# Pattern replacement and filtering for post processing

This Application Note details the usage of the Filter and Replace modules which are part of the layout modification toolbox of BEAMER. The Filter module allows to select critical shapes, regions, or layers of a design. The filtering facilitates and accelerates the simulation of these areas in a design. The Replace module, on the other hand, gives the alternative to substitute a filtered region by other shapes or entire layout layers.

## INTRODUCTION

The layouts for chips are drawn using complex polygons which are attained by many small simple geometries. Accordingly, the simulation and optimisation of the entire layout is complicated and time consuming. Additionally, sections of the layout require to be changed to obtain an optimal design for a certain application. These problems open the need for a tool that allows us to modify the respective sections on the layout. The filter and replace modules available in BEAMER facilitate this job.

The Filter and Replace modules are found within the layout tab and they are put into action by left clicking the mouse and dragging them into the GUI or by double left clicking on the module (see Fig. 1).


*Figure 1. Filter and Replace modules in the Layout tab.*

## FILTER MODULE

The filter module opens a dialogue for setting the instructions to choose the features that fulfil those attributes (see Fig. 2).

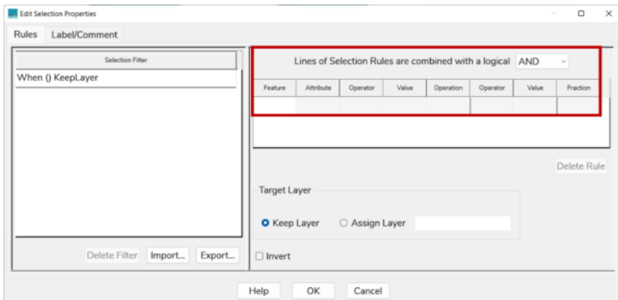


*Figure 2. Filter module settings.*

The *Feature* tab displays different alternatives that compound a layout: *All*, *Circle*, *Ring*, *Path* and *JobdeckTitle* (see Fig. 3). These options represent the available shapes in the design giving the possibility to filter closed figures or segments.

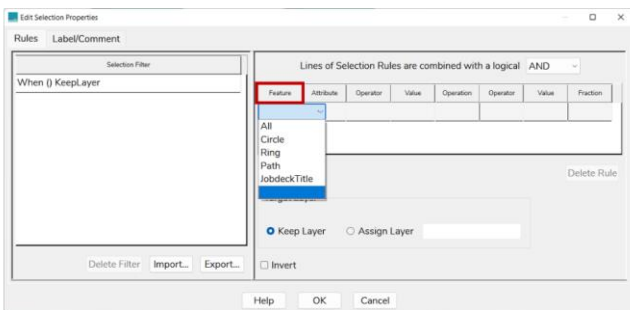


*Figure 3. Available features to filter a layout.*

The *Attribute* tab presents the features to implement the filtering (see Fig. 4). The *Width*, *Height*, *Area*, *Height/Width*, *Width/Height* and *CD* attributes refer to spatial properties of the shapes. The *RelativeDose* refers to the dose factor of the shapes and *Angle* to a positional attribute.

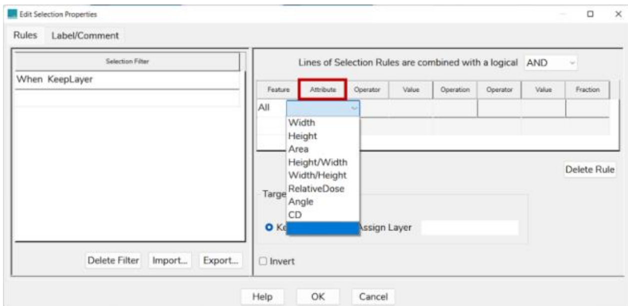


*Figure 4. Attributes to select the shapes in a layout.*

The *Operator* tab displays the logical operation to employ, while the *Value* tab accepts a numerical factor which is used by the *Operator* (see Fig. 5).

