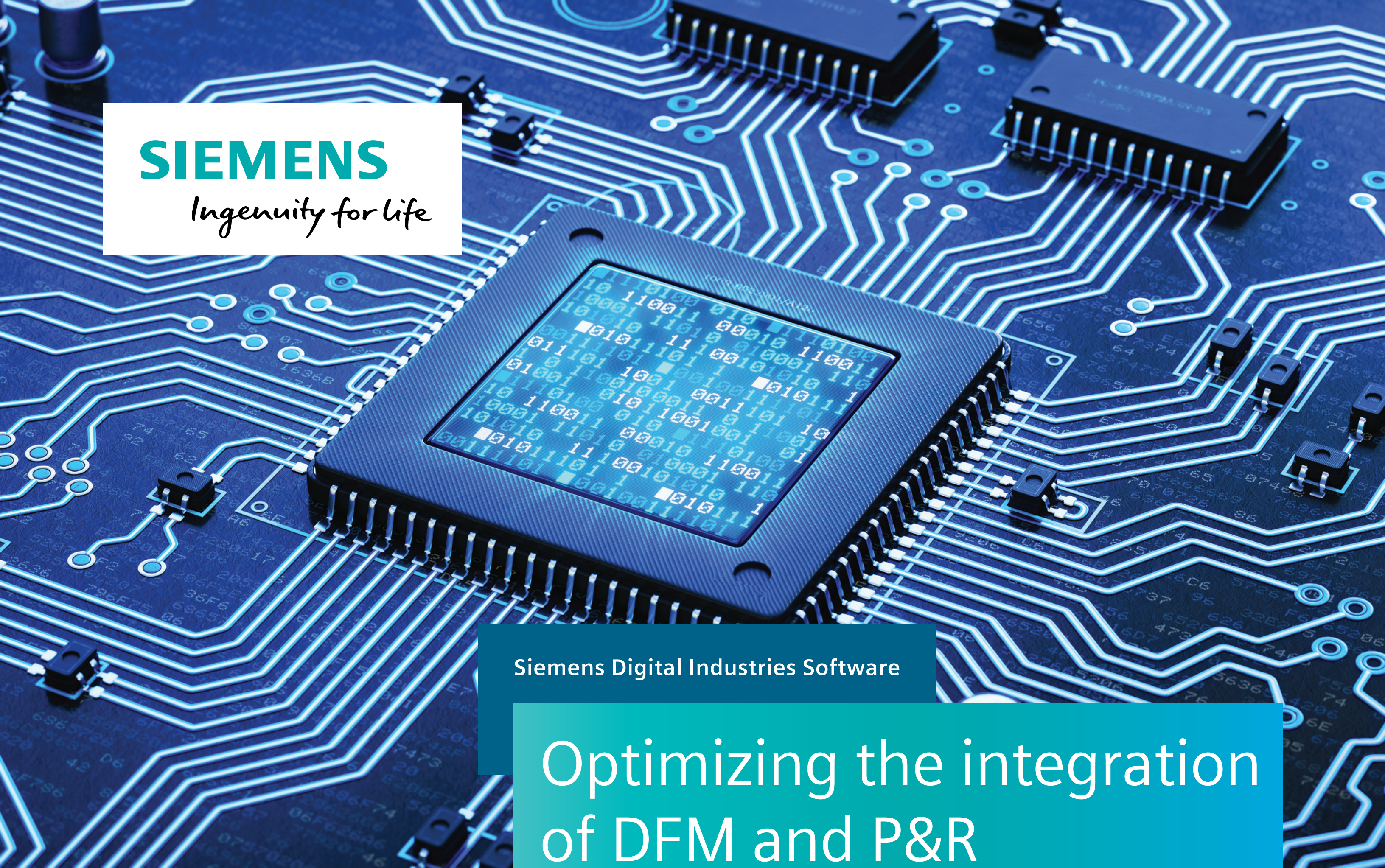

Siemens Digital Industries Software

Optimizing the integration of DFM and P&R

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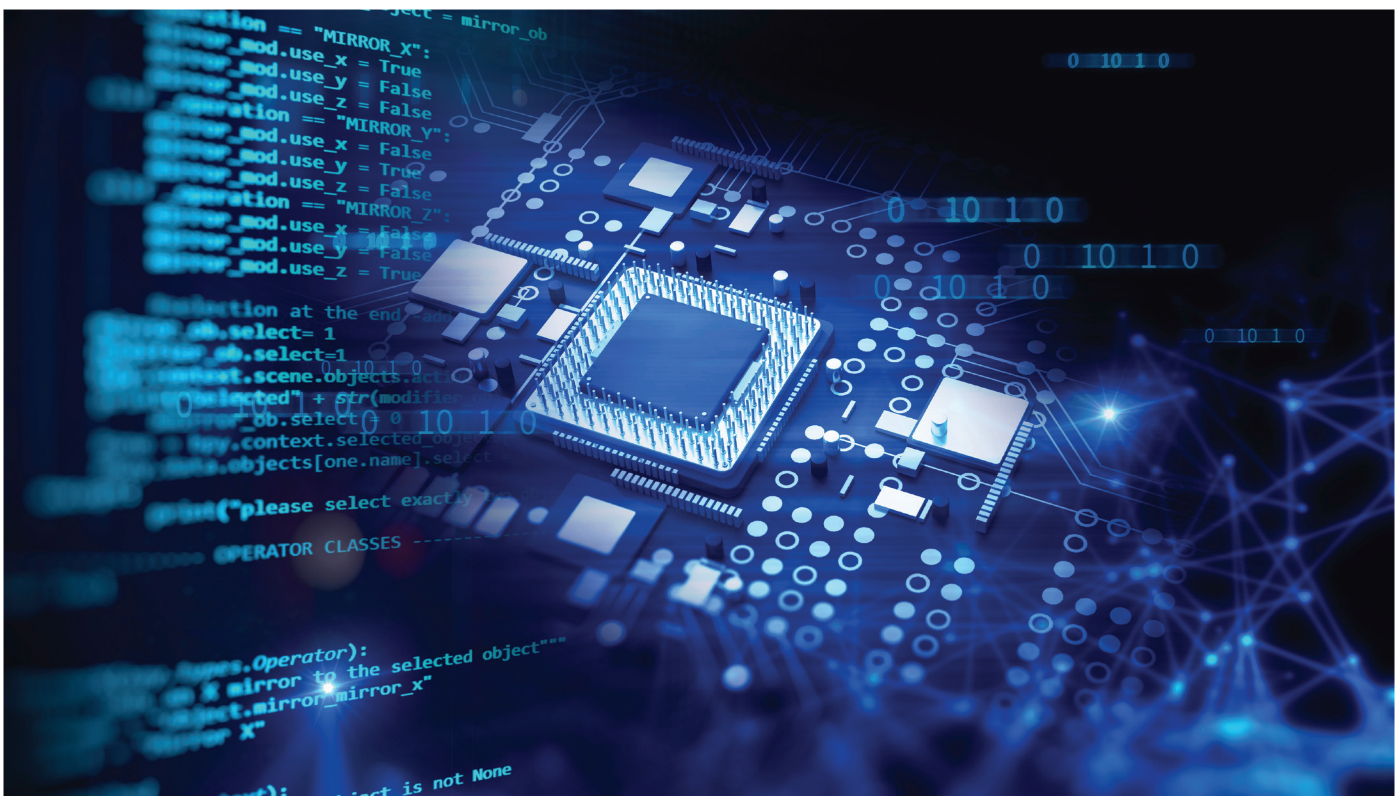
Introduction

Comprehensive system-on-chip (SoC) design implementation, analysis, and verification methodologies are built around the place and route (P&R) application. In turn, the P&R application relies on well-defined interfaces with other electronic design automation (EDA) tools to enable a first class design flow that delivers the required functionality and optimal performance. One challenge that must be overcome to make this integration successful is the difference in database formats used by the various toolsuites. P&R applications primarily read/write library exchange format (LEF) and design exchange format (DEF) files, while most design verification and optimization tools use the graphic design system (GDS) or open artwork system interchange standard (OASIS) formats. To support full integration with P&R tools, the design verification and optimization tools must able to read and write DEF files, either through direct read/write capabilities or by using database conversion processes.

Design companies use full-featured design for manufacturing (DFM) tools, such as the Calibre® YieldEnhancer tool, that are constructed specifically to analyze design layouts and identify changes and optimizations that can improve yield. While the use of these tools can help shorten design iterations, and assist teams in developing tailored solutions for their specific design methodology, they are typically not well-integrated with P&R environments. To enable designers to transfer data from these tools to the P&R environment, database conversions are required. In the past, conversion options have been limited, reducing their value to the design flow. A new solution introduces a direct write DEF capability for fast, accurate back-annotation of fill, via, and net objects to P&R applications.



