What is Model-Based Design (MBD)? – How it Works? | Synopsys

Definition

Model-based design (MBD) is the practice of leveraging simulation to understand the behavior of a to-be-constructed or existing physical system. Models are software representations of any components of the physical system under study and may span a range of energy-conserved disciplines such as electrical, mechanical, thermal, hydraulic, pneumatic, optical, or any combination of these. This implies the system may consist of electronic integrated circuits (ICs), as well as passive and active devices.

For example, resistors to transistors, electromechanical actuators and motors, thermal hydraulic pumps and valves, electrothermal magnets, fiber optics, combustion engines with flow of chemical species, and even biological systems like neuron synapses and the human heart could be among the systems studied. For systems to work reliably or as designed, feedback control (analog, digital, or both) is usually employed to monitor the output versus input commands and system operating requirements.

A simulation study via model-based design must have a purpose, or a specific list of objectives or questions to be answered. For example, simulation can be used to verify a design of a system and optimize the hardware and software implementation before its construction to avoid potentially expensive physical prototype iterations. Other purposes may be behavioral sensitivity or stress level and functional safety fault (failure) analyses, or statistical variations of component tolerances and verification against expected performance with respect to reliability to permit yield analysis and reduce warranty costs, all while weighing against part sizing reduction and assembly costs.

To achieve model-based design objectives, three key things need to be in place:

1. Modeling tools that permit specialized device characterization or custom model development, as well as hardware description languages (HDLs), can empower engineers to cross the model vacancy chasm. The assembly of the simulation models in a system implementation permit the executable specification recognized as the virtual prototype.
2. Design knowledge and thorough understanding of simulation objectives. Expectations of system behavior either from knowledge of applied theory or hands-on experience can go far to eliminate inefficiencies in the implementation process. The questions being asked from simulation need to be aligned with the fidelity of the employed models, otherwise unnecessary complexity could stymie project progress.
3. A simulator that is robust and reliable. In this case, robust means that the simulator can generally provide results to permit design troubleshooting, while reliable means that the results provided can always be accepted with confidence that they reflect the state of the system.

How Does Model-Based Design Work?

A physical system as it exists in nature, on the testbench, or within an application is usually defined as a set of interconnected and interacting objects or components which perform a task or variety of functions. In model-based design, it is implied that a physical system is the study of the mechanisms inside a system using fundamental physical laws and engineering principles. A model, as it exists within a physical system simulation environment, reflects a selected object or component, indicating it is an approximation. This then implies that a model can have different levels of abstraction with respect to fidelity compliance of the actual physical component it represents. The specification of a model's fidelity is dependent on the simulation objections of the present design phase and the information available to characterize and verify the model, which may include manufacturer datasheets, measurements, and/or calculated parameters from targeted performance characteristics.