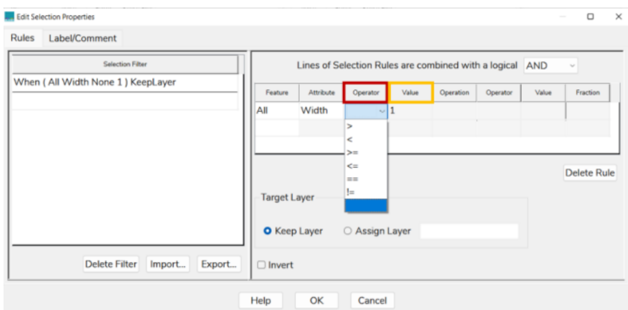


*Figure 5. Operator tab displays all the logical operations.*

The following tabs: *Operation*, *Operator*, *Value* and *Fraction* are used when more than one instruction is implemented to the same *Feature* (this is clearly seen in Fig. 8). Alternatively, the Boolean *AND/OR* is useful when more than one *Feature* are implemented at the time (see Fig. 6).



**Kommentiert [KV1]:** This makes sense to me but might be a little difficult to comprehend by a new user. Maybe we can add some more details on the difference between top line AND/OR, and the logical operation AND/OR. Through an example image?

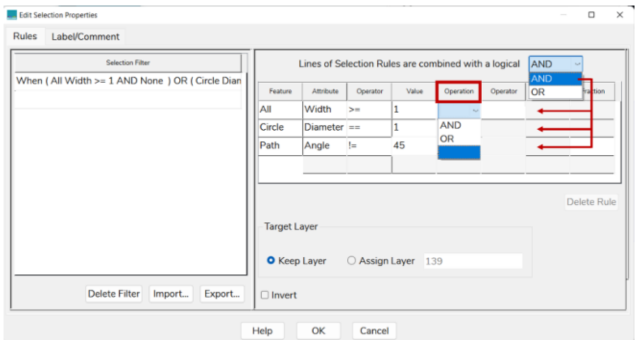


*Figure 6. Two Boolean operations available within the module; one for separate features and one for stablish ranges for a single feature.*

The *Import/Export* buttons either use an external file for the filtering instructions or create a file with the instructions inserted in the previously described tabs, respectively (see Fig. 7). Particularly, exporting a file can be used as an example to create other instruction files.

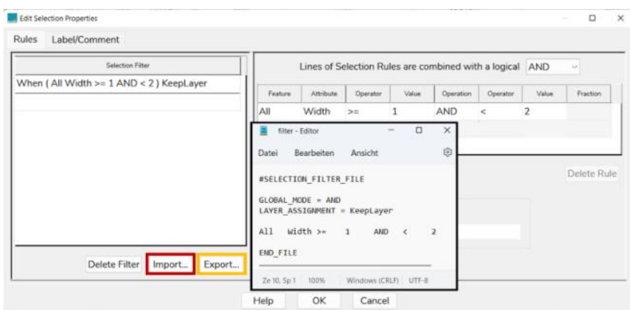


*Figure 7. Exemplary file with a filtering instruction.*

Let us consider a design as the one in the Fig. 8a, comprising of different shapes and layers (each colour represents a layer). For this layout, we can set instructions to filter shapes for which the widths are between 60 nm and 150 nm (see Fig. 8b and c). The section *'Target Layer'* provides the options to modify the original layer number and to invert the filter instructions. The *Keep Layer* checkbox, as its name suggests, preserves the layer of every shape as can be seen in Fig. 8b. The *Assign Layer* checkbox changes all the layers by a fixed one. The *Invert* checkbox works as a negative operation of the filter. As a result, the remaining shapes correspond to the geometries that do not fulfil the filter conditions as shown in Fig. 8c.


