Fractal Transport: Enabling the IP Qualification Handshake

A Fractal whitepaper

Introduction

Designing an advanced System-on-Chip relies mainly on the capability of successfully integrating pre-designed IP blocks obtained from different suppliers. Often these IP's are designed in parallel with the end-product, so multiple releases will be delivered to the SoC integration team during the design cycle. Each of these IP deliveries carries the risk of introducing delays to the integration because of missing models, characterization errors or design-tool incompatibilities. An adequate qualification handshake between IP provider and integrator is needed to ensure that such disruptions are avoided.

This paper introduces the Fractal Transport™ formalism for capturing and exchanging IP qualification requirements. It will be shown how Transport in conjunction with the Fractal's Crossfire™ IP qualification tool is used as an IP sign-off solution between semiconductor design partners.

Fractal Transport

Transport serves as an input format to Crossfire, describing what checks Crossfire needs to execute on which IP databases, as specified by the IP integrator.

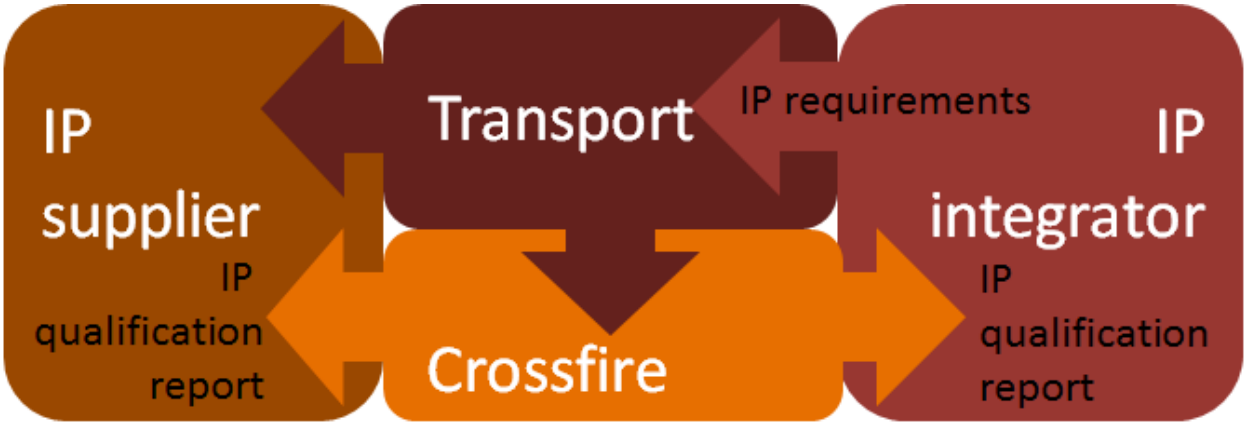

Figure 1: Fractal Crossfire and Transport

Transport describes what is required of a piece of IP for it to be dragged and dropped as-is into an existing SoC design under-construction. The IP integrators will use the Transport formalism to specify their needs on the following aspects of IP qualification:

- IP completeness: Which databases and models are required?
  - Is there a CCSP model for all process corners?
  - Are supply pins properly labeled in the GDSII?

- IP integrity: Are the various models intrinsically consistent?
  - Are the timing or power trends in accordance with temperature or output-load?
  - Are all cell and terminal names properly reflected in all databases?

- IP integration: Is the IP compatible with the design-tools used?
  - Are routing pins available at the right pitch and metal-layer?
  - Are clock-domains appropriately represented?

Transport introduces a formal way of describing these requirements such that they are generic for an entire IP/design-flow category. That allows SoC designers to maintain, and incrementally improve, a single set of IP qualification requirements which can be shared with multiple IP suppliers.

Transport achieves this by defining a mapping between the databases and models that are supplied with an IP release and the IP quality checks that may be applied. These checks are provided by Fractal's Crossfire tool which comes with an extensive database of pre-defined, parameterizable IP quality checks. IP-qualification using Crossfire essentially targets the right checks on the right IP models and reports the results. Using the Transport formalism, IP integrators capture the checks that are appropriate for the various models in the IP release.

