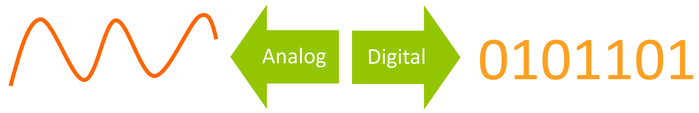
What?

A passive sigma-delta analog to digital converter (∑-Δ ADC) was designed and fabricated onto a silicon chip. This chip takes analog electrical signals, which can represent the natural signals around us such as sound or light and then convert the signals into digital values that a computer can read. These analog to digital converters (ADC) are found in almost all consumer electronics. The significance of the ADC presented here is that it consumes very low power and is suited for a wide variety of applications where the lowest power consumption is desired such as in mobile devices.



Passive Sigma-Delta Analog to Digital Converters

By Angsuman Roy

Advisor: Dr. R. Jacob Baker

Why?

The main motivation for this research is to reduce power consumption in analog to digital converters. A large portion of the total power consumption in a sigma delta ADC is due to an active amplifier circuit. Our design eliminates this active amplifier and replaces it with passive components such as resistors and capacitors. This reduces total power consumption by 20%-50% over an active amplifier. Although accuracy is diminished as a side effect, the decrease in power usage is beneficial in many applications and the trade-off is worth it. Ultimately, this translates to power savings that increase battery life in mobile devices and remotely deployed sensors.

Publications

Roy, A. and Baker, R. J., "A Passive 2nd-Order Sigma-Delta Modulator for Low-Power Analog-to-Digital Conversion"
IEEE 57th Midwest Symposium on Circuits and Systems

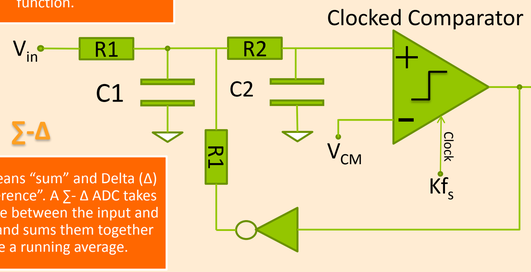
Roy, A., Meza, M., Yurgelon, J. and Baker, R.J. "An FPGA Based Passive K-Delta-1-Sigma Modulator"
(to be presented at the 58th MWSCAS in 2015)

How?

Analog In

The resistors and capacitors are used to filter the input signal. C2 implements the sigma or summing function.

Block Diagram



Digital Out

The output of the ∑- Δ ADC is a stream of 1s and 0s. The ADC counts the number of 1s and divides it by the total number of bits in a set time interval. The resulting average is the value of the input signal.

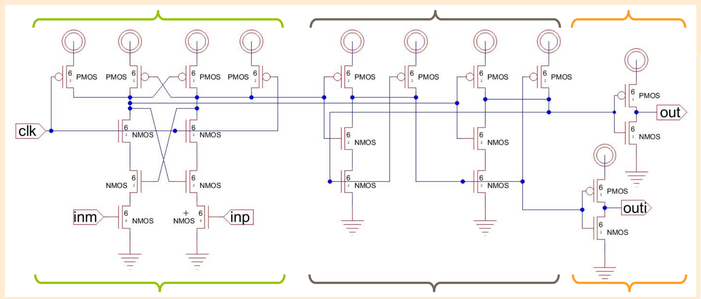
∑-Δ

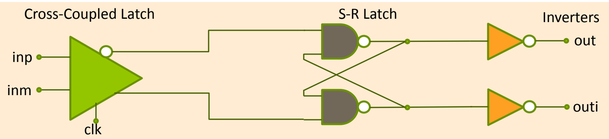
Sigma (∑) means "sum" and Delta (Δ) means "difference". A ∑- Δ ADC takes the difference between the input and the output and sums them together to create a running average.

Active Vs. Passive

What do the terms active and passive mean? In electronics, active parts are those that can control a source of power. For example, an amplifier is an active component. Passive parts are those that only consume power such as an incandescent light-bulb.

