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# Delay and power calculation standards

Part 1: Integrated Circuit (IC) Open Library Architecture (OLA)

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This British Standard is the UK implementation of IEC 61523-1:2023. It supersedes BS EN 61523-1:2002, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/501, Electronic Assembly Technology.

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# DELAY AND POWER CALCULATION STANDARDS –

## Part 1: Integrated Circuit (IC) Open Library Architecture (OLA)

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# IEEE Standard for Integrated Circuit (IC) Open Library Architecture (OLA)

Developed by the

**Design Automation Standards Committee**
of the
**IEEE Computer Society**

Approved 7 November 2019

**IEEE SA Standards Board**

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**Abstract:** Ways for integrated circuit designers to analyze chip timing and power consistently across a broad set of electric design automation (EDA) applications are covered in this standard. Methods by which integrated circuit vendors can express timing and power information once per given technology are also covered. In addition, the means by which EDA vendors can meet their application performance and capacity needs are discussed.

**Keywords**: chip delay, electronic design automation (EDA), IEEE 1481™, integrated circuit (IC) design, power calculation

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## IEEE Introduction

This introduction is not part of IEEE Std 1481-2019, IEEE Standard for Integrated Circuit (IC) Open Library Architecture (OLA).

The objective of the delay and power calculation system (DPCS) is to make it possible for integrated circuit designers to consistently calculate chip delay and power across electronic design automation (EDA) applications and for integrated circuit vendors to express delay and power information only once per technology while enabling sufficient EDA application accuracy.

This is accomplished by a coordinated set of standards that support a standard method to describe timing and power characteristics of integrated circuit design units (cells and higher level design elements); a standard method for EDA applications to calculate chip design instance specific delay, slew, and power for logic and interconnects; and standard file formats to exchange chip parasitic and cluster information.

## Acknowledgments

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# IEEE Standard for Integrated Circuit (IC) Open Library Architecture (OLA)

## 1. Overview

The delay and power calculation system (DPCS) is a coordinated set of standards that support a standard method to describe timing and power characteristics of integrated circuit (IC) design units (cells and higher level design elements); a standard method for electronic design automation (EDA) applications to calculate chip design instance specific delay, slew, and power for logic and interconnects; and standard file formats to exchange chip parasitic and cluster information. The standard specifications covered in this document are as follows:

— Description language for timing and power modeling, called the "delay calculation language" (DCL)

— Software procedural interface (PI) for communications between EDA applications and compiled libraries of DCL descriptions

— Standard file exchange format for parasitic information about the chip design: Standard Parasitic Exchange Format (SPEF)

— Informative usage examples

— Informative notes

Notes and examples are informative. All other components of this specification are considered normative unless otherwise directed.

### 1.1 Scope

The scope of this standard focuses on delay and power calculation for integrated circuit design with support for modeling logical behavior and signal integrity.

### 1.2 Purpose

To improve the IEEE Std 1481™-1999 system for integrated circuit designers to more accurately and more completely analyze semiconductor designs across EDA applications and for integrated circuit vendors to express logical behavior, signal integrity, delay, and power information only once per technology while enabling sufficient EDA application accuracy.

### 1.3 Introduction

The DPCS standard covers delay and power calculation for integrated circuit design with support for modeling logical behavior and signal integrity, which makes it possible for integrated circuit designers to

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analyze chip timing and power consistently across a broad set of EDA applications, for integrated circuit vendors to express timing and power information once (for a given technology), and for EDA vendors to meet their application performance and capacity needs. The intended use for this standard is IC timing and power. This standard may be applied to both unit logic cells supplied by the IC vendor and logical macros defined by the IC designer. Although this standard is written toward the integrated circuit supplier and EDA developer, its application applies equally well to representation of timing and power for designer-defined macros (or hierarchical design elements).

These specifications make it possible to achieve consistent timing and power results, but they do not guarantee it. They provide for a single executable software program that computes delay and power based on IC vendor-supplied algorithms (or designer-supplied algorithms for macros) but does not guarantee EDA applications can correctly communicate the design-specific information required for these algorithms. By specifying standard exchange formats for parasitic data and floorplanning information, this standard provides a marked improvement over design environments with no such standards. However, it is the responsibility of the EDA application to correctly correlate the information between these standard exchange files and the actual design. This standard also does not detail how the information contained within the standard exchange files shall be obtained.

As feature sizes for chips have shrink below 0.25 µm, interconnect delay effects have begun to outweigh those of the logic cells. This means placement of cells and wire routing of the interconnects become as important a factor as the type of cell drivers and receivers on the interconnect. As a result, EDA logic design applications (such as synthesis) have begun to interact closely with physical design applications (such as floorplanning and layout). Applications that before could consider only simple delay and power models now need to deal with complex, interrelated delay and power algorithms. Plus, due to the complexities of the delay and power algorithms, the integrated circuit vendor needs to have control of application calculations and not be restricted by the limitations of a broad set of applications demanded by the customers (the designers).