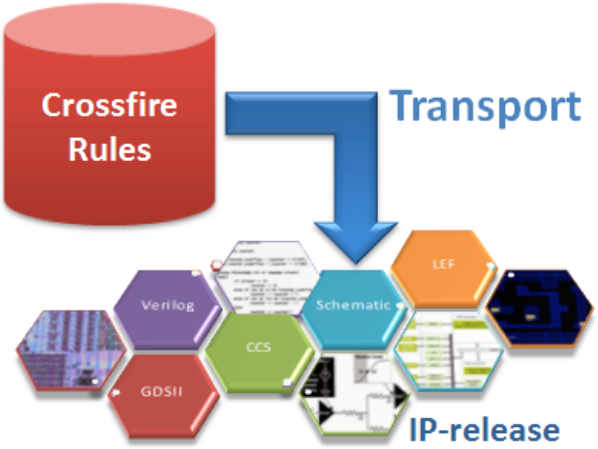

Figure 2: Transport maps checks to IP formats

By defining solely the mapping between the rules and the classes (or types) of objects in the IP databases a Transport qualification rule-deck achieves a level of re-usability that is novel to the industry. The core of a Transport deck consists of the definition of classes and checks applied to those classes. A class can be regarded as a collection of objects, like "all Liberty files", "all supply terminals" or "all noise-arcs". Mapping these classes to an actual instance of an IP release can be left to the IP exploration and classification capabilities of Crossfire. Rules from the Crossfire rule-database are then mapped to these classes to specify the individual checks. A small fragment of Transport code for checks serves to illustrate this principle:

```
R7201:                    # name of the entry
  rule:                   # Crossfire rule 7201:
    7201                  # range-check on cell_rise and cell_fall tables
  golden:
    liberty1              # Reference format for this rule
  formats:
    allLiberty            # Group of databases to be checked
  checkparameters:
    Check From Index: 1   # Check-specific parameters: range is 1..10 ps
    min: 1 ps
    max: 10 ps

R7203:                    # name of the entry
  rule:
    7203                  # Max-difference in adjacent delay values
  golden:
    liberty1              # Reference format for this rule
  formats:
    allLiberty            # Group of databases to be checked
  table classes:
    Delays                # Group of tables in Liberty to be checked
  checkparameters:
    Absolute tolerance: 10 ns # Specific: differences < 10 ns and < 10%
    variation: 10
```

In the example names like “allLiberty” refer to classes of formats. In this case Crossfire may automatically recognize this name as all Liberty files supplied with the IP release. A name like “Delays” typically refers to all delay-tables among all arcs between pin-pairs, and could be populated from sources as various such as Verilog, Liberty, ECSM or VHDL.

The example also shows how rules and checks are distinguished within Transport. A rule can be regarded as a template from which individual checks are instantiated, as described in Transport. Crossfire currently defines 250 different rules, each of which can be instantiated in Transport multiple times as different checks. Each check can be specific to the classes that are checked by specifying different control parameters.

Having discussed the essence of Transport and its relation to Crossfire, the way Transport is used for IP quality sign-off can now be explored in more detail.

The DRC-deck analogy

The Transport usage model is best illustrated using an analogy with the familiar concept of design-rule checks applied to GDSII files before tape-out. Each of the steps in the flow is discussed, comparing layout and IP quality sign-off.

1. Rule deck construction
    a. **DRC**: When introducing a new manufacturing process the Foundry decides on the layout drawing rules for each layer (pitches, widths, extends), according to what can be reliably manufactured with the available materials, litho and etch tools. These rules are coded up as design-rule manuals and as rules in a DRC-

deck for automated execution by a DRC-checker. The manual and DRC-deck are then released to Foundry customers.

b. **IP Quality**: The IP integrators decide based on the tools used for SoC integration and design architecture what IP databases are required, together with the internal consistency that is expected and design-tool compatibility requirements. These are coded as a Transport file for automated execution by the Crossfire tool. The Transport deck is then released to the IP-suppliers.