P&R back-annotation

The Calibre YieldEnhancer tool enables designers to identify and implement automated design for manufacturing (DFM) layout enhancements that can improve yield, beginning with programmable edge modification to adjust line-ends. The tool’s SmartFill and PowerVia functionalities are used to generate correct-by-construction fill and via objects, based on design inputs from the P&R application. Once these changes have been implemented and verified, back-annotation is used to update the P&R design database with the DFM optimizations.

While the Calibre YieldEnhancer tool can use a built-in direct read DEF capability to map LEF/DEF objects and properties to Calibre layers for input, the default output has traditionally been in GDS/OASIS format, requiring a database conversion before the DFM optimizations can be back-annotated into the P&R design database. Design teams seeking a tighter integration throughout their entire design flow need a fast, efficient means of directly annotating the P&R database with DFM design elements in DEF format.

DEF format

Incremental DEF format is frequently used in DFM back-annotation, meaning the input file contains the objects added to the design database, but not the original design data. However, some use models require a DEF output that includes the source DEF design data merged with the added objects in a single output DEF database. Regardless of how the content is structured, using the industry standard DEF format ensures that DFM optimization objects can be read into any commercial P&R tool.

Flexibility

Design methodologies and tools differ from company to company, and even team to team, so foundry and computer-assisted design (CAD) teams need flexibility to build the best solutions for their users. Some methodologies may require tools to both directly read and write DEF data from/to the P&R database, while other flows may use a process that reads OASIS/GDS output files, then converts and writes DEF data as input to the P&R database. This flexibility to build the best flow based on team and company requirements is essential to support the wide variety of users and flows across the industry.

Flexibility also depends on the foundry rule deck a team is using. For example, foundry rule decks designed for fill generation are traditionally set up to read and write OASIS/GDS format. Changing a fully qualified foundry deck is never recommended, so if an existing flow must be augmented to meet new direct read/write requirements, a team would need to implement a secondary rule deck containing a database conversion step to back-annotate the P&R database with the fill data in DEF format. However, if a new process flow and/or rule deck is being developed, the rule deck could be constructed to include the operations required to directly read LEF/DEF format and back-annotate to P&R in DEF format.

Calibre FDIBA utility

The Calibre platform currently provides a utility (fdiBA) that enables limited back-annotation of Calibre layout enhancements in DEF format to commercial P&R tools. The fdiBA utility is invoked using command line execution to back-annotate fill, via, and metal enhancements. The fdiBA utility operates in two modes, depending on the type of change being processed.

Fill

For fill data, the fdiBA utility requires an input database of fill objects in GDS/OASIS format, and a map file defining the mapping between fill layers in the input database and DEF layers in the output database (figure 1).

Compressed fill is used in most foundry-qualified rule decks. When the Calibre SmartFill functionality must generate fill output in a compressed format, the only way to accurately back-annotate this data is to stream it out into GDS/OASIS output (because the Calibre stream-out process is designed to automatically handle compressed data correctly), then run the fdiBA utility to back-annotate fill objects to DEF format.

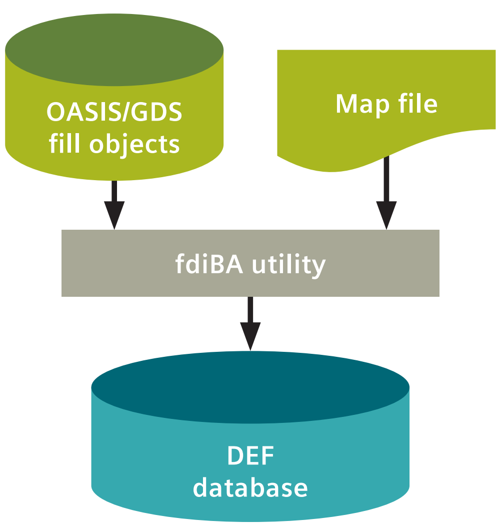


Figure 1. Fill back-annotation flow using the fdiBA utility.

Metal and via objects

Before designers can use the fdiBA utility to back-annotate metal enhancement and via objects into DEF format, they must modify the input objects data with the names of the nets to which these objects belong. To do this, they can write a connectivity stamping rule deck that reads the GDS/OASIS input, performs a connectivity extraction, propagates the net information to the via and metal enhancement objects, and saves the resulting data into a new GDS/OASIS database (DFMDB).