Over the past few years, it has become increasingly apparent that modern very large-scale integration (VLSI) design is no longer bounded only by timing and area constraints. Power has become significantly more important. In an era of hand-held devices, ranging from mobile computing to wireless communication systems, managing and controlling power takes on an important role. Several benefits can be attained from low-power designs in addition to extended battery life. Low-power devices often run at a lower junction temperature, which leads to higher reliability and lower cost cooling systems. There are also several challenges for calculation and modeling of power (and delay) in deep submicron (less then 0.25 µm) designs. EDA tools can now accurately calculate and model power by using this DPCS standard.

## 1.4 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (shall equals is required to).[1,2]

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (should equals is recommended that).

The word *may* is used to indicate a course of action permissible within the limits of the standard (may equals is permitted to).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (can equals is able to).

[1] The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.
[2] The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

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ISO/IEC 9899:1990, Programming Languages—C.[3]

ISO/IEC 14882:2003, Programming Languages—C++.

## 3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[4]

**application, electronic design automation (EDA) application**: Any software program that interacts with the delay and power calculation module (DPCM) through the procedural interface (PI) to compute instance-specific timing values. Examples include batch delay calculators, synthesis tools, floor-planners, static timing analyzers, and so on. *See also:* **delay and power calculation module; procedural interface**.

**arc**: *See:* **timing arc.**

**argument**:The value or the address of a data item passed to a function or procedure by the caller.

**back-annotation**: The annotation of information from further downstream steps (toward fabrication) in the design process. *See also:* **back-annotation file**.

**back-annotation file**: A file containing information to be read by a tool for the purpose of back-annotation, for example, Physical Design Exchange Format (PDEF) and Standard Parasitic Exchange Format (SPEF) files. *See also:* **back-annotation; timing annotation**.

**bidirectional**: A pin or port that can place logic signals onto an interconnect and receive logic signals from it (i.e., act both as a driver and as a receiver).

**bias**: The time difference between the data arrival time and a specified signal edge (e.g., of a clock). Also, the *BIAS* clause used in a *CHECK* statement.

**C-effective**: A capacitance value, often computed as an approximation to a resistor/inductor/capacitor (RLC) network or a model, that characterizes the admittance of an interconnect structure at a particular driver. The reduction of real parasitics and pin capacitances to a C-effective allows the calculation of delay and slew values from cell characterization data that assumes a pure capacitive output load.

**bus**: In Physical Design Exchange Format (PDEF), a physical collection of nets and/or pnets or of pins and/or nodes. If the items collected in the PDEF bus are logical, the PDEF bus may or may not correspond to a logical bus described in the netlist.

**cell**: A primitive in an integrated circuit library. For the purposes of this specification, “primitive” means the timing properties of the cell are directly described in the delay and power calculation module (DPCM) without reference back to the application for the internal structure of the cell. This primitiveness typically is

[3]ISO publications are available from the International Organization for Standardization (http://www.iso.org/) and the American National Standards Institute (http://www.ansi.org/). IEC publications are available from the International Electrotechnical Commission (http://www.iec.ch) and the American National Standards Institute (http://www.ansi.org/).
[4]*IEEE Standards Dictionary Online* is available at: http://dictionary.ieee.org.

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a result of the characterization of that cell by the semiconductor vendor, but it may instead be a result of the construction of a timing model for a sub-circuit by the application and its loading into the DPCM at run time. The term "cell" can arise in the context of the abstraction of a type of cell available in the library or in the concrete selection and placement of a cell in the final design. If the context is not clear, the terms "cell type" and "cell instance" (or just "instance") shall be used. *See also:* **cell type; instance**.

**cell type**: Name used to identify a particular cell in the library.

**cluster**: A grouping of cell instances and/or clusters that are constrained to each other due to physical location or some other shared characteristic(s). It is not valid to have a cell instance explicitly made a member of more than one cluster. *See also:* **region**.

**column**: In a Physical Design Exchange Format (PDEF) datapath cluster, a cluster of cell, spare_cell, and/or cluster instances placed or constrained to be placed in the vertical (y-axis) direction. *See also:* **row; datapath**.

**constraint**: A timing property of a design that is supplied as a goal or objective to an electronic design automation (EDA) tool, such as logic synthesis, floorplanning, or layout. The tool shall not start out with a fixed design implementation; it shall build or modify the design to meet the constraint. *See also:* **timing check**.

**datapath**: A type of electronic design automation cluster that contains rows and/or columns of cluster, cell, skip, and/or spare_cell instances. A PDEF datapath typically corresponds to structured logic. See also: **row; column**.

**delay**: The time taken for a digital signal to propagate between two points.

**delay and power calculation module** (**DPCM**): A delay and power calculation system (DPCS)-compliant software component supplied by a semiconductor vendor that is responsible for computing instance-specific timing data under control of an electronic design automation (EDA) application. The DPCM is loaded into memory at run time and linked to the application via the procedural interface (PI). A DPCM typically is created from delay calculation language (DCL) subrules compiled by the DCL compiler and linked together with run-time support modules.

**delay and power calculation system** (**DPCS**): The complete system detailed in this specification: the delay calculation language (DCL) language, the procedural interface (PI) for delay and power calculations, and text formats for physical design and parasitic information.

