ADDRESSING THE CHALLENGES OF IoT DESIGN

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WHITEPAPER

AMS DESIGN & VERIFICATION

INTRODUCTION

Internet of Things (IoT) designs mesh together several design domains in order to successfully develop a product that interfaces real-world activity to the internet. Individually, these design domains are challenging for today's engineers. Bringing them all together to create an IoT product can place extreme pressure on design teams. Figure 1 shows the elements of a typical IoT device.

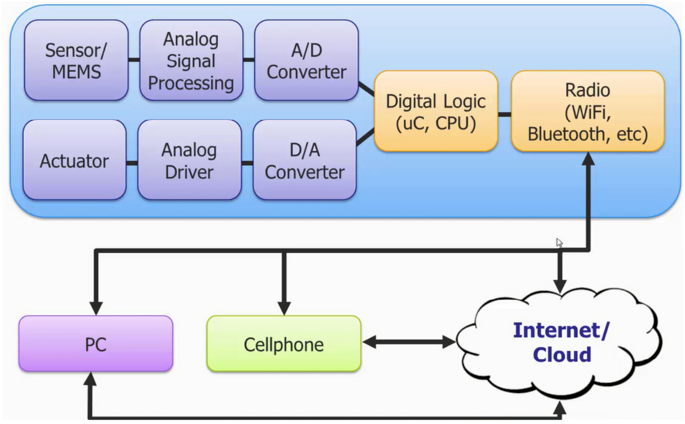

Figure 1: A typical IoT device.

This IoT device contains a sensor and an actuator that interface to the Internet. The sensor signal is sent to an analog signal processing device in the form of an amplifier or a low-pass filter. The output connects to an A/D converter to digitize the signal. That signal is sent to a digital logic block that contains a microcontroller or a microprocessor. Conversely, the actuator is controlled by an analog driver through a D/A converter. The sensor telemetry is sent and control signals are received by a radio module that uses a standard protocol such as WiFi, Bluetooth, or ZigBee, or a custom protocol. The radio transmits data to the Cloud or through a smartphone or PC.

DESIGN CONVERGENCE

Each of these major IoT functional blocks can be assembled from off-the-shelf, discreet components. However, there is strong pressure to converge the component from Figure 1 into a smaller number of individual packaged devices.

Convergence improves the cost, size, performance, and power consumption of the IoT device. By creating a multi-functional chip, the part count can be reduced and design integration can be improved. Figure 2 shows two examples of convergence. A radio chip company adds a microcontroller and the A/D and D/A converter. A sensor company adds the analog signal processing and A/D converter.

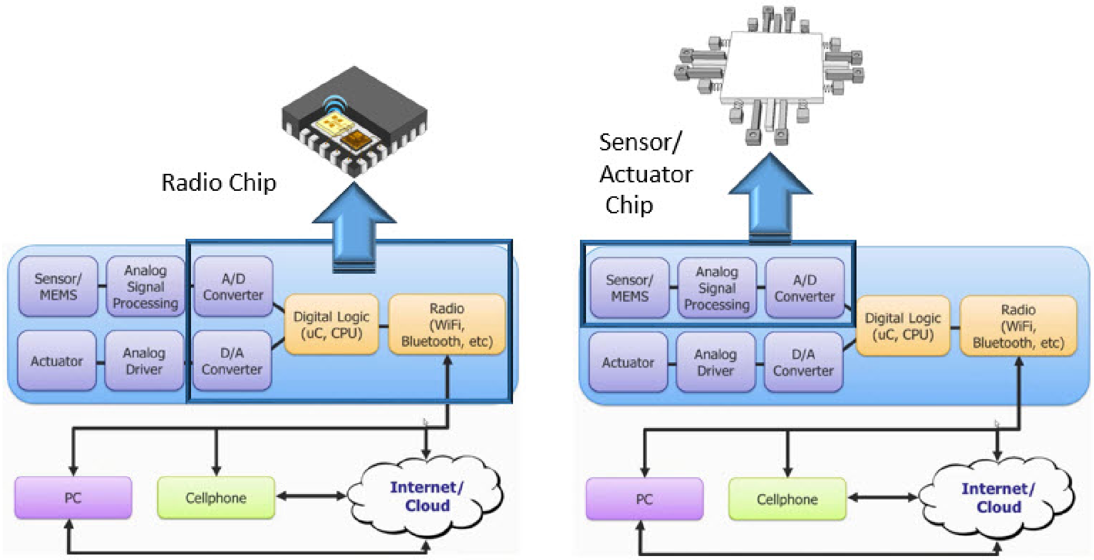

Figure 2: Converging functional blocks in order to create a multi-functional chip.

THE IoT DESIGN CHALLENGE

Convergence is the first clue to the fundamental challenge of IoT design. But let's dig deeper by looking at an actual IoT design, as Figure 3 shows.

