SAND MicroSystems

Innovation with Sand

Two Strategic Recommendations for Companies Developing New Sensor Products (e.g.: MEMS, LiDAR)

Farzad Parsaie
SAND MicroSystems, Switzerland

Two strategic recommendations are given here for companies developing new innovative sensor products to become more efficient and faster in bringing their products to the market. Sensor products contain sensor, actuator or a MEMS (Micro Electro-Mechanical System) element together with a readout Electronic or ASIC (Application Specific Integrated Circuit) (Figure 1) and package. Some examples are like: MEMS Microphone, Accelerometer, Gyroscope, Pressure sensor or MEMS Mirror for applications like automotive, consumer, industry or medical. LiDARs (Light Radar), which are developed for object detection and 3-D scanning in automotive, industrial or other applications, are also considered as sensor product.

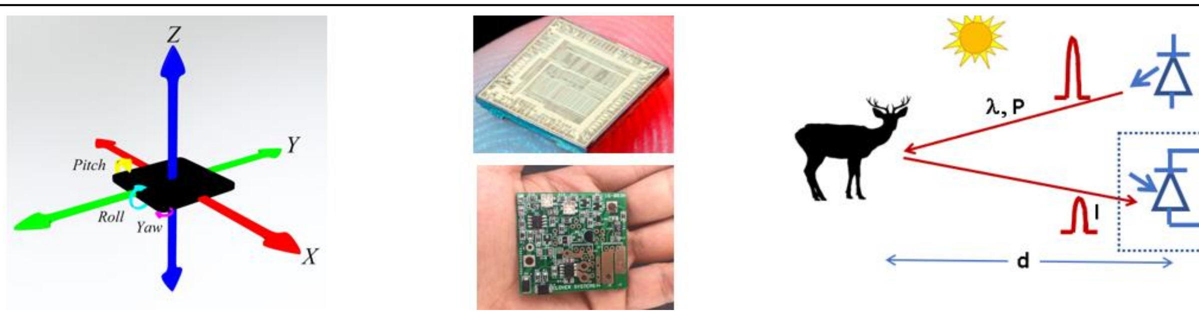

Figure 1: Sensor Products (MEMS/LiDAR) require Interface Electronics (on PCB) or ASIC for Signal Conditioning.

1- Do not only start with the Sensor Element but also with the Front-end Electronics

A sensor product cannot be sold without carefully designed interface Electronics on PCB or ASIC. Many companies making innovative sensor products spend most of their valuable time only on the development of the Sensor Element. It is very important to consider from the very beginning also the interfacing front-end Electronics on PCB or even on an ASIC.

Early stage consideration and simulations of Sensor/MEMS lumped element model together with the front-end Electronics, "Co-Design", opens new perspectives for the product by finding the optimum on the product level and not only on the Sensor/MEMS element. Mostly it is about the sensitivity, noise and the power consumption. By Co-Developing the Sensor Element together with Electronics (most importantly the Analog Front-end) from the very beginning we can identify how much additional effort is really necessary and justified to improve the physical Sensor Element behavior. The Co-Design of Sensor/MEMS together with the Front-end Electronics should be understood as an iterative optimization process.

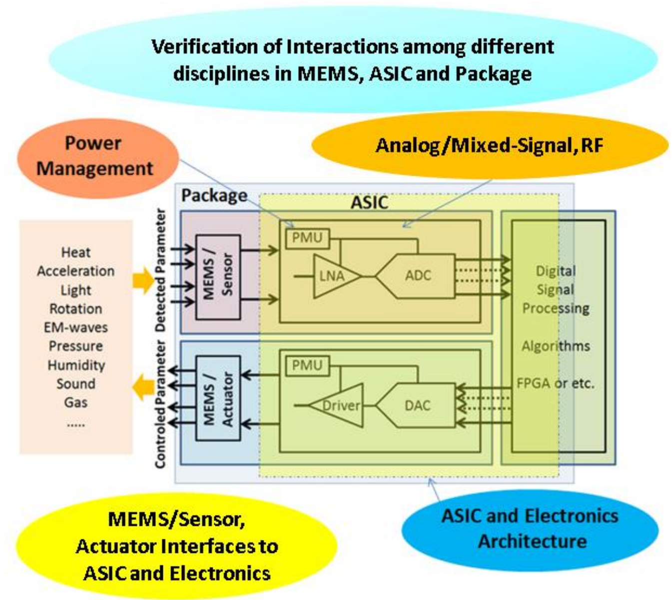

Figure 2: MEMS/Sensor, Actuator and ASIC, which may reside in the same package and hence are all quite interdependent. All the blocks shown here like PMU, LNA, ADC, etc. can either be realized on a PCB or on an ASIC.

Figure 2 shows beside the MEMS/Sensor and Actuator Elements the main blocks to be considered for the interfacing Electronics that can be either realized on PCB with off the shelf components or on an ASIC and the package, which may reside both MEMS and ASIC.