**delay arc**: *See:* **timing arc**.

**delay calculation language** (**DCL**): The programming language used to calculate instance-specific timing data. DCL contains high-level constructs that can refer to the aspects of the design topology that influence timing and also express the sequence of calculations necessary to compute the desired delay and timing check limit values.

**delay calculation language (DCL) compiler**: A software program, used in conjunction with a C compiler, that reduces DCL from ASCII text to computer executable format. *See also:* **delay and power calculation module**.

**delay equation**: Any mathematical expression describing cell delay or interconnect delay.

**driver**: A pin of a cell instance that, in the current context, is placing or can place a signal onto an interconnect structure.

**early mode**: The first edge that propagates through a given cone of logic.

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**fanout**: The pin count of a net (the number of pins connected to the net), minus one. This definition includes all input, output, and bidirectional pins on the net with the sole exception of one pin (assumed to be related to the particular timing arc currently of interest). Although less fundamental than pin count, fanout is frequently used in the definition of wire load models.

**forward annotation**: The annotation of information from further upstream (earlier in the design flow) in the design process. *See also:* **forward annotation file**.

**forward annotation file**: A file containing information to be read by a tool for the purpose of forward annotation, for example, an Standard Delay Format (SDF) file containing PATHCONSTRAINTS. *See also:* **forward annotation**.

**function**, **procedural interface (PI) function**: One of the C functions that comprise the **delay and power calculation system (DPCS)** procedural interface.

**gap**: In Physical Design Exchange Format (PDEF), spacing between rows and/or columns in a datapath.

**gate**: In Physical Design Exchange Format (PDEF), the physical abstraction of a library primitive.

**hard macro**: A cluster whose cell placements relative to each other are fixed. Often the interconnect routing between the cells is also fixed and a parasitics file describing the interconnect is available for the hard macro. The location of the hard macro in the floorplan may or may not be fixed.

**hard region**: A cluster that has defined physical boundaries in a floorplan. All cells contained in the cluster shall be placed within the boundaries of the cluster.

**hierarchical instance**: The concrete appearance of a design unit at some hierarchical level. Because higher level design units may be instantiated multiple times, a single such appearance may give rise to multiple instances of the lower level design units within it. Where instances are referred to as "occurrences," hierarchical instances are referred to simply as instances.

**hold timing check**: A timing check that establishes only the end of the stable interval for a setup/hold timing check. If no setup timing check is provided for the same arc, transitions, and state, the stable interval is assumed to begin at the reference signal transition and a negative value for the hold time is not meaningful. *See also:* **setup/hold timing check**.

**hold time**: *See:* **setup/hold timing check; nochange timing check**.

**implementation-defined behavior**: Behavior, for a correct program construct and correct data, that depends on the software implementation and that each implementation shall document. The range of possible behaviors is delineated by the standard.

**implementation limits**: Restrictions imposed by an implementation.

**input**: A pin or port that shall only receive logic signals from a connected net or interconnect structure.

**instance**, **cell instance**: A particular, concrete appearance of a cell in the fully expanded (flattened, unfolded, elaborated) design description of an integrated circuit, also referred to elsewhere as an "occurrence." An instance is a "leaf" of the unfolded design hierarchy. In Physical Design Exchange Format (PDEF), this is a physical cluster or a logical cell. *See also:* **cell; cell type; cluster**,; **hierarchical instance**.

**interconnect**: A collective term for structures (in an integrated circuit) that propagate a signal between the pins of cell instances with as little change as possible. These structures include metal and polysilicon

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segments, vias, fuses, anti-fuses, and so on. But interconnect shall not include such structures if they occur as part of the fixed layout of a cell.

**late mode**: The very last edge that propagates through a given cone of logic.

**layer**: In Physical Design Exchange Format (PDEF), a particular level of interconnect on which a logical or physical pin is located.

**library (integrated circuit)**: A collection of circuit functions, implemented in a particular integrated circuit technology, which an integrated circuit designer or electronic design automation (EDA) synthesis application can select in order to implement a design. *See also:* **cell**.

**library (software)**: A collection of object code units that may be linked, either statically or at run time, with other libraries and/or object code to produce a software program.

**library control statements**: These statements control the logical organization and loading of subrules in a technology library. *See also*: **technology library**.

**load-dependent delay**: That part of a delay through a cell instance attributed to the admittance (load) presented to the arc sink pin and the internal impedance of the output.

**mesh table**: A multidimension table that defines every type of delay model in terms of discrete points. Each point represents a delay value in terms of several cell parameters or interconnect parameters. The delay calculation module is expected to interpolate between these points based on a mathematical expression defined by the technology file.

**(to) model a cell**: The creation of a specific elaboration of a model using *modelSearch*.

**modeling procedures**: Describe the action of a circuit with respect to timing and power. These actions include creating segments and nodes, determining the propagation properties, and setting the delay and slew equations to use.

**modeling statements**: Delay calculation language (DCL) statements that map cell configurations to modeling procedures.

**net**, **net instance**: An abstraction expressing the idea of an electrical connection between various points in a design. In a hierarchical representation of the design, nets can occur at all levels and may connect to pins of lower hierarchical levels (including cell instances), ports of the current hierarchical level, and each other. In a flattened (unfolded and elaborated) design, electrically connected nets are collapsed and each net instance corresponds to a unique interconnect structure in the implementation.

