7 DESIGN ASPECTS OF IoT PCB DESIGNS

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WHITEPAPER

P C B D E S I G N

INTRODUCTION: IoT EVERYWHERE

Designing electronic products with IoT capabilities is no longer the exception, it is the rule. IoT technology not only opens up numerous new product categories of electronic devices, it drives innovators to rethink the ways that consumers interact with traditional tech-less products. From Makers to start-up companies and beyond, the opportunities to invent new tech devices and reinvent existing products with IoT capabilities, from health trackers (Fig. 1) to thermostats (Fig. 2), are seemingly endless.

Figure 1: IoT wearables

Figure 2: IoT-enabled thermostat

Imagine you're at the office and someone pushed the button on your IoT-enabled video doorbell that's connected to your home's WiFi network. Your smartphone receives the notification that the doorbell rang and suddenly you're accessing a live video stream of the visitor. Next, imagine that you can speak to the visitor directly, telling them that you're busy and instructing them to leave a package at the door, all without ever revealing whether you are physically home or not. The reality is, you don't have to imagine this technology, it's already available today.

The ecosystem of IoT-enabled devices is growing faster than ever, connecting the real world of objects, systems, and people with products that connect users to users, to other devices, and even to manufacturers. From the comfort of your couch, you can use voice commands to turn lights on, off, or dim without budging. Controlling IoT devices with simple intuitive mobile apps enables you to communicate with products like smart wearables, door locks, thermostats, your entertainment of choice, and much, much more.

To consumers, IoT devices look sleek and simple but they are comprised of a distinct set of components, physical interfaces, PCBs, and rigid-flex circuitry that presents unique design and layout challenges.

Ensuring IoT products don't fail or encounter unexpected delays and costs associated with reliability, manufacturing, or assembly problems is critical. Modern IoT designs require a PCB design environment with advanced functionality that includes pre- and post-layout simulation, layout constraint management, verification, and more.

This white paper describes seven design areas that must be considered in IoT PCB design.

1 – THE IoT DESIGN DOMAINS (FIG. 3)

Analog (A) and Digital (D) – Analog-to-digital converters are used in IoT designs to process, store, or transport virtually any analog signal in digital form to a microprocessor. These converters are most often referred to as A-to-D (A/D), D-to-A (D/A), and ADC (Analog-to-Digital Converter). The ADC is a mixed-signal device that provides an output that digitally represents the input voltage or current level. The key advantage of analog is that is offers an infinite number of representations, while digital has a finite number of possible representations. Converting from the analog world to the digital world enables us to use electronics to interface to the analog world around us.

MEMS (Micro-electro-mechanical systems) – MEMS are miniature sensors and actuators that are now commonplace in many of today's IoT designs. MEMS sensors gather information from their surroundings while actuators execute given commands. From fitness trackers that detect your steps, to your smartphone sensing when you've tilted your phone and rotating the screen, MEMS are key components in IoT design.

RF (radio frequency) – A radio module connects the IoT device to the Cloud via WiFi, Bluetooth®, or custom protocols. Multiple factors including application needs, technology constraints, and different hardware and software integration requirements must be considered for wireless connectivity. Understanding the IoT product's power consumption, range, connectivity, and throughput is critical to meeting each device's wireless technology requirements.

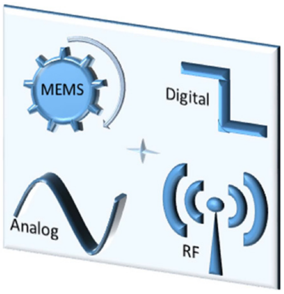

Figure 3: The domains of IoT design

2 – THE FORM AND FIT OF IoT DEVICES

IoT designs can be quite complex; as such, the product's software, network elements, and PCB(s) need to be prototyped. A driving requirement for the design of many mass-consumer, particularly human-interface IoT devices is the form factor. If a fitness tracker is not light, comfortable, or even fashionable, or if a smart watch is too bulky, or an IoT door lockset doesn't fit in aesthetically, the product is unlikely to ever get off the ground.

IoT devices are typically developed in one of two ways. The first way is to explore, design, and develop the product with a proof-of-concept prototype. Once the prototype is proven, market demand can be quantified by investigating whether the device can be packaged in a consumer-friendly form factor and meet the market demand and consumer price-point requirements.

The second development process is more typical for an established company. It starts with the physical design requirements. For example, for an IoT wearable, size and weight drive the final product shape and the overall look and feel. In other words, if a product's physical size is not ergonomic or appealing to the consumer, the product might never take off.

3 – IoT DESIGN COMPONENTS

An important step for IoT devices is researching and selecting all of the components needed. Part selection for analog/mixed-signal ICs, D/A-A/D converters, sensors, actuators, MEMS, and radio modules (Fig. 4) is critical with regard to both functionality and cost. IoT products often have miniaturized components including LEDs, displays, cameras, microphones, and speakers. Additionally, physical interface components such as buttons, switches, touch sensors, and charging ports are typical.

