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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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Contents

1. Overview	13
1.1 Scope	13
1.2 Purpose	13
1.3 Key characteristics of the Unified Power Format	13
1.4 Contents of this standard	15
2. Normative references	16
3. Definitions, acronyms, and abbreviations	16
3.1 Definitions	16
3.2 Acronyms and abbreviations	22
4. Concepts	23
4.1 Introduction	23
4.2 Design structure	24
4.3 Design representation	24
4.4 Power architecture	28
4.5 Power distribution	31
4.6 Power management	39
4.7 Supply states and power states	44
4.8 Simstates	51
4.9 Power intent specification	52
5. Language basics	58
5.1 UPF is Tcl	58
5.2 Conventions used	59
5.3 Lexical elements	61
5.4 Boolean expressions	65
5.5 Object declaration	67
5.6 Attributes of objects	67
5.7 Precedence	72
5.8 Generic UPF command semantics	75
5.9 effective_element_list semantics	76
5.10 Command refinement	79
5.11 Error handling	80
5.12 Units	80
5.13 SystemC language basic	80
6. Power intent commands	81
6.1 Introduction	81
6.2 Categories	81
6.3 add_parameter	82
6.4 add_port_state (legacy)	83
6.5 add_power_state	84
6.6 add_pst_state (legacy)	91
6.7 add_state_transition	92
6.8 add_supply_state	94
6.9 apply_power_model	95
6.10 associate_supply_set	97
6.11 begin_power_model (legacy)	99
6.12 bind_checker	100

6.13 connect_logic_net.....	102
6.14 connect_supply_net.....	104
6.15 connect_supply_set.....	106
6.16 create_composite_domain.....	107
6.17 create_hdl2upf_vct.....	109
6.18 create_logic_net.....	110
6.19 create_logic_port.....	111
6.20 create_power_domain.....	112
6.21 create_power_state_group.....	119
6.22 create_power_switch.....	121
6.23 create_pst (legacy).....	128
6.24 create_supply_net.....	129
6.25 create_supply_port.....	133
6.26 create_supply_set.....	134
6.27 create_upf2hdl_vct.....	136
6.28 define_power_model.....	137
6.29 describe_state_transition (deprecated).....	139
6.30 end_power_model (legacy).....	139
6.31 find_objects.....	140
6.32 load_simstate_behavior.....	144
6.33 load_upf.....	145
6.34 load_upf_protected (deprecated).....	146
6.35 map_power_switch.....	146
6.36 map_repeater_cell.....	147
6.37 map_retention_cell.....	148
6.38 name_format.....	152
6.39 save_upf.....	153
6.40 set_correlated.....	154
6.41 set_design_attributes.....	155
6.42 set_design_top.....	156
6.43 set_domain_supply_net (legacy).....	157
6.44 set_equivalent.....	158
6.45 set_isolation.....	160
6.46 set_level_shifter.....	167
6.47 set_partial_on_translation.....	173
6.48 set_port_attributes.....	175
6.49 set_repeater.....	181
6.50 set_retention.....	185
6.51 set_retention_elements.....	189
6.52 set_scope.....	190
6.53 set_simstate_behavior.....	191
6.54 set_variation.....	194
6.55 sim_assertion_control.....	195
6.56 sim_corruption_control.....	197
6.57 sim_replay_control.....	200
6.58 upf_version.....	202
6.59 use_interface_cell.....	203
7. Power-management cell definition commands.....	205
7.1 Introduction.....	205
7.2 define_always_on_cell.....	206
7.3 define_diode_clamp.....	207
7.4 define_isolation_cell.....	208
7.5 define_level_shifter_cell.....	211
7.6 define_power_switch_cell.....	216
7.7 define_retention_cell.....	218