**nochange timing check**: A timing check similar to a setup/hold timing check except the setup and hold times are referred to opposite transitions of the reference signal. The stable interval is extended to include the period between these transitions, that is, the time for which the reference signal stays in a specified state. This timing check is frequently applied to memory and latch-banks to establish the stability of the address or select inputs before, during, and after the write pulse.

**node**: A conceptual point (through which logic signals pass) that has been identified as an aid to modeling the timing properties of a cell but may not correspond to any physical structure. In Physical Design Exchange Format (PDEF), this is a physical pin that does not correspond to a logical structure.

**nugget**: A data structure used in the procedural interface (PI) for rapid switching between technologies.

**output**: A pin or port shall only place logic signals onto a connected net or interconnect structure.

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**parameter**: A data item required for the calculation of some result.

**parasitics**: Electrical properties of a design (resistance, capacitance and impedance) that arise due to the nature of the materials used to implement the design.

**period timing check**: A timing check that specifies the allowable time between successive periods of a signal.

**periphery**: The outer part of an integrated circuit where instances of cell types designed specifically to interface the internal circuitry to the "outside world" are placed. This part includes "pad" cells (which are input and output buffers) and power and ground pads; it may also include test circuitry, such as boundary scan cells.

**pi-model**: A simplification of a general resistor/inductor/capacitor (RLC) network that represents the driving-point admittance for an interconnect.

**pin**: A terminal point where an interconnect structure makes electrical contact with the fixed structures of a cell instance or the conceptual point where a net connects to a lower level in the design hierarchy.

**pin count**: The number of cell instance pins that an interconnect structure visits, including all input, output, and bidirectional pins. Pin count is the number of "places" the interconnect goes to on the chip.

**pnet**: A physical net that has no correspondence to the logical function of the design, such as a route segment that is reserved for future routes across a hard macro, or a power net not described in the design netlist.

**pole**: The complex frequency where a Laplace Transform is infinite. Combined with residues, this is a convenient mathematical notation for the impedance or transfer function of a passive circuit, such as an resistor/inductor/capacitor (RLC) circuit because poles above this frequency can be ignored in calculations without significant loss of accuracy.

**port**: A conceptual point at that a cell or a hierarchical design unit makes its interface available to higher levels in the design hierarchy.

**primary input**: The point where a logic signal arrives at the boundary of the design as currently known to an electronic design automation (EDA) application. For a complete integrated circuit design, for example, this point is the metal pad of an input or bidirectional pad cell.

**primary output**: The point where a logic signal leaves the design as currently known to an electronic design automation (EDA) application. For a complete integrated circuit design, for example, this point is the metal pad of an output or bidirectional pad cell.

**procedural interface (PI)**: The set of C functions used by an application and a delay and power calculation module (DPCM) to exchange information and determine the timing calculation for a design.

**pulse width timing check**: A timing check that specifies the minimum time a signal shall remain in a specified state once it has transitioned to that state.

**receiver**: A pin of a cell instance that is receiving or can receive a signal from an interconnect structure.

**recovery/removal timing check**: A timing check that establishes an interval with respect to a reference signal transition during which an asynchronous control signal may not change from the active to inactive state. This timing check is frequently applied to flip flops and latches to establish a stable interval for the set and reset inputs with respect to the active edge of the clock or the active-to-inactive transition of the gate.

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Two limit values are necessary to define the stable interval. The recovery time is the time before the reference signal transition when the stable interval begins. The removal time is the time after the reference signal transition when the stable interval ends.

If the asynchronous control signal goes inactive during the stable interval, it is unknown whether the flip flop or latch takes on the state of the data input, remains set, or is reset.

**recovery time**: *See*: **recovery/removal timing check**.

**recovery timing check**: A timing check that establishes only the beginning of the stable interval for a recovery/removal timing check. If no removal timing check is provided for the same arc, transitions, and state, the stable interval is assumed to end at the reference signal transition and a negative value for the recovery time is not meaningful. *See also*: **recovery/removal timing check**.

**region**: A particular physical section or block of a floor plan. *See also*: **cluster**.

**removal time**: *See*: **recovery/removal timing check**.

**removal timing check**: A timing check that establishes only the end of the stable interval for a recovery/removal timing check. If no recovery timing check is provided for the same arc, transitions, and state, the stable interval is assumed to begin at the reference signal transition and a negative value for the removal time is not meaningful. *See also*: **recovery/removal timing check**.

**residue**: The value that has the complex pole. *See also*: **pole**.

**resistance times capacitance (RC) time constant**: The product of some resistance and some capacitance (having the dimensions of time) or a time constant computed in some other way.

**return code**: A value returned by a function indicating whether the function completed successfully. If the function did not complete successfully, it may return a nonzero return code; the exact value may indicate one of several possible severity conditions: informational, warning, error, severe, terminal error, etc.

**route**, **global route**: In Physical Design Exchange Format (PDEF), the physical description of interconnect routing between logical and physical pins of cell, spare_cell, and/or cluster instances.