2. Design
   a. **DRC**: The Foundry customer designs the GDSII and uses the DRC-deck supplied by the foundry to ensure correctness and manufacturability at every stage in the design-flow.
   b. **IP-Quality**: The IP provider starts designing the IP, and uses the Transport qualification deck with Crossfire to make sure that errors are detected early in the design flow and thatthey are quickly fixed.

3. Sign-off
   a. **DRC**: Once the entire GDSII has been completed, a final DRC-check is run, the DRC report produced by the DRC-checker is sent together with the GDSII to the Foundry.
   b. **IP-Quality**: The final release of the IP is run through Crossfire, and the IP is shipped to the IP-integrators together with the Crossfire error report.

4. Waiving
   a. **DRC**: On specific locations relaxing design-rules will be discussed between Foundry and customer. This can allow for more densely designed silicon to be produced, but requires the Foundry to guarantee that yield will not be affected. The waivers remains always associated with a particular design.
   b. **IP-Quality**: In certain instances Crossfire rules as specified by Transport may have been violated. Discussion between IP provider and integrator may lead to some of these violations to be waived. The waivers are captured also within Transport, but remain dedicated to a specific IP.

5. Best-practices improvement
   a. **DRC**: Based on discussions with customers, repeated occurrences of design-rule waives lead to improvements in the way design-rules are described in the manual and coded in the DRC-deck to automatically capture exceptions. A new version of the DRC-deck and manual is then supplied to Foundry customers.
   b. **IP-Quality**: IP suppliers and integrators will discuss frequently repeating waives, as a result IP integrators may decide to enhance the Transport deck to automatically capture these exceptions, either by relaxing a parameter or by pre-coding the exceptions as waivers in the format. The new Transport deck is then distributed to the IP suppliers.

These analogies to the DRC-checking scenario show how the introduction of Fractal Transport helps the IP design community to progress to the next maturity level. Transport allows IP providers to capture all issues relevant for IP integrators while they are designing

and characterizing the circuits, thereby preventing major design schedule delays that would occur if such issues were discovered by the IP integrators at the time of IP-qualification or, even worse, when debugging before tape-out.

Transport allows IP qualification rules to become independent from the IP database or IP provider at hand, just like a DRC-deck does not depend on the customer designing the actual GDSII. This makes it possible to improve IP qualification rules over time, and to share Transport files with different IP suppliers. Having a mature Transport deck in place for a certain class of IP enables second sourcing of IP suppliers, without risk to the tape-out schedule.

Transport for IP providers

In the previous section the viewpoint of the IP integrator on Transport has been discussed. It is worth pointing out that Transport also benefits IP providers, and their customers, even if those customers do not provide Transport rule-decks for IP qualification. An IP provider may use Transport to describe its own internal quality standards and run Crossfire checks on the IPs under development as part of their internal development process. Crossfire and Transport in a way implement the regression testing that is required when new versions of a model need to be committed to the design repository.

Also the report as produced by Crossfire (along with the Transport description) can be provided with every shipment of an IP version to a customer. Such a Crossfire report has value as a qualification report for an IP integrator even if they are not using Crossfire yet in their design flow.

Finally, the best-practices argument can be also recognized as a benefit for IP providers. Every time a customer reports an issue with a particular IP release, the detection of these issues can be added to the Transport rule deck that the IP provider is maintaining as an internal standard. This standard Transport deck can be shared and discussed with customers in order to align on design-practices.

Conclusions

An IP qualification handshake between IP provider and integrator is made possible by the introduction of Fractal Transport. Transport lets IP integrators capture their IP quality requirements in a formal way that is not tied to any particular IP provider or instance. IP providers may use Transport as part of their IP design flow, for qualification reporting and as a basis for standardization discussion with IP integrators. By inserting Crossfire and Transport into the IP design flow, IPs will be designed for qualification from day 1. Transport and Crossfire enable SoC designers to drag-and-drop a new IP release into an existing SoC design without the risk of introducing new design schedule delays because of unexpected quality issues.