2- Do not postpone ASIC feasibility studies and its development for your new product

For products, where due to the expected number of pieces to be sold integration of Electronics on ASIC is justified, start with the feasibility studies for ASIC development already at early stages of Sensor product development.
Most differentiative and vital features (like sensitivity, speed, size, cost, …) of sensor products can only be achieved and realized by integration of interface Front-end Electronics on ASIC.
Many companies developing innovative and new sensor products postpone the ASIC studies and development by arguing that they should first run the product demonstrator with discrete components neglecting three important facts: a) falling behind those who have already started with ASIC integration, b) becoming unable to tackle issues, that will for sure popup on ASIC, earlier, c) failing to consider innovative and competitive architectures that can only be realized with ASICs rather than with discrete components having many parasitic effects on PCB.
There are several fabs around, which provide the option to make Test-Chips and MPWs (Multi Project Wafers) with reasonable prices. These offer the sensor product companies the possibility to realize the demonstrator of their sensor products together with the main components of the very critical and challenging Front-end Electronics to be integrated on Test-Chips.

Figure 3 shows the typical steps for ASIC development and manufacture. A process that can take up to 2 years or more to get to the supply. This process can be minimized in terms of time, risk and cost if problems are identified early enough through more intensive and earlier feasibility studies and fabrication of Test-Chips by designing and housing the most vital components on it. These vital components are mainly the Analog Front-end, Power Management and the Analog to Digital or Digital to Analog Converters (ADC, DAC). During the feasibility study, while analyzing and deciding for the right Fab and process one needs to determine the riskiest parts to design and manufacture them on the Test-Chip. The behavior of these elements can have a strong impact on the architecture, performance, cost, time to market and finally success of the whole product. With the main components designed on Test-Chip one needs to analyze and optimize their behavior under realistic and/or emulated conditions in the lab.

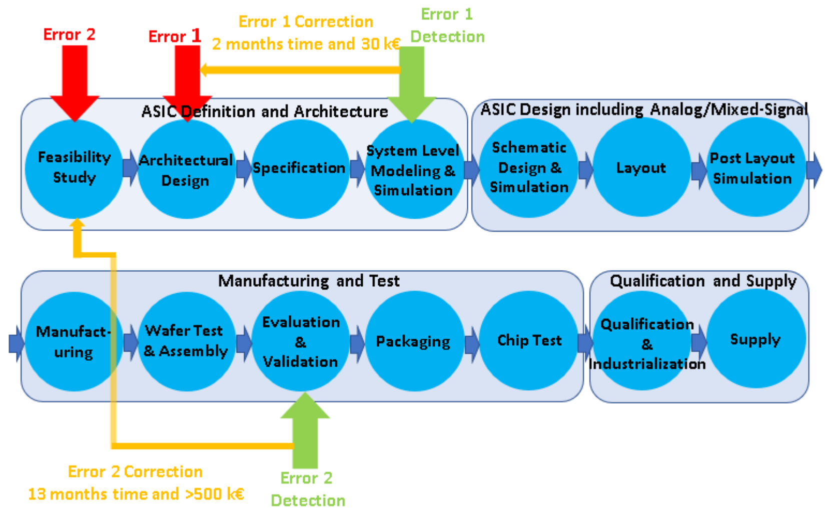

Figure 3: The typical steps of ASIC Development and Manufacture. The earlier an error is made and the later it is detected the higher the costs and time delay (compare the numbers given in the examples for Error 1 vs Error 2). Therefore, more intensive and earlier feasibility studies together with earlier design and fabrication of vital on-chip components (especially the Analog Front-end) on Test-Chips can contribute tremendously to cost and risk reduction.

Please note: Analog, Mixed-Signal and RF (radio frequency) blocks need always to be verified and investigated in their new environment and Chip. Never rely on a fact that because such a block has worked on another Chip in the past, as the case for purchased IPs, then it will work also best on your Chip. The performance of Analog, Mixed-Signal and RF blocks depends strongly on the environment, neighboring blocks and conditions they are being used. So, every time intensive simulations and lab tests are required to validate these blocks for a new Chip.

Examples for a high-speed and a highly sensitive Sensor product:

Example 1: Receive channel of a LiDAR Sensor

This is shown in a simple realization in Figure 4. Many LiDAR companies realize their new LiDAR product by using discrete off-the-shelf components such as Operational Amplifiers (OpAmps), Comparators etc. assembled on PCBs for their demonstrators. The fact is however, that LiDAR receive channels need to convert very weak and short incoming light pulses in the lower nanosecond range into analog voltage signals to be digitized later. Using discrete components connected on PCBs we won´t be able to receive very fast and weak signals. This is due to non-optimal discrete components, which are not tailored to the challenging requirements of today's LiDARs with corresponding parasitic effects on the PCB. To avoid this the product developer companies are forced to select more conservative architectures in order to be able to show the functionality of their LiDAR sensor. To remain competitive however, many decide finally or plan to go for an ASIC but unfortunately in many cases this happens too late.