**row**: In a Physical Design Exchange Format (PDEF) datapath cluster, a cluster of cell, spare_cell and/or cluster instances placed or constrained to be placed in the vertical (Y-axis) direction. *See also*: **column; datapath**.

**scalar**: An integer constant.

**sequence point**: A certain point in the execution sequence of a program where all side effects of previous evaluations are complete and no side effects of subsequent evaluations have occurred. (Refer to ISO/IEC 9899:1990, Section 5.1.2.3, page 7.[5])

**segment**: A portion of an interconnect structure treated as a unit for the purposes of extracting or estimating its electrical properties. *See also*: **parasitics**.

**setup/hold timing check**: A timing check that establishes an interval with respect to a reference signal transition during which some other signal may not change value. This timing check is frequently applied to flip flops and latches to establish a stable interval for the data input with respect to the active edge of the clock or the active-to-inactive transition of the gate.

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

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Two limit values are necessary to define the stable interval. The setup time is the time before the reference signal transition when the stable interval begins and shall be negative if the stable interval begins after the reference signal transition. The hold time is the time after the reference signal transition when the stable interval ends and shall be negative if the stable interval ends before the reference signal transition. If the data signal changes during the stable interval, then the reliability of the resulting state of the flip flop or latch is unknown.

**setup time**: *See*: **setup/hold timing check; nochange timing check**.

**setup timing check**: A timing check that establishes only the beginning of the stable interval for a setup/hold timing check. If no hold timing check is provided for the same arc, transitions, and state, the stable interval is assumed to end at the reference signal transition and a negative value for the setup time is not meaningful. *See also*: **setup/hold timing check**.

**shared port**: An output or bidirectional port where some other output port of the cell derives its logic function. The output load at a shared port affects not only the delay to that port itself but also the delay to any ports sharing it.

**sink**, **sink pin**: The sink pin is the end of a delay arc (i.e., the destination of the logic signal). For arcs across cell instances, the sink is the driver pin. For arcs across an interconnect, the sink is the receiver pin.

**size metric**: A value used to estimate properties of interconnect wholly contained in a region. The metric may be freely chosen (for example, square microns or gate sites), but it needs to be consistent between the cells and the wire load models. *See also*: **wire load model**.

**skew timing check**: A timing check that specifies the maximum time between two signal transitions. This timing check is frequently applied to dual-clock flip flops to specify the maximum separation of the active edges of the two phases of the clock.

**skip**: In Physical Design Exchange Format (PDEF), spacing between the ordered cell, spare_cell, and/or cluster instances in rows and/or columns of a datapath.

**slew**: A measure of the shape of the waveform constituting a logic state transition. A slew value can have the dimensions of time (in which case, it is a *slew time*) or the dimensions of voltage per time (in which case, it is a *slew rate*). The delay and power calculation system (DPCS) allows either interpretation if used consistently.

**slew-dependent delay**: That part of an input-to-output delay that can be attributed to the signal at the input of the arc taking longer to make a transition than is considered ideal.

**slew rate**: A measure of how quickly a signal takes to make a transition (i.e., a voltage-per-unit time). Slew rate is inversely related to slew time and is sometimes used incorrectly where slew time is intended.

**slew time**: A measure of how long a signal takes to make a transition (i.e., the rise time or fall time). Slew time is inversely related to slew rate. The way a slew time value is abstracted from the continuous waveform at a cell pin varies with different cell characterization methods.

**soft region**: A cluster that does not have a specified physical location in a floorplan. It may have constraints on how closely the cells within the cluster are placed relative to each other. A soft region may be located within a hard region.

**source**, **source pin**: The source pin is the start of a delay arc (i.e., the origin of the logic signal). For arcs across cell instances, the source is the receiver pin. For arcs across interconnect, the source is the driver pin.

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**spare_cell**: A cell instance that is presently not part of the logical function of a design and therefore is not included in the design's logical netlist. A spare_cell is typically reserved for future logic modifications to be implemented through changes in the interconnect layers of the chip.

**Standard Structure**: A particular C structure, defined in `std_stru.h`, which contains fields used to pass data over the procedural interface (PI) (thus avoiding large numbers of arguments). Most functions of the PI have a pointer to a Standard Structure as their first argument.

**technology data**: Data used to calculate the timing properties of a cell instance based on its context in the design. This term includes information that is not cell type specific and data specific for each cell type in the library. The kind of data used varies with the timing calculation methodology. General data and cell data may be contained in the same file or in separate files. Cell data also may be merged with the timing models of each cell, for example, when a tool performs its own timing calculation.

**technology library**: A technology library is a program written in delay calculation language (DCL) consisting of one or more subrules, each of which may contain references to other subrules (yet to be loaded). There is no hierarchical limit to the nesting of subrules within the scope of a technology library. Subrules can also be segmented into technology families, which alters the way they are made available to the application.

**time-of-flight**: The time delay between a signal leaving a driving pin or primary input port and reaching a receiving pin or primary output. Time-of-flight is generally dominated by the time taken to charge the distributed capacitance of the interconnect and the capacitance of the driven pins through the distributed impedance of the interconnect. The internal impedance of the driving port affects the load-dependent delay but not (directly) the time-of-flight.