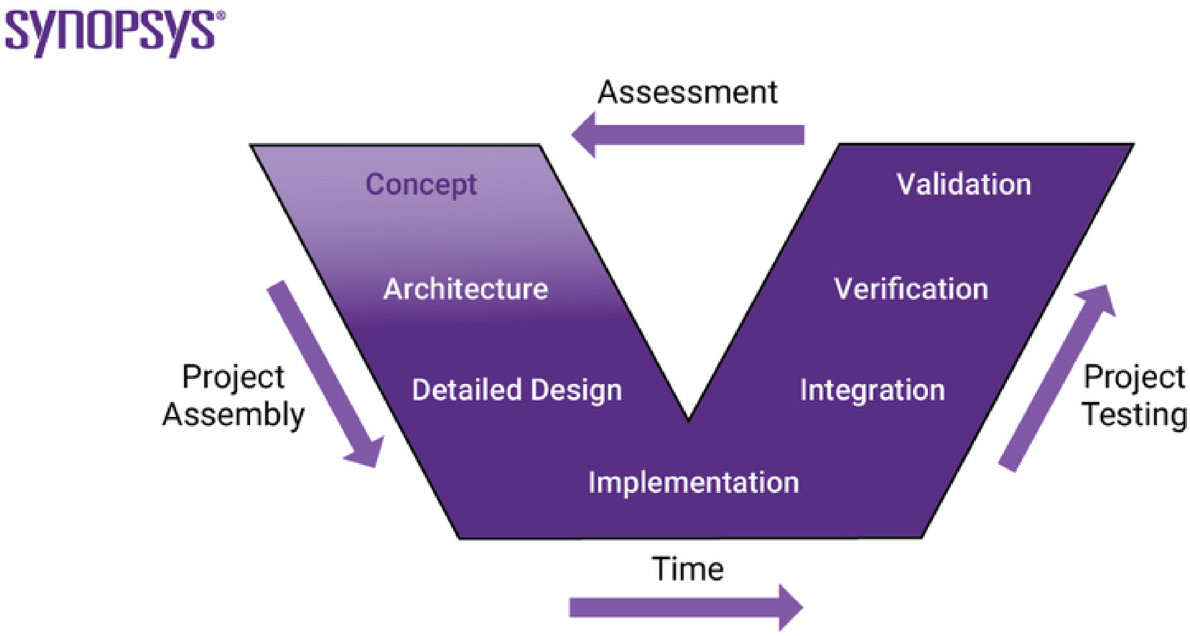

Figure 1: V-diagram of MBD flow

Model-based design enables a design flow described by the V-diagram. At each stage of the process, models of appropriate abstraction for that phase are used to represent system components and to simulate the design. These models can initially be high abstraction, modeling macro behavior for the purpose of general concept and conceptual architecture exploration. But under different design phases where more specific questions are being asked, the models can become more detailed as the design under study becomes more finalized until the entire system is rendered in models of appropriate accuracy to validate the design for production.

It may be useful to break out the implementation and project testing section of the model-based design flow and illustrate the iterative process to build a credible model. Before evaluating the quality of compliance between the observed and simulated behaviors, model verification is necessary. Model verification is the confirmation that the virtual prototype represents the system model within the specified limits of accuracy. With this realized and understood, the level of agreement of the observed and simulated behaviors is the essence of the model validation step. The evolution of an acceptable and valid model is an iterative procedure.

In general, all models in the system should indeed be individually characterized, verified, and validated before being introduced in more complex system designs.

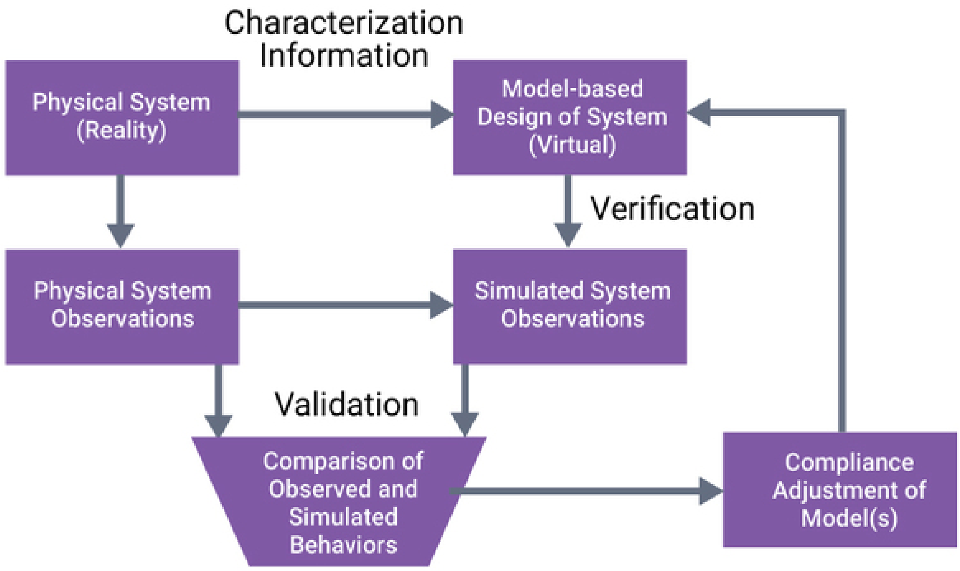

Figure 2: Building a credible model; verification and validation process

Benefits of Model-Based Design

With design engineers under pressure to achieve better quality designs that can be brought to market faster and at an increasingly lower cost of manufacture, the need to confirm the robustness of a design now extends beyond the verification of nominal system performance and into such areas as the impact of component tolerances, yield, and manufacturing options. The same criterion applies to existing design platforms which are often reused with updated or new functionality or improved performance features. To support this, it is essential to leverage model-based design and simulation technology to facilitate the production of robust, tolerance-neutral systems for which the yield can be determined, sensitivity and stress analyses undertaken, and critical parts identified prior to physical prototyping. Here are some key benefits of a model-based design:

- **Reduces expensive hardware iterations.** Designers can verify the design of a system and optimize the hardware and software implementations before its construction or do so with existing designs and avoid potentially expensive physical prototype iterations.
- **Enhances functional safety.** Virtual smoke from a virtual prototype of the physical system implies that aggressive and extensive testing can be performed efficiently and safety. This includes detection of potential embedded software failures in the event of erroneous sensor signals, voltage drops, or other fault circumstances that provide sanity checks of intermittent steering stability scenarios.
- **Time-to-market reduction for new product development cycles.** Model-based design methodology can be very efficient to significantly reduce time-to-market on new designs, permitting additional, critical flexibility to meet customer performance requirements.