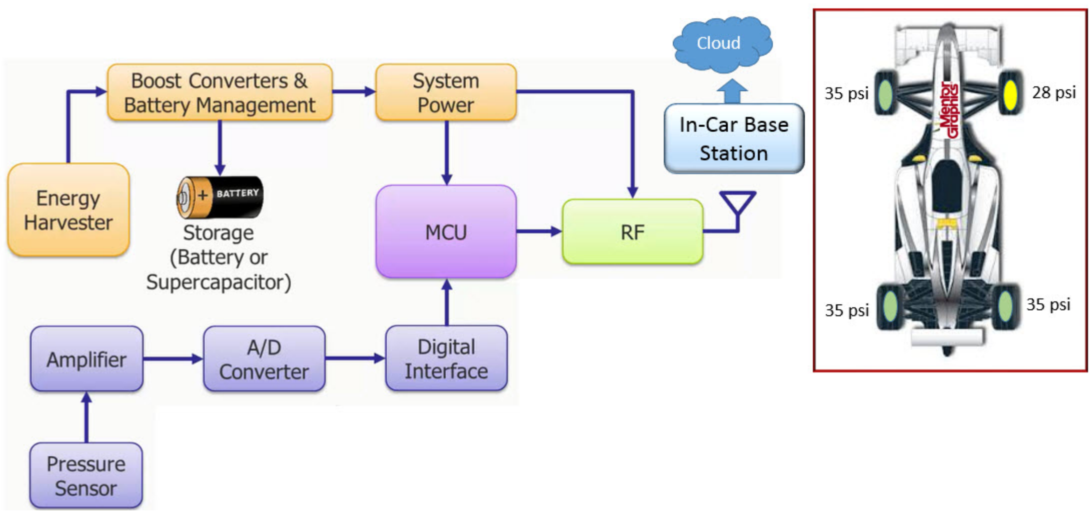

Figure 3: A racing team tire pressure monitoring system.

One tire pressure monitoring device is embedded in each of the tires of a race car. The tire pressure values are sent to an in-car base station that then sends the data to the Cloud. This data is available for the racing team to monitor. If the pressure is getting too low, the team is alerted and the driver is instructed to make a pit stop.

A MEMS pressure sensor constantly measures the air pressure for the tire. The analog signal from this sensor is amplified and converted to a digital signal. A digital interface sends the signal to the microcontroller for processing, which in turn sends the data to the radio. The in-car base station receives that data from the radio, and then uploads it to the Cloud. The racing team's software interprets the data stream and presents a readout of the tire pressure. A MEMS energy harvester uses the motion of the wheel to charge a battery or supercapacitor that powers the microcontroller and the radio.

The tire pressure design points out the fundamental challenge to IoT design: the four design domains that Figure 4 shows all live together in the IoT device.

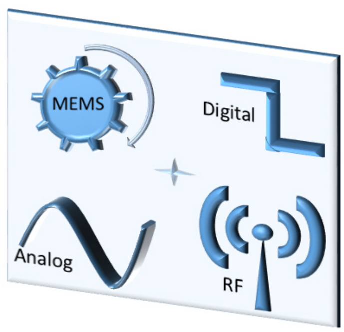

Figure 4: The four IoT design domains.

While design convergence can involve two or more design domains, the IoT challenge is even greater. IoT design requires that all four design domains are designed and work together, especially if they are going on the same die. Even if the components are targeting separate dies that will be bonded together, they still need to work together during the layout and verification process. In the tire pressure design, the A/D and amplifier are analog, the digital interface and microcontroller are digital, the radio is RF, and the pressure sensor and energy harvester are MEMS. The design team needs to capture a mixed analog and digital, RF, and MEMS design, layout the chip, and perform both component and top-level simulation.

THE TANNER SOLUTION

Tanner provides a single, top-down design flow for IoT design, unifying the four design domains. Whether you are designing a single die or multiple die IoT device, you can use this design flow for creating and simulating this device:

- Capturing and simulating the design. S-Edit captures the design at multiple levels of abstraction for any given cell. You can represent a cell as a schematic, RTL, or SPICE and then swap those descriptions in and out for simulation. T-Spice simulates SPICE and Verilog-A representations of the design which is fully integrated with S-Edit. ModelSim simulates the digital, Verilog-D portions of your design.
- Simulating the mixed-signal design. S-Edit creates the Verilog-AMS netlist and passes it to T-Spice. T-Spice splits the netlist automatically to partition the design for analog simulation and for digital simulation in ModelSim, as Figure 5 shows.

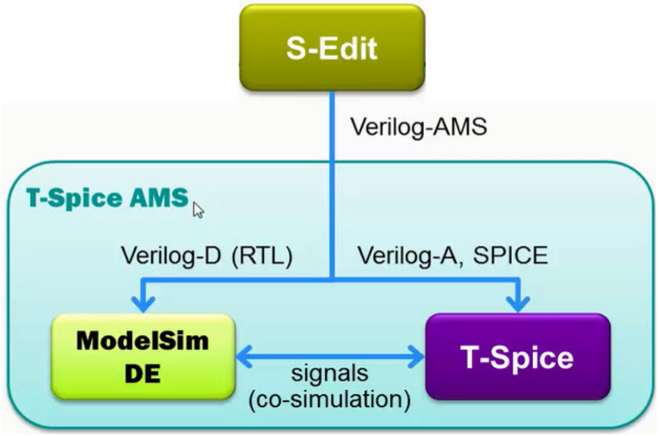

Figure 5: Analog and digital partitions for simulation.