**timing annotation** (**file**):The annotation of a design in one tool with timing data computed by another tool. If timing calculation is performed as an offline process (separately from the application using the timing data), the process of reading the timing data into the tool is known as timing annotation. A timing annotation file stores the data written by the timing calculator and is later read by an application.

**timing arc**: A pair of ports, pins, or nodes possess some timing relationship such as the propagation delay of a signal from one to the other or a timing check between them. Delay arcs may be between two distinct ports or nodes of a cell or over the interconnect from driver pins to receiver pins.

**timing calculation**, **delay calculation**: The process of calculating values for the delays and timing checks associated with the physical primitives (cells) of an integrated circuit design, or part of an integrated circuit design, and their interconnections.

**timing check**: A timing property of a circuit (frequently a cell) that describes a relationship in time between two input signal events. This relationship needs to be satisfied for the circuit to function correctly.

**timing model**: A timing model represents the timing behavior of a cell for applications such as simulation and timing analysis. For black-box timing behavior, it represents the definition of pin-to-pin delays between any pair of pins as well as internal nodes. In addition, for sequential cells it provides the definition of timing checks and constraints on any pair of pins and/or internal nodes.

**transition**: The change of a logic signal from one state to another (as in "... a transition at the input shall cause ...") or the pair of logic states between which a transition may occur (as in "... the delay for a low-to-high transition ...").

**unloaded delay**: The conceptual delay value for a delay arc of a cell when the output pin is unloaded (unconnected) and the signal at the input pin conforms to some ideal waveform.

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**undefined behavior**: Behavior for which the standard imposes no requirements (e.g., use of an erroneous program construct). Permissible undefined behavior may occur in the following range:

a) Ignoring a situation completely with unpredictable results

b) Behaving during translation or program execution in a documented manner characteristic of the environment (with or without the issuance of a diagnostic message)

c) Terminating a translation or execution (with the issuance of a diagnostic message)

NOTE—Many erroneous program constructs do not engender undefined behavior; they are required to be diagnosed.[6]

**unspecified behavior**: Behavior (for a correct program construct and correct data) that depends on the implementation. The implementation is not required to document which behavior occurs. Usually the range of possible behaviors is delineated by the standard.

**via**: In Physical Design Exchange Format (PDEF), a physical connection between two different levels of interconnect or between a level of interconnect and a physical or logical pin.

**wire load model**: A statistical model for the estimation of interconnect properties as a function of the geometric measures available before the completion of layout and routing. Typical model properties include fanout, capacitance, length, and resistance. *See also*: **size metric**.

## 4. Acronyms and abbreviations

This clause lists the acronyms and abbreviations used in this standard, as follows:

| | |
|---|---|
| API | application programming interface |
| ASIC | application specific integrated circuit |
| AWE | asymptotic waveform evaluation |
| BNF | Backus-Naur form |
| CGHT | clock gating hold test |
| CGST | clock gating setup test |
| CST | clock separation test |
| DCL | delay calculation language |
| DHT | data hold test |
| DPCM | delay and power calculation module |
| DPCS | delay and power calculation system |
| DPW | data pulse width |
| DST | data setup test |
| EDA | electronic design automation |
| EDIF | Electronic Design Interchange Format |
| HDL | hardware description language |

[6]Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

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| | |
|---|---|
| IC | integrated circuit |
| PDEF | Physical Design Exchange Format |
| PI | procedural interface |
| PVT | process/voltage/temperature |
| RLC | resistor/inductor/capacitor |
| RC | resistance times capacitance |
| SDF | Standard Delay Format |
| SPEF | Standard Parasitic Exchange Format |
| SPICE | Simulation Program with Integrated Circuit Emphasis |
| VHDL | VHSIC Hardware Description Language |
| VHSIC | very-high-speed integrated circuit |
| VLSI | very-large-scale integration |

# 5. Typographical conventions

This clause describes the typographical conventions used within this specification.

## 5.1 Syntactic elements

a) Italicized, lowercase words, some containing embedded underscores, are used to denote syntactic categories (terminals and nonterminals), for example, *rule_name*

b) Boldface words are used to denote reserved keywords, operators, and punctuation marks as a required part of the syntax.

**MODEL_SLEW**, ***D_NET** or **:**

c) The ::= operator separates the two parts of a Backus-Naur form (BNF) syntax definition. The syntax category appears to the left of this operator, and the syntax description appears to the right of the operator. For example, the following step shows the four options for a *suffix_bus_delim*.

d) A vertical bar separates alternative items (use one only) unless it appears in boldface; in which case, it stands for itself. For example,

*suffix_bus_delim* ::= **]** | **}** | **)** | **>**

e) Square brackets enclose optional items unless it appears in boldface; in which case, it stands for itself. For example,

*r_net* ::= ***R_NET** *net_ref total_cap* [*routing_conf*] {*driver_reduc*} ***END**

indicates *routing_conf* is an optional syntax item for *r_net*, whereas

*suffix_bus_delim* ::= **]** | **}** | **)** | **>**

indicates the closing square bracket is part of the *suffix_bus_delim* character set.