IoT devices may even contain reed sensors, fingerprint detectors, force sensing resistors (FSR), and flexibility sensors. Human interface devices (HID) like smartphones and compact wearables that house batteries with wired or wireless charging are low power and highly efficient, while other IoT-enabled devices that have been historically high-techless like doorbells and thermostats make use of existing electrical wiring for power.

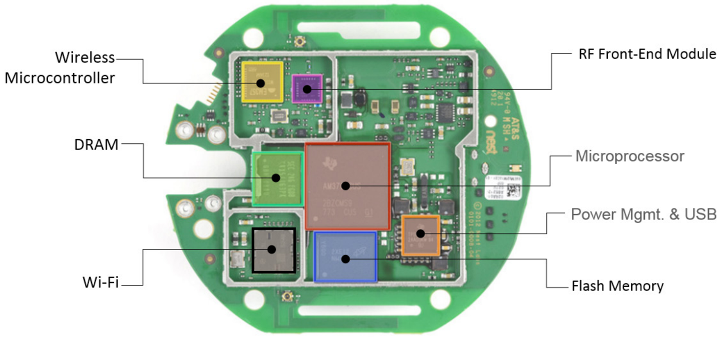

Figure 4: Typical components in IoT designs (example: Nest® thermostat)

4 – CAPTURING THE IoT DESIGN INTENT IN THE SCHEMATIC DIAGRAM

Once the IoT component selections are made and symbol library creation is complete, the next step is to define connections between the components in a schematic diagram. To achieve design efficiency and productivity, schematic creation should include component management to source components and manage costs. Direct access to analog/mixed-signal circuit analysis and pre-layout signal integrity analysis from within the schematic design environment (Fig. 5) is critical to ensuring that the design's signal integrity and physical characteristic requirements are achieved.

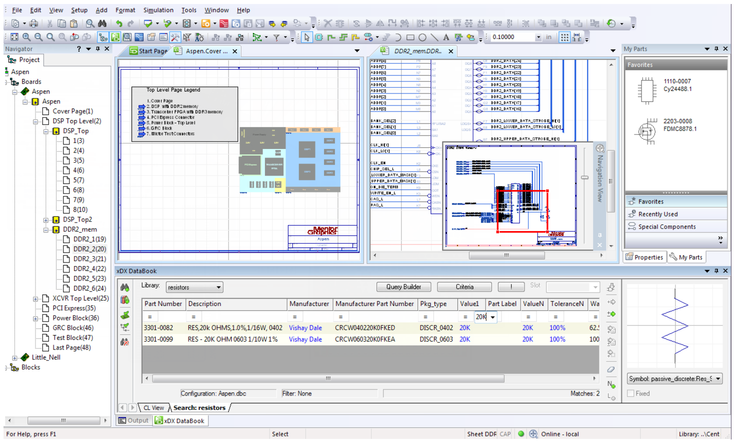

Figure 5: A fully integrated schematic-capture design environment

5 – ADDRESSING SIMULATION, VALIDATION, POWER, AND MEMORY IN IoT DESIGNS

IoT designs contain analog/mixed-signals (AMS). The high performance of AMS circuits is achieved through model-based AMS design, simulation, and analysis for mixed-technology circuits during the design phase (Fig. 6). From DC operating point, time domain, and frequency domain analyses to parametric sweep, sensitivity, Monte Carlo, and worst-case investigations, the behavioral verification, scenario exploration, and component optimization of an AMS circuit are critical to ensuring the design intent, performance, and reliability of IoT designs.