- **Warranty overhead cost reduction.** Simulation on a nominal characterized system is very useful, but simulation on a system where the components include assigned tolerances permit invaluable statistical analyses and worst-case analysis (WCA) performance evaluations. Designers can thereby predict manufacturing yield, how many units may pass final quality assurance inspection and ship, or how many units could potentially fail in the field. WCA simulation information may help circumvent financial obstacles and make early design change decisions, thereby avoiding expensive warranty callbacks.

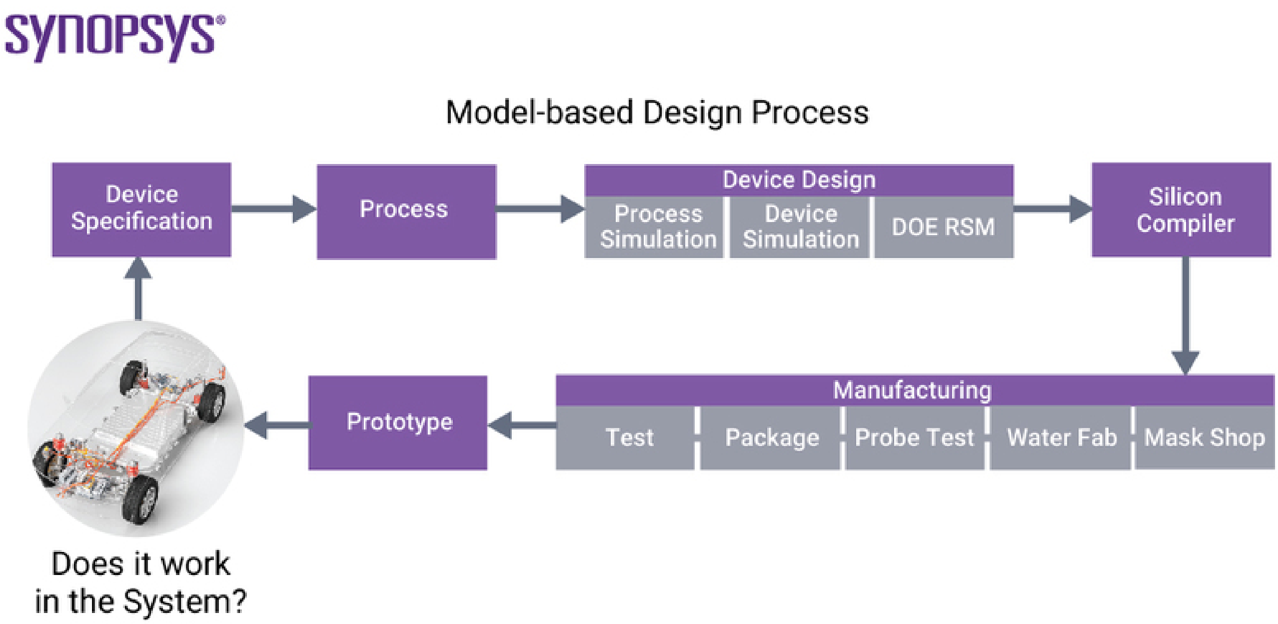

Figure 3: The MBD process reduces hardware design iterations and costs

Model-based design first and foremost requires "models." Synopsys SaberRD and SaberEXP simulation products provide ASMLs that enable a design engineer to get from point to point in their simulation objectives. These libraries span a range of mixed technologies to permit assembly of the physical plant, system to be controlled, and the feedback elements. Modeling tools that permit specialized component device characterization or custom model development, as well as HDLs, can empower engineers to cross the model vacancy chasm. This helps users solve their modeling problems, increasing the efficiency within Synopsys tool usage for library development by making it easier to:

- Characterize component models (BJTs, MOSFETs, IGBTS, diodes, batteries, etc.)
- Verify/validate existing models
- Create new models
- Investigate limitations, boundary conditions
- Reduce the gap between top-down and bottom-up design methods
- Run high-level to detailed embedded code against virtual hardware

Providing a wide-ranging and automatic set of analyses to ensure the robustness of designs, SaberRD and SaberEXP help designers realize the substantial benefits that can arise out of early yield, stress, and fault analyses. These tools enable critical parts of a system to be identified, including components that are overloaded or those that are likely to adversely impact performance the most.

The "virtual manufacture" techniques of model-based design are not only extremely effective in revealing potential problems of yield caused by tolerance problems but can also achieve significant cost savings by identifying those components for which tight tolerance specification is not an issue so that expensive, narrower tolerance components are designed in only where their use is critical.

ECU emulators such as Synopsys Silver and Virtualizer™ enable genuine software testing to identify and resolve software bugs early in the design cycle, before hardware exists or is finalized, or as part of a software update and verification in a reused design platform.