*Figure 8. a) Layout with several layers. Filter to select features between 60 and 150 nm where b) keeps their layering, and c) assigns a new layer (139) and applies a NOT operation to the filter instruction (Invert).*

## REPLACE MODULE

Let us investigate the options that the *Replace* module provides. This module consists of *Replacement* and *Comment* tabs, with the former allowing all the layout modification options and the latter used for adding user comments. Particularly in the *Replacement* tab are the types of changes to be implemented (see Fig. 9):

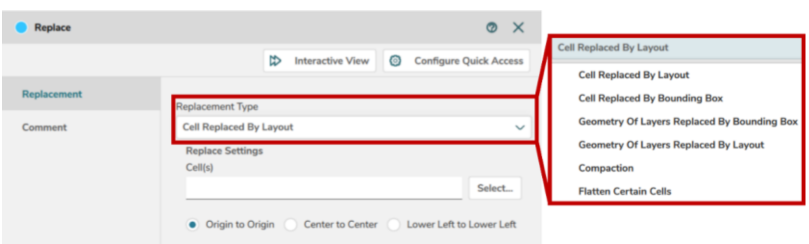


*Figure 9. Replace module and all the replacement types available.*

1. ***CELL REPLACED BY LAYOUT***

This option allows to select among the cells of the layout to replace it by a second layout. For this, the cells are chosen in the '*Replace Settings*' section. In the following figure, a layout is composed of 2 cells. The cell that contains a concentric rectangle and a circle are replaced by the layout of a star (see Fig. 10).

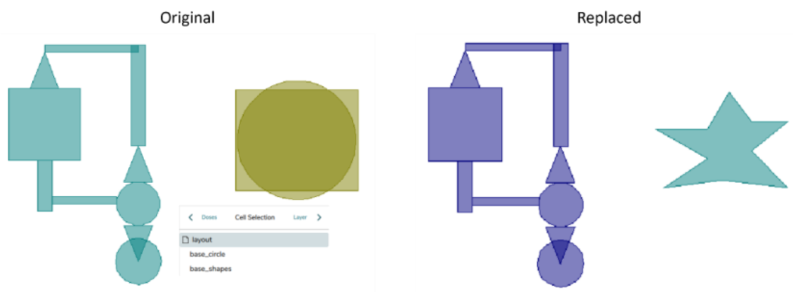


*Figure 10. (Left) Layout design with 2 Cell and (Right) 'base_circle' Cell replaced by a star.*

### *2. CELL REPLACED BY BOUNDING BOX*

This option activates the *Cell to Replace* button in the '*Replace Settings*'. This button opens a dialogue to select the cell to replace (see Fig. 11).

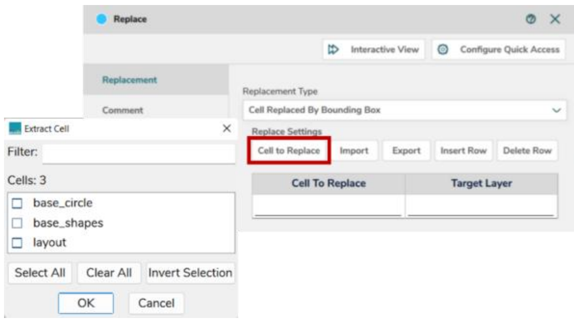


*Figure 11. Dialogue opening to select among the cell of a layout.*

Once the cell is chosen, it is replaced by a '*Bounding Box*' (or a rectangular shape). The box takes up the 4 out most vertices of the selected cell and then draws a box such that the complete structure gets covered within that box (see Fig. 12).