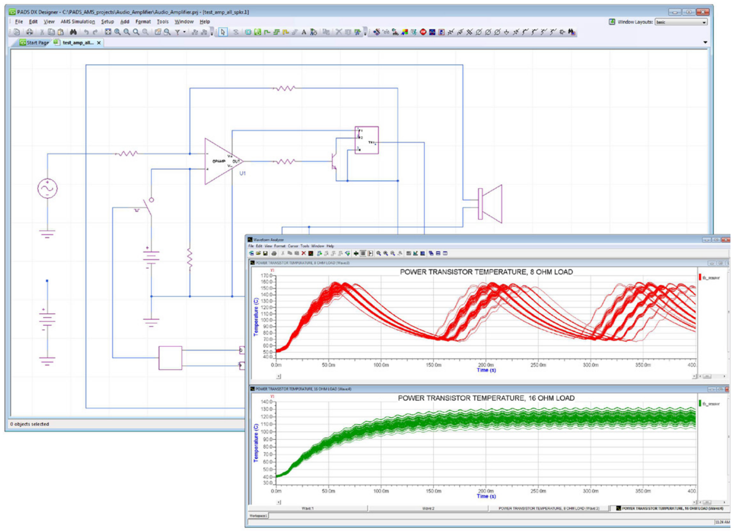

Figure 6: AMS simulation and analysis environment

IoT designs are especially unique in that they typically operate in multiple modes, such as standby, transmit/receive, active sensing, recharging, etc. As such, functional verification of each mode, and from mode to mode, must be specified and verified. For example, transistor-level simulation is required to verify that a built-in A-to-D converter operates correctly in a specified temperature range. Performing pre-layout simulation and planning for post-layout verification of IoT designs is critical for ensuring the product meets all of the product's functional requirements.

Many of today's most popular IoT devices are compact wearables. They are small, lightweight, and must be extremely power efficient. Power consumption must adjust from mode to mode to preserve battery life which, in turn, reduces the time between charging. To prevent product malfunction or failure caused by voltage loss on critical supply nets, it's important to analyze power integrity during layout. Unexpected or unpredictable circuit behavior can also be caused by power-delivery issues. To ensure power going to your ICs is clean and efficient, it's important to find and resolve areas of excessive current density early in the product creation process.

IoT products use modern microprocessors that connect to DRAM and flash memory. To take into account board-level effects such as lossy transmission lines, reflections, impedance changes, via effects, ISI, crosstalk, timing delays, and more, detailed simulations are necessary to provide a comprehensive view of your memory interface.

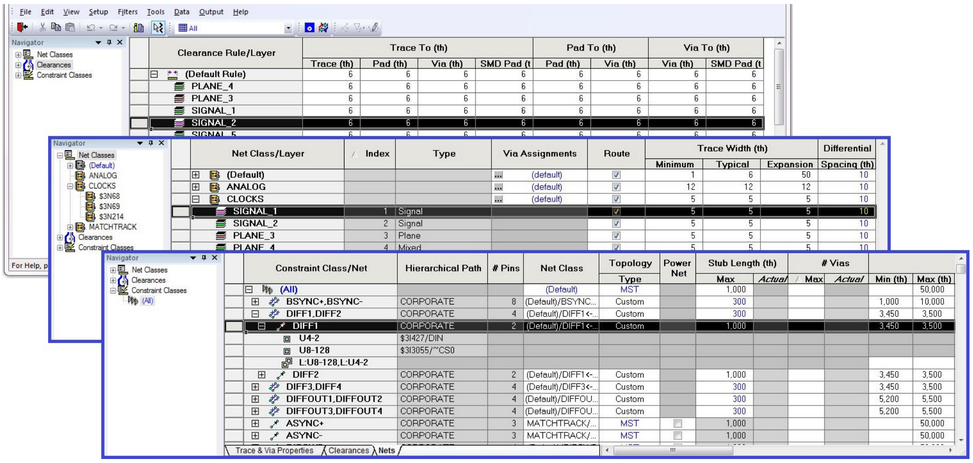

Figure 7: Advanced constraint management

The ability to accurately constrain and route memory connections is essential to reduce design time and debug cycles of DDR-based designs. With PCB layout capabilities including advanced constraint management (Fig. 7) and advanced DDR routing (Fig. 8), designers can quickly and accurately route high-speed, high-bandwidth traces.

6 – PCB LAYOUT

IoT designs, especially for consumer products like wearable devices, are driven by a pre-defined, marketable form factor that is typically designed within a 3D mechanical CAD tool. Being able to see the board in its enclosure in 3D prior to routing traces or pouring planes is essential for ensuring that the design will meet all of the product's physical requirements. In addition to the PCB outline, other factors, including the product's use environment and flexibility, must be taken into consideration. Here is a look at some of those factors:

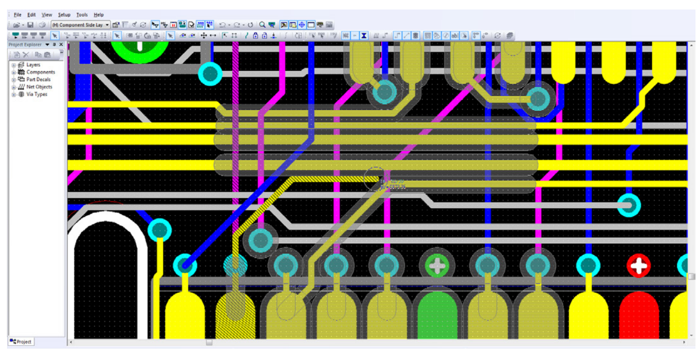

Figure 8: Constraint-based interactive routing

1. **Component placement** – Once your IoT schematic design is complete and you've imported the board outline (including the fixed physical interface component locations, mounting holes, cutouts, etc.) into the layout environment, component placement should be quick and easy. Bi-directional cross-probing between the schematic and layout helps a lot. The ability to place components in 2D or 3D while ensuring the placements meet your design constraints reduces design time and avoids violations.
2. **Constraint management** – Since components are often referred to as the building blocks for the PCB design, think of the connections between these building blocks as the mortar. Using integrated constraint management to propagate predefined electrical constraints throughout the design flow lets you control net classes and groups, define pin pairs, and more. Hierarchical rules nest constraints for more efficient route control, ensure that routes meet high-speed performance rules, and enable you to define high-speed rules for matched lengths, differential pairs, max/min lengths and more.

