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Design and Verification of Low-Power Integrated Circuits

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Accellera Systems Initiative

Unified Power Format (UPF) Standard, Version 1.0

Cadence Design Systems, Inc.

Library Cell Modeling Guide Using CPF

Hierarchical Power Intent Modeling Guide Using CPF

Silicon Integration Initiative, Inc.

Si2 Common Power Format Specification, Version 2.0

Abstract: A method is provided for specifying power intent for an electronic design, for use in verification of the structure and behavior of the design in the context of a given power management architecture, and for driving implementation of that power management architecture. The method supports incremental refinement of power intent specifications required for IP-based design flows.
Keywords: corruption semantics, IEEE 1801™, interface specification, IP reuse, isolation, level-shifting, power-aware design, power domains, power intent, power modes, power states, progressive design refinement, retention, retention strategies

IEEE Introduction

This introduction is not part of IEEE Std 1801-2013, IEEE Standard for Design and Verification of Low-Power Integrated Circuits.

The purpose of this standard is to provide portable low-power design specifications that can be used with a variety of commercial products throughout an electronic system design, analysis, verification, and implementation flow.

When the electronic design automation (EDA) industry began creating standards for use in specifying, simulating, and implementing functional specifications of digital electronic circuits in the 1980s, the primary design constraint was the transistor area necessary to implement the required functionality in the prevailing process technology at that time. Power considerations were simple and easily assumed for the design as power consumption was not a major consideration and most chips operated on a single voltage for all functionality. Therefore, hardware description languages (HDLs) such as VHDL (IEC 61691-1-1/ IEEE Std 1076™)[a] and SystemVerilog (IEEE Std 1800™) provided a rich set of capabilities necessary for capturing the functional specification of electronic systems, but no capabilities for capturing the power architecture (how each element of the system is to be powered).

As the process technology for manufacturing electronic circuits continued to advance, power (as a design constraint) continually increased in importance. Even above the 90 nm process node size, dynamic power consumption became an important design constraint as the functional size of designs increased power consumption at the same time battery-operated mobile systems, such as cell phones and laptop computers, became a significant driver of the electronics industry. Techniques for reducing dynamic power consumption—the amount of power consumed to transition a node from a `0` to `1` state or vice versa—became commonplace. Although these techniques affected the design methodology, the changes were relatively easy to accommodate within the existing HDL-based design flow, as these techniques were primarily focused on managing the clocking for the design (more clock domains operating at different frequencies and gating of clocks when logic in a clock domain is not needed for the active operational mode). Multi-voltage power-management methods were also developed. These methods did not directly impact the functionality of the design, requiring only level-shifters between different voltage domains. Multi-voltage power domains could be verified in existing design flows with additional, straight-forward extensions to the methodology.

With process technologies below 100 nm, static power consumption has become a prominent and, in many cases, dominant design constraint. Due to the physics of the smaller process nodes, power is leaked from transistors even when the circuitry is quiescent (no toggling of nodes from `0` to `1` or vice versa). New design techniques were developed to manage static power consumption. Power gating or power shut-off turns off power for a set of logic elements. Back-bias techniques are used to raise the voltage threshold at which a transistor can change its state. While back bias slows the performance of the transistor, it greatly reduces leakage. These techniques are often combined with multi-voltages and require additional functionality: power-management controllers, isolation cells that logically and/or electrically isolate a shutdown power domain from “powered-up” domains, level-shifters that translate signal voltages from one domain to another, and retention registers to facilitate fast transition from a power-off state to a power-on state for a domain.

The EDA industry responded with multiple vendors developing proprietary low-power specification capabilities for different tools in the design and implementation flow. Although this solved the problem locally for a given tool, it was not a global solution in that the same information was often required to be specified multiple times for different tools without portability of the power specification. At the Design

[a]Information on references can be found in Clause 2.

Automation Conference (DAC) in June 2006, several semiconductor/electronics companies challenged the EDA industry to define an open, portable power specification standard. The EDA industry standards incubation consortium, Accellera Systems Initiative, answered the call by creating a Technical SubCommittee (TSC) to develop a standard. The effort was named Unified Power Format (UPF) to recognize the need of unifying the capabilities of multiple proprietary formats into a single industry standard. Accellera approved *UPF 1.0* as an Accellera standard in February 2007. In May 2007, Accellera donated UPF to the IEEE for the purposes of creating an IEEE standard, and in March 2009, the first version of the IEEE Std 1801 was released. So this standard, although the second version of the IEEE Std 1801, represents the third version of what is more colloquially referred to as UPF.

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