The fdiBA utility uses the internal Calibre YieldServer DFM data management tool to read and process the annotated data in the DFMDB database. It then uses this data with the map file to generate an output DEF database containing all the metal enhancement and via objects (figure 2).

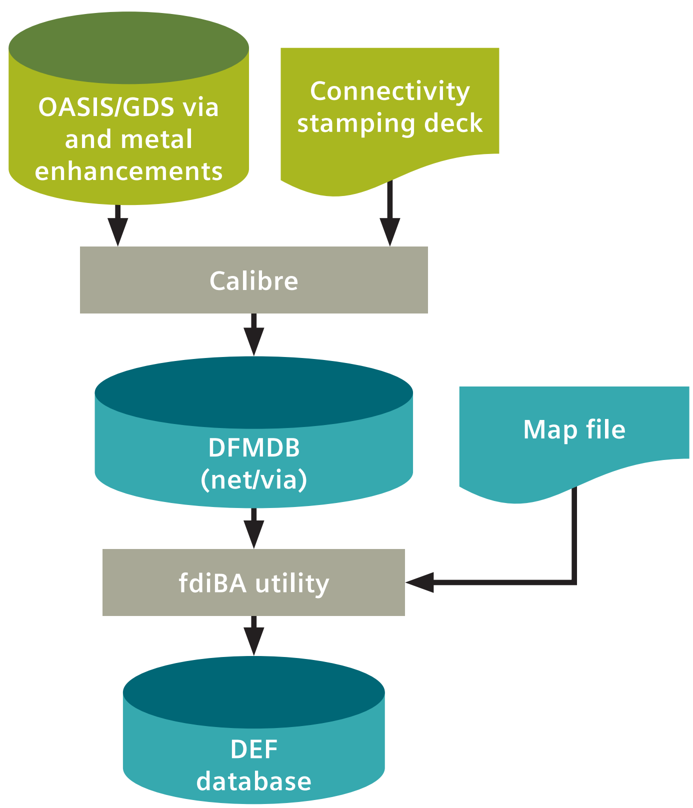


Figure 2. Metal enhancements and via back-annotation flow using the fdiBA utility.

Limitations

The requirements for data preparation processing can be onerous, limiting the usefulness of the fdiBA utility:

- Writing the map file and connectivity stamping rule deck can be difficult and time-consuming.
- Metal enhancements must be rectangles, or they are ignored.

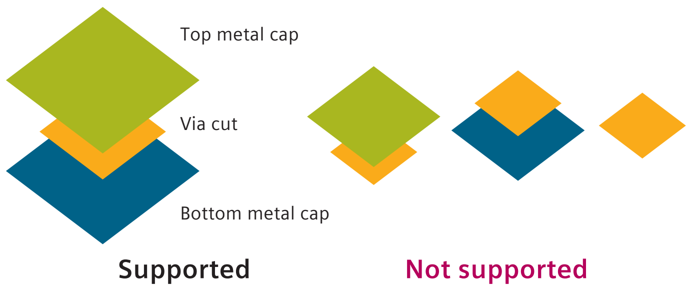


Figure 3. Only complete via object structures are supported in the fdiBA utility.

- Via objects must have shapes present in all three layers (top metal, via cut, and bottom metal), and these shapes must overlap and have the same net info. Via objects missing metal caps are ignored (figure 3).
- A single via placed with different orientations is back-annotated as multiple separate vias.
- There is no support for via array detection

In addition, the fdiBA utility has operational limitations:

- Limited results reporting: Only the number of successfully back-annotated objects is reported. No information is provided on objects that were skipped
- Because application of the fdiBA utility depends on the types of the objects being back annotated, it can be challenging for design teams to consistently select and apply the correct data preparation process
- The fdiBA utility also faces limitations in capacity and runtime. Performance drastically drops when the number of objects exceed ten million, which is becoming more common

Direct write DEF

Direct write DEF is the next generation of Calibre back-annotation functionality that can create a DEF format database without the need for an intermediate GDS/OASIS database conversion. Implemented as a rule deck operation (DFM RDB DEF), the direct write DEF process provides a straightforward way to define the mapping of the fill, net and via objects to DEF layers. Keywords control what data is selected and how it is backannotated to DEF format. Direct write DEF provides process uniformity and eliminates the drawbacks and limitations of the fdiBA utility. Figure 4 illustrates the basic direct write DEF flow.