3. **2D/3D layout** – When designing an IoT product with tight form-factor constraints and a complex assembly procedure, having the ability to lay out and explore the design within a detailed 3D physical layout environment offers a huge advantage. With photorealistic 3D visualization during placement and dynamic design rule checking (DRC), you can ensure the layout is correct by construction. Accurate STEP models of components provide a view of the end product that ensures that the fit and clearances meet product specifications. Additionally, the ability to import the IoT product's mechanical enclosure into the 3D view gives the designer a photorealistic view of the final assembly to ensure fit and conflict avoidance.

4. **Rigid-flex circuits in IoT designs:** Flex and rigid-flex (Fig. 9) PCBs are now found in all types of electronics products and are frequently required for IoT designs.

   3D verification ensures that bends are in the right position, and that components do not interfere with folding. Managing flex bends, parts placement on flex layers, flex routing, and plane shape fills, etc. is especially critical for these designs. Having the ability to visualize IoT designs with rigid-flex early and throughout the design phase can prevent costly redesigns. Furthermore, the ability to export the rigid-flex design as a 3D solid model to MCAD promotes efficient bi-directional collaboration between ECAD and MCAD domains to ensure that manufacturing (DFM) and assembly (DFMA) issues are avoided.

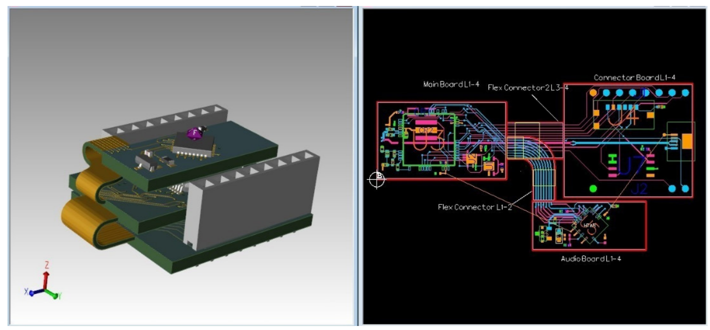

Fig 9: Rigid-flex in 3D and 2D design environments

5. **Testing IoT designs:** IoT products are low-power and require test platforms that can adapt quickly to new technologies. Four key testing parameters for wireless IoT products are range, battery life, interoperability, and response time. Devices that use Bluetooth® technology, for example, will have shorter ranges than those that use Wi-Fi technology. For battery-powered IoT devices, it's necessary to measure the power consumption of the device in realistic scenarios to ensure they have sufficient battery life throughout multiple modes.

7 – MANUFACTURING AND ASSEMBLY FOR IoT DESIGNS

Ensuring IoT devices are designed for manufacturing and assembly should be considered throughout the product design flow. DFT (Design for Test), for example, can provide the testability of the design from a bare-board perspective to identify shorts and other manufacturing defects. Similarly, performing DFMA (Design for Manufacturability and Assembly) analysis can identify issues such as resist slivers and unintended copper exposed by soldermask so that they can be corrected prior to fabrication.

From major electronics manufacturers to Makers, manufacturing IoT designs can be a complex process and saving a few pennies, whether it be on short prototype runs or in mass production, can impact profits or break a budget. Working with a layout tool that supports manufacturing features like DFMA analysis, panelization, and an ODB++ lean manufacturing data exchange flow helps avoid the issues that increase cost or lower yield by identifying problems that can cause delays and costly re-spins.

SUMMARY

IoT devices are being designed for an increasing number of industries, including consumer, automotive, medical, industrial, military, and more. As such, consideration for the signal and power requirements and power integrity must become part of the IoT product design and analysis methodology. The explosion of IoT devices over the past decade and the expected growth of IoT-enabled devices in new and existing products makes time to market, rapid prototyping, and designing for mass production essential to the success of a product.

The PADS® product creation platform directly addresses your technological IoT design challenges by providing the tools and horsepower needed to solve them. Achieve those aggressive design schedules and stay ahead of the competition, confident in the knowledge that you have the right tools to address the complex IoT design challenges not just of today, but of tomorrow as well. For IoT designs requiring rigid-flex support, choose Xpedition®.

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