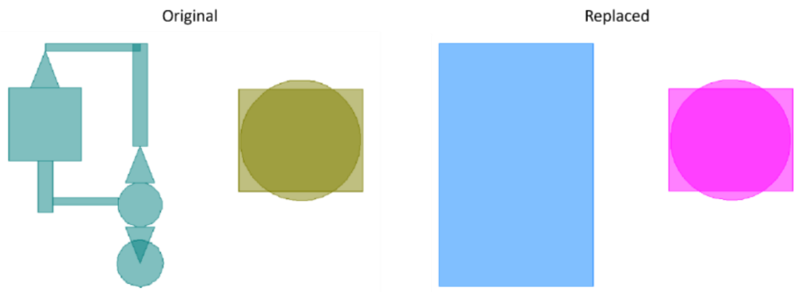


*Figure 12. (Left) Layout design and (Right) bounding box replacing the cell 'base_shapes'.*

### *3. GEOMETRY OF LAYERS REPLACED BY BOUNDING BOX*

The '*Replace Settings*' allows choosing among all the available layers, by using the layers checkboxes, in the layout to replace them with a '*Bounding Box*'. For instance, the layer 0(0) which corresponds to a triangle and is marked with a black circle, is replaced with a bounding box in Fig. 13.

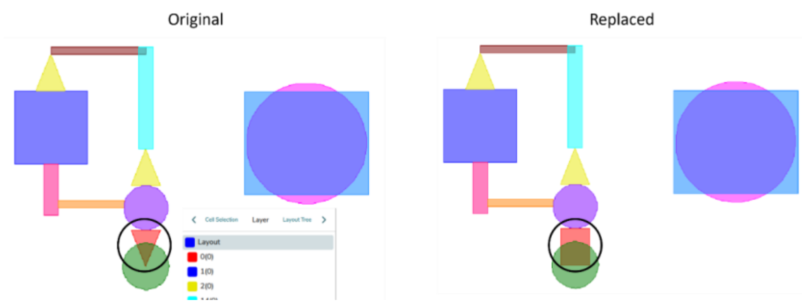


*Figure 13. (Left) Layout marking a triangle in layer 0(0) and (Right) replacing layer 0(0) for a bounding box.*

### *4. GEOMETRY OF LAYERS REPLACED BY LAYOUT*

Similarly, this option replaces layers by the star layout (see Fig. 14).

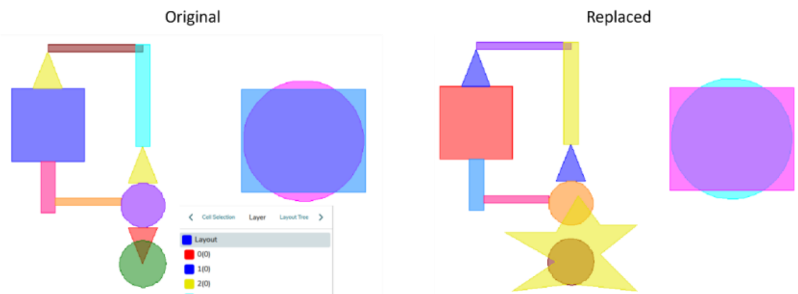


*Figure 14. (Left) Layout and (Right) triangle in layer 0(0) replaced by a layout of a star.*

### *5. COMPACTION*

Simplifies a layout by extracting the shapes/patterns that are repeated. Later, the base shape/pattern is used to build the original layout. Similarly, if cells are repeated, these are removed reducing computation and fabrication processing time. For this, the '*Remove Cell Duplicates*', '*From Compressed Arrays From References And Arrays*' and '*Replace Repeated Geometries By Cells*' checkboxes are chosen (see Fig. 15).

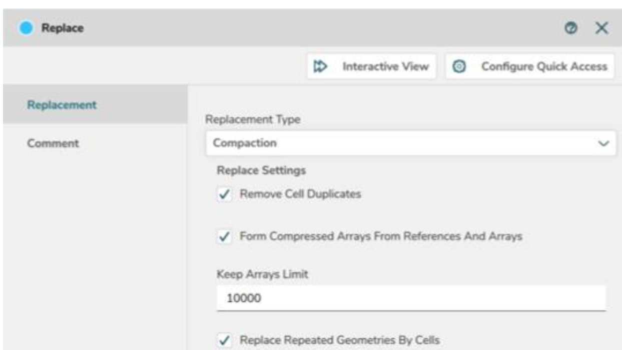


*Figure 15. Compaction replacement type with checked replace settings.*

For instance, the following layout is a matrix of shapes (see Fig. 16a). When looking at the layout tree, the pattern is formed with 'base_shapes' and 'base_circle' (see Fig. 16b). The replacement type '*Compaction*' detects that there is a shape (a triangle) which is repeated in 'base_shapes'. Therefore, the shape is created within the tree of this pattern. This change reduces the complexity of the original design without modifying the overall layout. The changes produced by the module are seen in the '*Layout Tree*' (see Fig. 16c).