8. UPF processing.....	220
8.1 Overview	220
8.2 Data requirements.....	221
8.3 Processing phases	221
8.4 Error checking	225
9. Simulation semantics.....	225
9.1 Supply network creation.....	225
9.2 Supply network simulation.....	227
9.3 Power state simulation.....	228
9.4 Power state transition detection.....	231
9.5 Simstate simulation.....	232
9.6 Transitioning from one simstate state to another.....	234
9.7 Simulation of retention	235
9.8 Simulation of isolation.....	241
9.9 Simulation of level-shifting.....	242
9.10 Simulation of repeaters.....	242
10. UPF information model.....	242
10.1 Overview	242
10.2 Components of UPF information model.....	243
10.3 Identifiers in information model (IDs).....	244
10.4 Classification of objects.....	247
10.5 Example of design hierarchy	253
10.6 Object definitions.....	254
11. Information model application programmable interface (API).....	313
11.1 Tcl interface.....	313
11.2 HDL interface.....	323
Annex A (informative) Bibliography.....	387
Annex B (normative) Value conversion tables.....	388
B.1 Overview.....	388
B.2 VHDL_SL2UPF	388
B.3 UPF2VHDL_SL	388
B.4 VHDL_SL2UPF_GNDZERO.....	388
B.5 UPF_GNDZERO2VHDL_SL.....	389
B.6 SV_LOGIC2UPF.....	389
B.7 UPF2SV_LOGIC.....	389
B.8 SV_LOGIC2UPF_GNDZERO.....	389
B.9 UPF_GNDZERO2SV_LOGIC.....	389
B.10 VHDL_TIED_HI.....	390
B.11 SV_TIED_HI.....	390
B.12 VHDL_TIED_LO.....	390
B.13 SV_TIED_LO.....	390
Annex C (informative) UPF query examples.....	391
C.1 Overview.....	391
C.2 Utility procs	391
C.3 High-level procs.....	392
C.4 Superseded UPF queries	394
Annex D (informative) Replacing deprecated and legacy commands and options.....	396
D.1 Overview.....	396
D.2 Deprecated and legacy constructs.....	396

D.3 Recommendations for replacing deprecated and legacy constructs	398
Annex E (informative) Low-power design methodology	401
E.1 Overview	401
E.2 Simple System on Chip (SoC) example design	401
E.3 Design, verification, and implementation flow	404
E.4 Power intent of the example design	407
Annex F (informative) Power-management cell definitions in UPF and Liberty	428
F.1 Introduction	428
F.2 define_always_on_cell	428
F.3 define_diode_clamp	430
F.4 define_isolation_cell	431
F.5 define_level_shifter_cell	434
F.6 define_power_switch_cell	436
F.7 define_retention_cell	438
Annex G (informative) Power-management cell modeling examples	442
G.1 Overview	442
G.2 Modeling always-on cells	442
G.3 Modeling cells with internal diodes	448
G.4 Modeling isolation cells	450
G.5 Modeling level-shifters	467
G.6 Modeling power-switch cells	484
G.7 Modeling state retention cells	494
Annex H (informative) IP power modeling for system-level design	506
H.1 Introduction	506
H.2 Overview of system-level IP power models	506
H.3 Content of system-level IP power models	507
H.4 Power calculation using power functions	508
H.5 Power model structure	510
H.6 Power model instantiation—example approach	511
Annex I (normative) Switching Activity Interchange Format	513
I.1 Syntactic conventions	514
I.2 Lexical conventions	515
I.3 Backward SAIF file	518
I.4 Library forward SAIF file	534
I.5 RTL forward SAIF file	542
Annex J (informative) Participants	547

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

Sponsor

Design Automation Standards Committee
of the
IEEE Computer Society

Approved 27 September 2018

IEEE-SA Standards Board

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.

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

1. Overview

1.1 Scope

This standard defines the syntax and semantics of a format used to express power intent in energy-aware electronic system design. *Power intent* includes the concepts and information required for specification and validation, implementation and verification, and modeling and analysis of power-managed electronic systems. This standard also defines the relationship between the power intent captured in this format and design intent captured via other formats (e.g., standard hardware description languages and cell libraries).

1.2 Purpose

The standard enables portability of power intent across a variety of commercial products throughout an electronic system design, analysis, verification, and implementation flow.

1.3 Key characteristics of the Unified Power Format

The Unified Power Format (UPF) provides the ability for electronic systems to be designed with power as a key consideration early in the process. UPF accomplishes this by allowing the specification of what was traditionally physical implementation-based power information early in the design process—at the register transfer level (RTL) or earlier. [Figure 1](#) shows UPF supporting the entire design flow. UPF provides a consistent format to specify power-design information that may not be easily specifiable in a hardware description language (HDL) or when it is undesirable to directly specify the power semantics in an HDL, as doing so would tie the logic specification directly to a constrained power implementation. UPF specifies a set of HDL attributes and HDL packages to facilitate the expression of power intent in HDL when appropriate (see [Table 4](#) and [11.2](#)). UPF also defines consistent semantics across verification and implementation to check that what is implemented is the same as what has been verified.