To avoid the initial high costs of full ASIC realization it makes for example sense to develop the critical parts of the Electronics, in Figure 4 the blue part including the TIA and the discriminator, on Test-Chips. By doing this one gains enormous opportunities to improve the product architecture and related performance from the very beginning. This includes selection of the right ASIC manufacturing process (e.g. CMOS or BiCMOS with Si or Si-Ge and the minimum node size), design of the right OpAmp with a high enough gain-bandwidth (GBW), selection of the right feedback and signal conditioning topology.

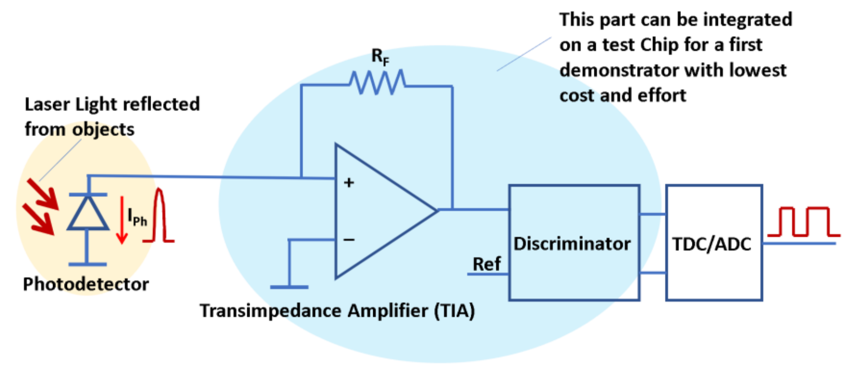

Figure 4: Simple depiction of a LiDAR Sensor receive channel

Example 2: Capacitive MEMS Microphone

There are three potential configurations, which can be used to sense capacitive MEMS Microphone signals: a) Voltage sensing, b) Current sensing and c) Charge sensing (see Figure 5).

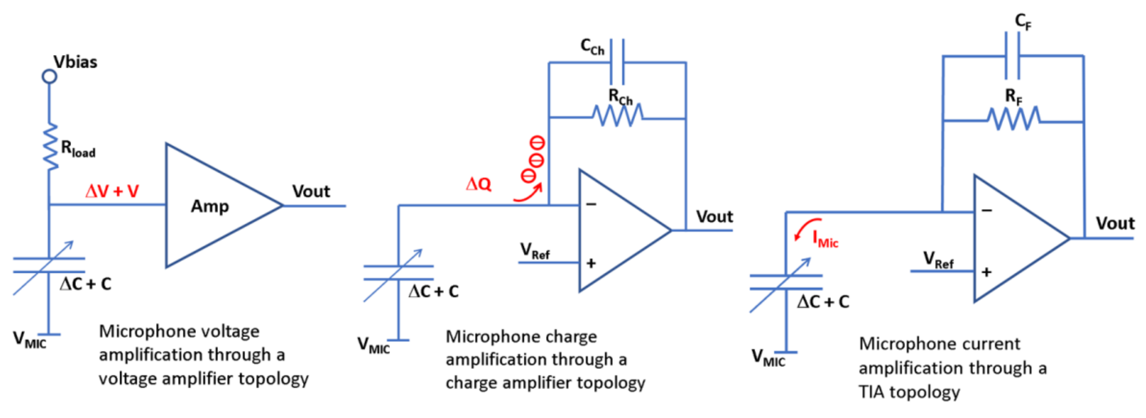

Figure 5: Possible configurations for MEMS Microphone capacitive sensing

The configuration we decide for depends strongly on the structure of the MEMS sensor and the strength and form of the signal received. No matter which configuration we select, we will have any way to deal with very sensitive and weak signals either in voltage, charge or current form. If we try to build the demonstrator on a PCB with discrete components, we will have several items worsening the performance of the MEMS Microphone giving us wrong indications causing non-optimal product architectures to be selected leading to sub-optimal performance. Additional parasitic components, larger OpAmp input currents, on-board supply noise and difficulties in making very symmetrical signal lines for differential signaling on PCB are some of the items that will have big impacts on MEMS Microphone behavior. Therefore, it is also here highly recommended to go from the very beginning towards ASIC development by starting feasibility studies, selecting architectures that can be implemented on ASIC and running a first Test-Chip with the Analog Front-end.

Conclusion

Two important recommendations have been given to companies that want to develop new sensor products, which have been briefly discussed.

First companies developing new Sensor products should not only focus on the development of the physical Sensor Element. They should keep in mind that no Sensor product can be sold without careful designed Electronics or ASIC. Therefore, it is a better idea to consider the Electronics or ASIC development from the very beginning.

Second for products, where due to the expected number of pieces to be sold integration of Electronics on ASIC is justified, the feasibility study of the interface ASIC and realization of important blocks (Analog Front-end) on it should be started very quickly. Interface Electronics on PCB can lead us to wrong directions or sub-optimal architectures with out exploiting all the possibilities we will have if using the right ASIC technology and process.

For inputs, discussions, questions and enquiries contact:

SAND MicroSystems GmbH, Switzerland
Phone: +41 (0) 44 500 48 68
Mobile: +41 (0) 76 349 62 11
E-Mail: Info@sand-microsystems.com
www.sand-microsystems.com