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f) Braces enclose a repeated item unless it appears in boldface; in which case, it stands for itself. The item may appear zero or more times; the repetitions occur from left to right as with an equivalent left-recursive rule. An item that may appear one or more times is listed first, followed by the item enclosed in braces, such as

*pos_integer* ::= <*digit*>{<*digit*>}

g) Parentheses enclose items within a group (use one only) unless it appears in boldface; in which case, it is a literal token. In the following example:

*bus* ::= **(BUS** *physical_name* {*attribute*} ( {*net_ref*} | {*pin_ref*} {*node_ref*} ) **)**

the first set of parentheses are part of the syntax for a *bus*, and the second set groups the items *net_ref* OR the combination of a *pin_ref* and *node_ref*.

h) Angle brackets enclose items when no spacing is allowed between the items, such as within an *identifier*. In the following example:

*identifier* ::= <*identifier_char*>{<*identifier_char*>}

the actual character(s) of the identifier cannot have any spacing.

i) A hyphen (-) is used to denote a range. For example:

*upper* ::= **A** – **Z**

indicates that *upper* can be an uppercase letter (from A to Z).

### 5.2 Conventions

Conventions used in the main text are as follows:

a) *Italicized* font is used when a term is being defined.

b) `Monospace` font is used for examples, file names, and references to constants such as `0`, `1`, or `x` values.

## 6. DPCS flow

The goals of the DPCS architecture are to make it possible in a multivendor, multitool environment for the following to occur:

a) Integrated circuit designers to calculate timing and power consistently

b) Integrated circuit vendors to express timing and power information once for a given technology while enabling sufficient EDA application accuracy

### 6.1 Overview

To meet these goals, the DPCS shall have total control of delay and power calculation, support arbitrary expressions for delay and power values, and have very high performance. In addition, the DPCS architecture shall permit integrated circuit vendors to supply data (equations, coefficients, or algorithms) for delay and power calculation to their customers independent of the release of design tools by EDA vendors.

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Figure 1 shows a high-level representation of the DPCS architecture and relationships among several key components for calculating delay and power in an integrated circuit design environment.

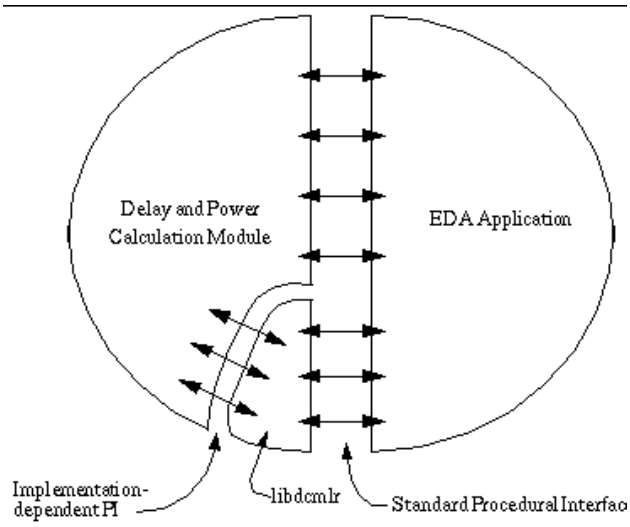


**Figure 1—High-level DPCS architecture linkage structure**

The DPCM contains the following code (compiled from a DCL source) that enables an application to compute power, delays, and timing constraints (for example, setup and hold tests) efficiently:

a) The PI is used by both an application and the DPCM to control delay and power calculations.

b) The Standard Delay Format (SDF) contains constructs for describing computed timing data (for back annotation) and specifying timing constraints (for forward annotation). In integrated circuit design, it is common for a delay calculator application to calculate delays from postlayout data and write out the results in SDF.

c) The Physical Design Exchange Format (PDEF) contains constructs to describe physical design information. It can be used as a back-annotation medium for passing physical design information from back-end applications (floorplanning and layout) to those on the front end; it can also be used to communicate physical constraints from frontend applications (synthesis, timing analysis, and partitioning) to those on the back end.

d) SPEF contains constructs to convey information between parasitic extractors and applications that utilize the extracted circuit information.

Figure 1 also illustrates the following key points about applications that require delay and power information:

— Applications shall be written (or modified) to use the DPCS-defined PI for all delay and power calculations.

— The application is fully responsible for mapping between design instances and cell types.

— The application is fully responsible for the state of the design. The DPCM is responsible for calculating delay and power and uses the PI to acquire all required design-specific information, including such data as models of parasitic effects (often contained in SDF, PDEF, or SPEF files).

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— The DPCM is composed of one or more subrules. Subrules are compiled C code constructed from an ASCII description following the rules of the DCL. A subrule may implement zero or more timing and power models. The DPCM is dynamically linked with the application during execution.

— Errors in timing and power models may be incrementally corrected by the release of one or more subrules.

### 6.1.1 Procedural interface

A crucial part of the DPCS standard is the PI between an application and the DPCM. This PI enables the same DPCM to function with multiple applications. Details of the PI are described in Clause 10.

To enable an application to be independent of implementation-specific characteristics of a DPCM, code that implements the functions *dcmRT_InitRuleSystem* and/or *dcmRT_BindRule* shall not be statically linked with the application. Figure 1 illustrates the required linkage structure. The code for the three functions mentioned previously shall reside in a shared object-code library named `libdcmappl+` that is dynamically linked to the application at run time. There may be implementation-dependent procedure calls between `libdcmapp+` and the DPCM, but this architecture isolates the application from such details.