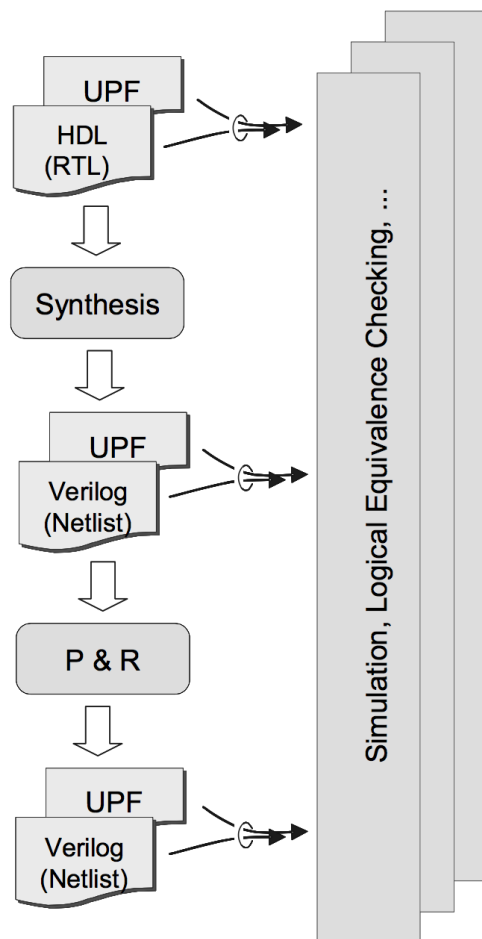


Figure 1—UPF tool flow

As indicated in [Figure 1](#), UPF files are part of the design source and, when combined with the HDL, represent a complete design description: the HDL describing the logical intent and the UPF describing the power intent. Combined with the HDL, the UPF files are used to describe the intent of the designer. This collection of source files is the input to several tools, e.g., simulation tools, synthesis tools, and formal verification tools. UPF supports the successive refinement methodology (see [4.9](#)) where power intent information grows along the design flow to provide needed information for each design stage.

- Simulation tools can read the HDL/UPF design input files and perform RTL power-aware simulation. At this stage, the UPF might only contain abstract models such as power domains and supply sets without the need to create the power and ground network and implementation details.
- A user may further refine the UPF specification to add implementation-related information. This further-refined specification may then be processed by synthesis tools to produce a netlist and optionally update the UPF fileset accordingly.
- In those cases where design object names change, a UPF file with the new names is needed. A UPF-aware logical equivalence checker can read the full design and UPF filesets and perform the checks to ensure power-aware equivalence.
- Place and route tools read both the netlist and the UPF files and produce a physical netlist, potentially including an output UPF file.

UPF is a concise, power intent specification capability. Power intent can be easily specified over many elements in the design. A UPF specification can be included with the other deliverables of intellectual property (IP) blocks and reused along with the other delivered IP. UPF supports various methodologies through carefully defined semantics, flexibility in specification, and, when needed, defined rational limitations that facilitate automation in verification and implementation.

1.4 Contents of this standard

The organization of the remainder of this standard is as follows:

- [Clause 2](#) provides references to other applicable standards that are presumed or required for this standard.
- [Clause 3](#) defines terms and acronyms used throughout the different specifications contained in this standard.
- [Clause 4](#) describes the basic concepts underlying UPF.
- [Clause 5](#) describes the language basics for UPF and its commands.
- [Clause 6](#) details the syntax and semantics for each UPF power intent command.
- [Clause 7](#) details the syntax and semantics for each UPF power-management cell command.
- [Clause 8](#) defines a reference model for UPF command processing.
- [Clause 9](#) defines simulation semantics for various UPF commands.
- [Clause 10](#) defines the UPF information model.
- [Clause 11](#) defines the UPF information model application programmable interface (API).
- [Annex A](#) lists potentially useful additional reference material.
- [Annex B](#) lists the predefined value conversion tables (VCTs) for use in power intent specifications.
- [Annex C](#) provides sample Tcl procs for retrieving power intent information.
- [Annex D](#) summarizes deprecated and legacy commands.
- [Annex E](#) provides an overview of UPF tool flows and use model with an illustrative example.
- [Annex F](#) provides a summary of UPF power-management cell command semantics and Liberty mappings.
- [Annex G](#) provides examples of UPF power-management cell modeling.
- [Annex H](#) provides an overview of UPF use model for system-level IP power modeling.
- [Annex I](#) defines the Switching Activity Interchange Format (SAIF) for representing power-related activity in a design.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC 61691-1-1/IEEE Std 1076™, Behavioural languages—Part 1-1: VHDL Language Reference Manual.^{10, 11, 12}

IEEE Std 1800™, IEEE Standard for SystemVerilog—Unified Hardware Design, Specification, and Verification Language.

ISO/IEC 19501:2005, Information technology—Open Distributed Processing—Unified Modeling Language (UML) Version 1.4.2.