



IEC 61523-4

Edition 2.0 2023-10

INTERNATIONAL STANDARD IEEE Std 1801™



**Delay and power calculation standards –
Part 4: Design and Verification of Low-Power, Energy-Aware Electronic Systems**

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IEC 61523-4:2023-10(en) IEEE Std 1801-2018





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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 25.040.01, 35.060

ISBN 978-2-8322-7540-5

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DELAY AND POWER CALCULATION STANDARDS –

Part 4: Design and Verification of Low-Power, Energy-Aware Electronic Systems

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IEEE Standard for Design and Verification of Low-Power, Energy-Aware Electronic Systems

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Design Automation Standards Committee
of the
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Approved 27 September 2018

IEEE-SA Standards Board

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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

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IEEE Introduction

This introduction is not part of IEEE Std 1801-2018™, IEEE Standard for Design and Verification of Low-Power, Energy-Aware Electronic Systems.

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™¹) and SystemVerilog (IEEE Std 1800™²) 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, straightforward extensions to the methodology.

With process technologies below 90 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 have been 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 Unified Power Format (UPF) was developed to enable modeling of these new power-management techniques and to facilitate automation of design, verification, and implementation tools that must account for power-management aspects of a design. The initial version of UPF, developed by the Accellera Systems Initiative, focused primarily on modeling power distribution and its effects on the behavior of a system. In

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May 2007 that initial version was donated to the IEEE, and in March 2009 a new version, IEEE Std 1801, was released. That update of UPF added many new features, including the concept of successive refinement, more abstract modeling of system-power states, and more abstract modeling of supply networks.

This document, the latest revision of IEEE Std 1801, makes available further enhancements to UPF, including enhanced concepts for modeling power states and transitions at all levels of aggregation, enhanced support for methodologies such as successive refinement and bottom-up implementation, and a detailed information model that serves as the basis for enhanced package UPF functions and query functions. This current version also provides support for component power modeling for system-level power analysis in virtual prototyping applications.