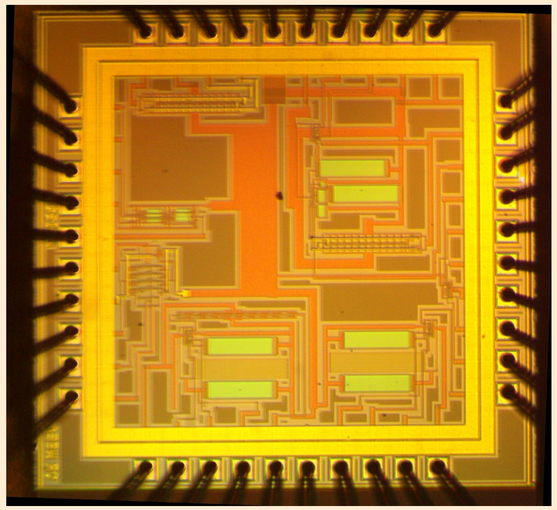
Detailed Schematic of Low Power Comparator

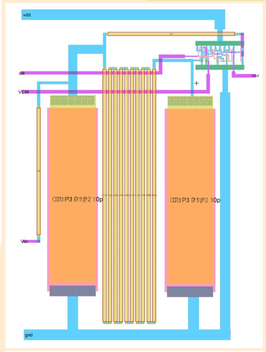




This is the detailed schematic of the low power comparator portion of the sigma delta ADC. The image below it shows the function of each section of the schematic. The cross-coupled swings high when the positive input is larger than the negative input. The S-R latch is used to ensure the circuit only triggers on the rising clock edge. The inverters are used to drive on-chip passive components.

Image of the Chip at 40x Magnification



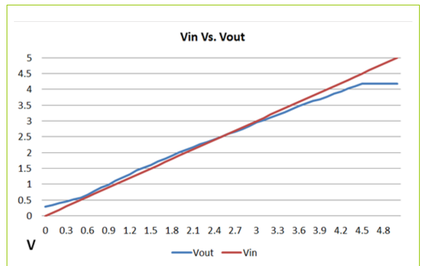


This is what the circuit looks like during the layout phase using the Electric VLSI software. This is one version of the circuit. There are many different versions on the full chip. If you look closely, you can see where this circuit is on the chip.

Fabrication

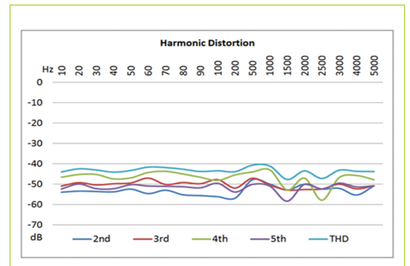
The chip was fabricated through MOSIS' educational program which lets students create integrated circuits for free. Semiconductor chips are made in multi-billion dollar foundries; universities require significant industry collaboration to do research in this area. The chip is built using On Semiconductor's C5 process with a minimum 500 nm feature size. The wires visible in the image are bonded to the silicon die to allow for connection to the outside world.

Results



DC Transfer

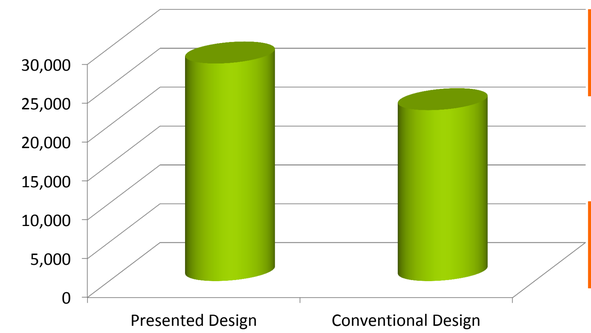
The red line indicates the input voltage. The blue line indicates the output voltage. The closer the blue line matches the red line, the better the performance.



Harmonic Distortion (dB Below Fundamental)

The colored lines indicate harmonics of the applied input signal. These are undesired and the lower the level, the better. The -40 dB marker corresponds to 1% distortion.

Battery Life (Hours)



Battery life based on a 560 mAh lithium coin cell battery.

Presented design can run off this battery for 28,000 hours while a conventional design can only last 22,000 hours.

Power Consumption = 100 micro-watts

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