is given below.

Description and testing results of the Sensor Circuits

Version 1

The block diagram of sensor circuit is shown in figure 1 and the simulation results are given in figure 2. 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 a chemical sensor that detects the specific analyte. The current level is about 0.2-2 μ 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 low 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.

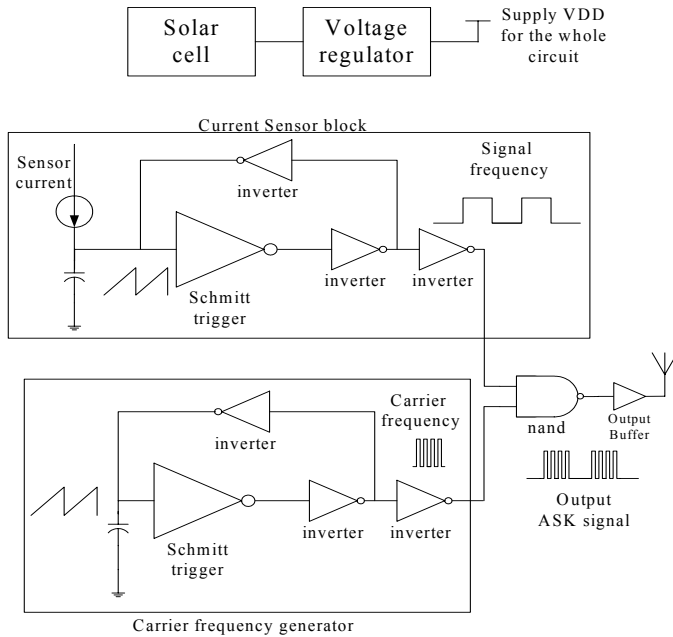


Figure 1. -Sensor circuit (version 1)

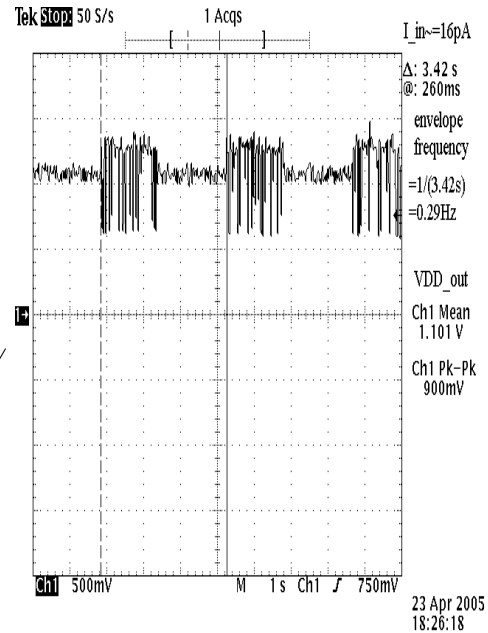


Figure 2.-Testing result of voltage regulator output (version 1)

The test result shows that with 2V unregulated supply voltage; the power consumption is 100uW in average. When the square wave output signal goes high, or during ASK oscillation, the power consumption is 200uW. When the square wave output become low, the power consumption is less than 10uW. And the regulated supply voltage is around 1.1V, just as designed. The oscillation frequency is around 300kHz, which is half of the simulation value. This is because the fabricated capacitance value is higher than the simulation value. With 1V unregulated voltage supply, the power consumption is below 1uW and the output is still an ASK signal.

On chip solar cell does not work well, since the parasitic photodiodes made up of n-well and p-substrate are also turned on. It is not possible to make a serially connected solar-cell on the same p-substrate.

Version 2

To stabilize the voltage supply and ensure the data transmitted out reliable, an on chip regulator is employed to create 1V supply for the system. A low voltage bandgap reference circuit is used to supply a reference voltage for the sensor and the regulator (0.7 V). The signal processing block will process signals received from the sensor and then the data will be modulated by using a low power consumption VCO (transmitter block). The amount of power transferred from outside into human body through light or

RF signal is limited, so the system is design in such a way it only consumes about $20\mu\text{W}$ (not including power delivered to the antenna). With this level of power, it's possible to transfer energy through light sources or RF links. The design is shown in figure 3.