When the EDA application is statically linked, the link editor shall be told which external symbols need be resolved with dynamically loaded code and how to locate that code. The specification of how to locate the code shall allow the application to choose from among multiple implementations of `libdcmapp+`.

### 6.1.2 Global policies and conventions

The DPCM assumes a single locus of control between it and the application. The DPCM also assumes the application understands any data returned as part of a call as well as any data passed to the DPCM by the application that is passed on to the application as part of a callback. For example, if an application passes a pointer to a port structure as one argument in a call to the DPCM, the DPCM assumes it can pass that same pointer as an argument to a callback function.

In general, the DPCM shall not cache any design-specific data values between calls because the DPCM cannot know when any such data might become invalid. The DPCM can cache within a single application call.

## 6.2 Flow of control

During execution, the flow of control within the DPCS moves between the application and the DPCM, which subject to the following two constraints:

— There is no “abnormal” flow of control across its PI; that is, all function calls return control through the normal procedure-return mechanism.

— A DPCM shall not terminate the execution of the application to which it is linked.

## 6.3 DPCM—application relationships

The DPCM has been designed to allow easy integration of dynamically linked executable modules that performs delay and power calculation. The library developer decides how the components of the technology library should be architected and implemented, and organized into physical units called “subrules.” Subrules may be segmented into technology families, which defines the way they are made available to the application (see 10.8). The run-time system assembles these subrules into a unified DPCM. The application then views the DPCM as a single module from which it can request services.

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### 6.3.1 Technology library

A technology library is a program written in DCL consisting of one or more subrules, each of which may contain references to other subrules (yet to be loaded). There is no hierarchical limit to the nesting of subrules within a technology library.

### 6.3.2 Subrule

A subrule contains a combination of definitions and prototypes used to implement a portion of a technology definition. A subrule is a separate compilation unit and consists of one or more of the following components:

a) C preprocessor directives

b) Embedded C code

c) DCL statements

## 6.4 Interoperability

Consideration has been given to having multiple implementations to supporting systems for this standard (compiler, run-time linker, and run-time library) and the desire to support at least a minimal level of interoperability among such implementations.

In particular, an application can concurrently access subrules constructed in multiple implementations by doing the following:

a) Limiting all subrules in a particular technology family to a single implementation

b) Appending an implementation-specific suffix to the `dcm` prefix for all PI calls whose names begin with `dcm`

c) Requiring the application to

   1) Track which technology families use which implementation

   2) Use the appropriately named PI calls

   3) Maintain separate implementation-specific Standard Structures

# 7. Delay calculation language (DCL)

This clause describes the language for delay modeling and calculation used in this standard.

## 7.1 Character set

The DCL character set shall be the same as that defined in Section 5.2.1 (“Character sets”) of ISO/IEC 9899:1990, excluding trigraph sequences and multibyte characters. The alphabetic escape sequences such as “\n,” representing newline, shall be the same as those defined in Section 5.2.2 (“Character display semantics”) of ISO/IEC 9899:1990.

## 7.2 Lexical elements

This subclause describes the lexical elements used to define the DCL syntax and semantics.

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### 7.2.1 Whitespace

Whitespace is a contiguous sequence of one or more characters in the set: *space*, *horizontal_tab*, *newline*, *carriage_return*, *vertical_tab*, and *form_feed*.

### 7.2.2 Comments

A comment shall be either of the following:

a) A character sequence that starts with /* and ends with the first occurrence of the character sequence */. Within a comment, the character sequence /* shall not be recognized as starting a nested comment.

b) A character sequence that starts with // and ends with the first occurrence of either the *newline* or *carriage_return* characters.

### 7.2.3 Tokens

The syntax for tokens in DCL is given in Syntax 7.1.

```
token ::=
    keyword
    | identifier
    | double_quoted_character_sequence
    | constant
    | string_literal
    | operator
    | punctuator
    | header_name
```

**Syntax 7.1—token**

Tokens other than *string_literal* and *double_quoted_character_sequence* shall not contain embedded *whitespace*.

#### 7.2.3.1 Keyword

DCL reserves many tokens as *keywords* (see Table 1). These keywords shall be used only in the context as defined by DCL. No keyword shall be used as an identifier (see 7.2.3.2).

**Table 1—Keywords**

| | |
|---|---|
| ABS | NODES |
| ABSTRACT | NUM_DIMENSIONS |
| ADD_ROW | NUM_ELEMENTS |
| AGGREGATE | NUMBER |
| ANYIN | ONE_TO_Z |
| ANYOUT | OPTIONAL |
| ARGV | OTHERWISE |
| ASSIGN | OUTPUT |
| AUTOLOCK | OUTPUT_PIN_COUNT |
| BIAS | OUTPUT_PINS |
| BIT | OVERRIDE |
| BINARY | PASSED |
| BLOCK | PATH |
| BOTH | PATH_DATA |
| BREAK | PATH_SEPARATOR |
| BUS | PHASE |

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