Both simulators are invoked automatically and during simulation the signal values are passed back and forth between the simulators. This means, that regardless of the design implementation language, you just run the simulation from S-Edit and the design is automatically partitioned across the simulators. Then, you can view the results using the ModelSim or T-Spice waveform viewers.

- Laying out the design. Create the physical design using L-Edit which allows you to create a full, custom layout of the IoT design. The parameterized layout library of common MEMS elements and true curve support facilitate MEMS design.

IMPLEMENTING THE MEMS DEVICE

The MEMS component is key to determining device performance because of the associated packaging and fabrication process. For example, for the energy harvester in our tire pressure example; the vacuum level sets the air damping and this in turn determines the maximum displacement, and that ultimately controls the power output. The package must be deep enough to accommodate the motion that Figure 6 shows. To characterize the harvester, you need to simulate fluid-mechanical and piezo-electric action.

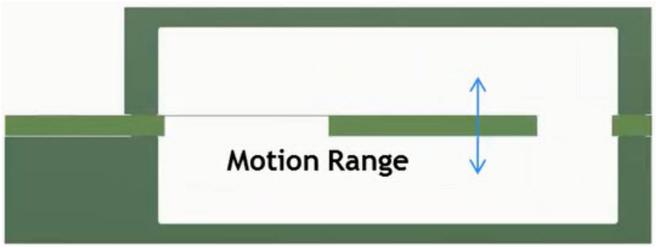

Figure 6: MEMS energy harvester motion range.

You could create a 3D model of the harvester and then analyze the physical characteristics. But, you need a 2D mask in order to fabricate the MEMS device. How do you derive the 2D mask from the 3D model? You follow the mask-forward flow that Figure 7 shows, that results in a successfully-fabricated energy harvester.

Start with 2D mask layout in L-Edit to create the device. Then, instruct L-Edit to automatically generate the 3D model from those masks in order to provide a simulation of the fabrication steps that occur at the Fab. Perform 3D analysis using your favorite finite element software and then iterate if you find any issues. Make the appropriate changes to the 2D mask layout and then repeat the flow. Using this mask-forward design flow, you can converge on a working fabricated MEMS device because you are directly creating masks that will eventually be used for fabrication, rather than trying to work backwards from the 3D model.

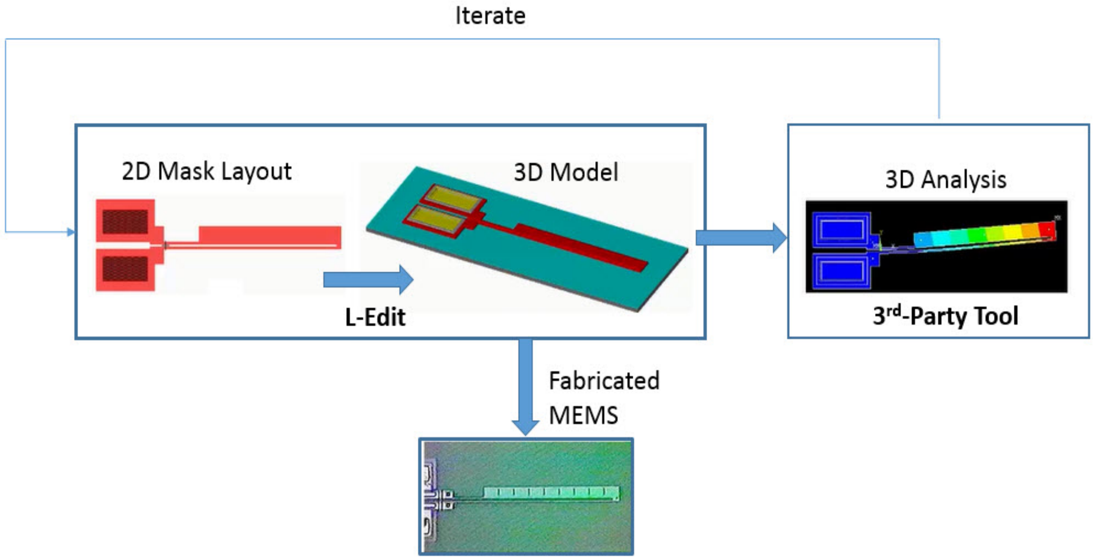

Figure 7: The mask-forward MEMS design flow.

CONCLUSION

The fundamental challenge of IoT design is working in four design domains; analog, digital, RF, and MEMS. The Tanner design flow is architected to seamlessly work in any of the design domains by employing an integrated design flow for design, simulation, layout, and verification.

A companion video to this whitepaper is available at: http://go.mentor.com/4ibuk

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