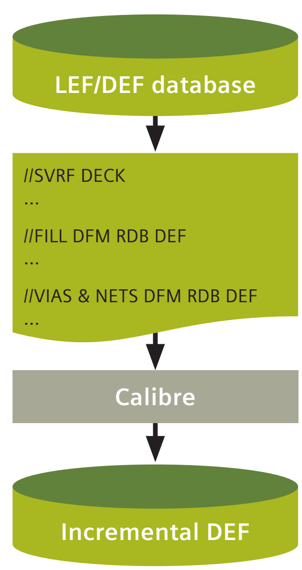


Figure 4. Direct write DEF flow.

Net and via back-annotation

For net and via object back-annotation, the direct write DEF process requires input objects with annotated net properties (layer and net name), eliminating the need for net information stamping. Attaching properties to net and via objects is typically done by operations that are already in the rule deck. The direct read DEF process reads the property value for net and via objects on input layers, and understands to which net each object belongs. Because direct write DEF is implemented as a rule deck operation, it enables streamlined data flow within the native Calibre environment, without any need for post-processing of data to generate the DEF output.

The direct write DEF operation eliminates the object processing limitations of the fdiBA utility:

- Supports back-annotation of all polygon shapes as metal extensions and via caps
- Recognizes multiple orientations of a single via
- Supports via-array detection to reduce DEF file size. Via array detection minimizes the number of placed via instances by grouping and placing them in via arrays instead
- Provides automated via repair (figure 5)

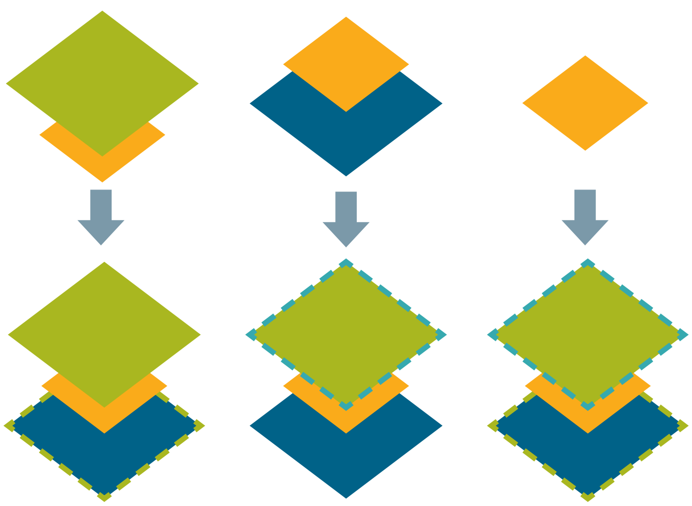


Figure 5. Automated repair of incomplete vias.

Fill back-annotation

For fill objects, the semantics of handling compressed fill data are incorporated in the direct write DEF solution, enabling back-annotation of fill data directly from the Calibre YieldEnhancer SmartFill functionality without generating an intermediate GDS/OASIS file.

If a design team is using a foundry-qualified rule deck to generate fill data in GDS/OASIS format, the direct write DEF process can still be used to back-annotate this fill data to the P&R application by creating a rule deck with the DFM RDB DEF operation and corresponding mapping of the input fill layers to layers in DEF.

Conclusion

Design companies and foundries are constantly modifying their design implementation flows to deliver the best possible solution for their operational needs, and the best possible designs for the market. While the use of DFM tools can help shorten design iterations, and assist teams in developing tailored solutions for their specific design methodology, they are typically not well-integrated with P&R environments. To enable designers to transfer data from these tools to the P&R environment, database conversions are required. In the past, conversion options have been limited, reducing their value to the design flow.

The Calibre direct read DEF and direct write DEF functionalities enable core Calibre applications to read P&R design data using rule deck operations. Direct read DEF enables LEF/DEF object and property mapping to Calibre layers, while the direct write DEF capability enables Calibre applications to write incremental or full design DEF data directly from Calibre operations. Together, they can be used to build tightly integrated flows for P&R engineers.

For back-annotation of DFM optimizations to a P&R design database, the Calibre direct write DEF solution supports development of both fully DEF-based flows and hybrid flows, as needed. Features like automatic array detection and via fixing minimize via instances for compact incremental DEF, and avoid dropping incomplete via definitions. The flexibility provided by the direct write DEF process provides teams with the ability to build the best flow based on team and company requirements, without modification to restricted foundry decks.

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