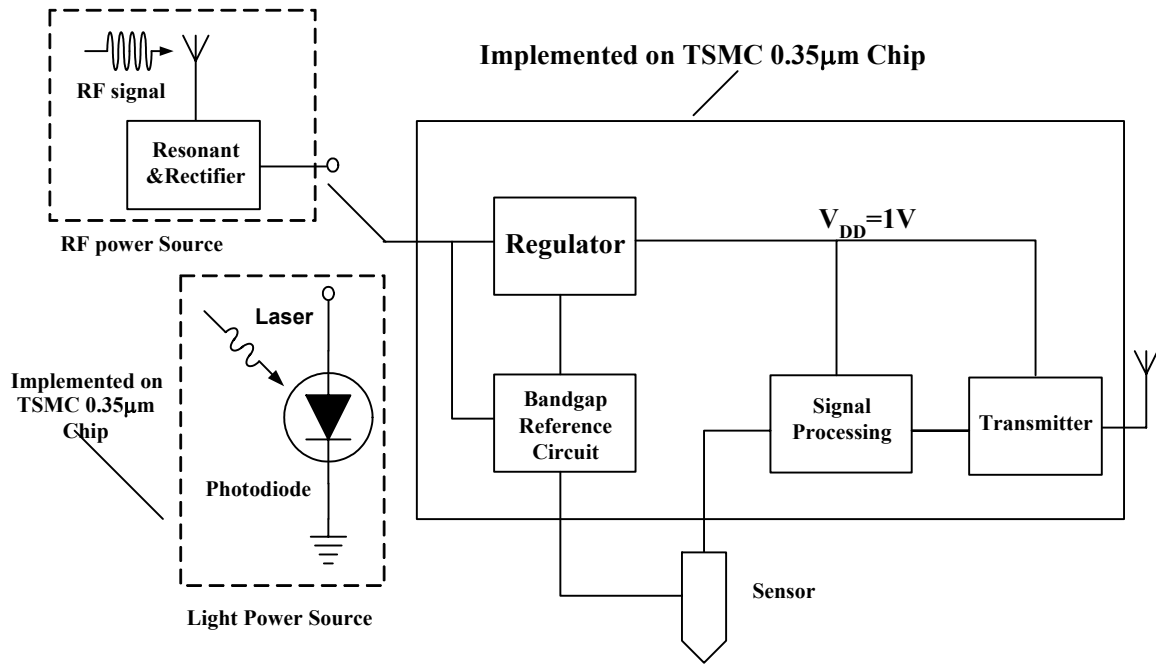


Figure 3. Sensor circuit (version 2)

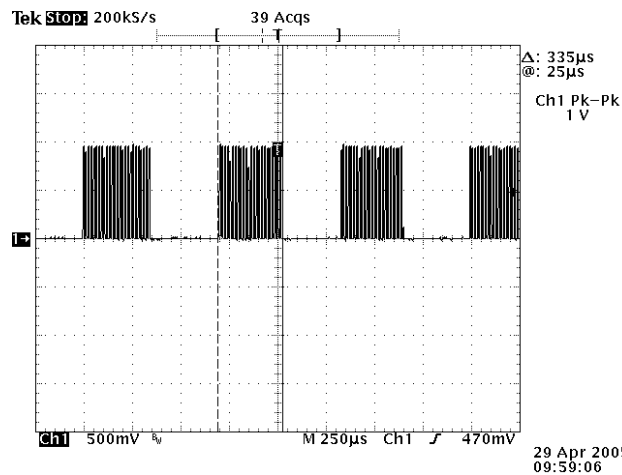


Figure4. The measurement result for input current of 35nA (version 2)

The testing result of version 2 circuit is shown in Figure4. When power supply is 1V, ASK signal is generated at the output.