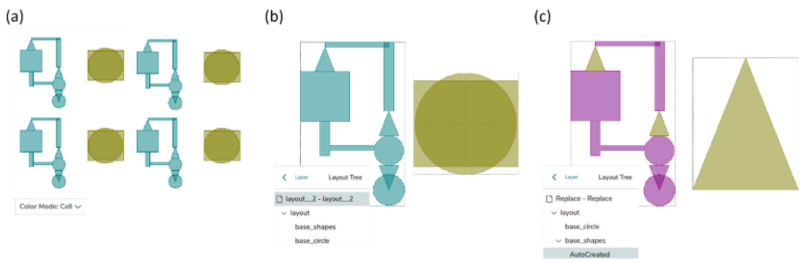


*Figure 16. a) Layout formed by a matrix of cells (blue and green), b) the layout tree of the pattern is composed for two base cells, and c) in the cell 'base_shapes' the compaction replacement detects the repetitive shapes and reduces the cell complexity.*

### *6. FLATTEN CERTAIN CELLS*

The flattening replacement uses either the cell's name, the size of features or the hierarchy level to simplify the layout.

- *Select By Name*: In the figure is shown the cell '*L1_RING*' which is formed with many base-shapes. After flattening, all the composing parts are united to form a single base pattern (see Fig. 17).

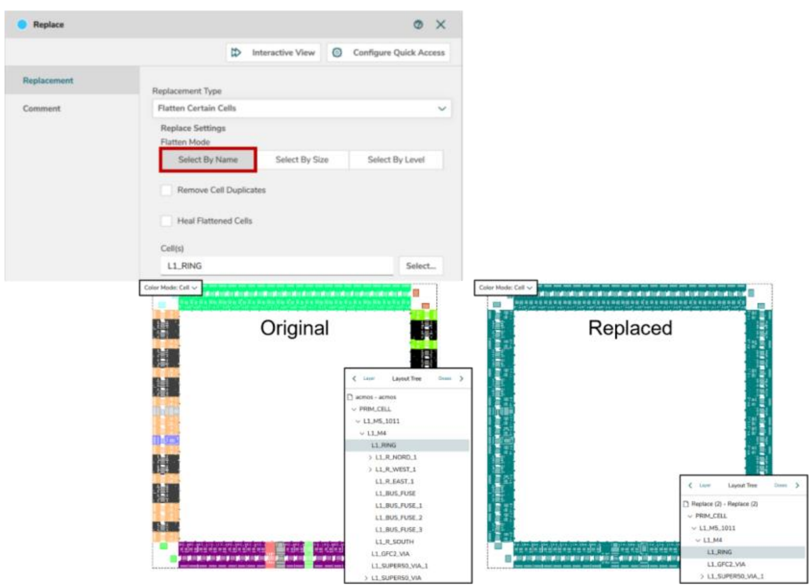


*Figure 17. (Left) 'L1_RING' cell in a CMOS layout composed by several cells and (Right) cell 'L1_RING' flattened.*

- *Select By Size*: The layout is simplified by choosing the area of regions in the design. For this, the size in *X* and *Y* are typed in microns and *Delta XY* gives the error margin for the chosen area. In the figure, the upper and lower areas of the desing are 1439 um in *X* and 150 um in *Y*, while the left and right areas are 150 um in *X* and 1439 um in *Y*. Therefore, these areas become the base paterns to form the '*L1_RING*' (see Fig. 18).

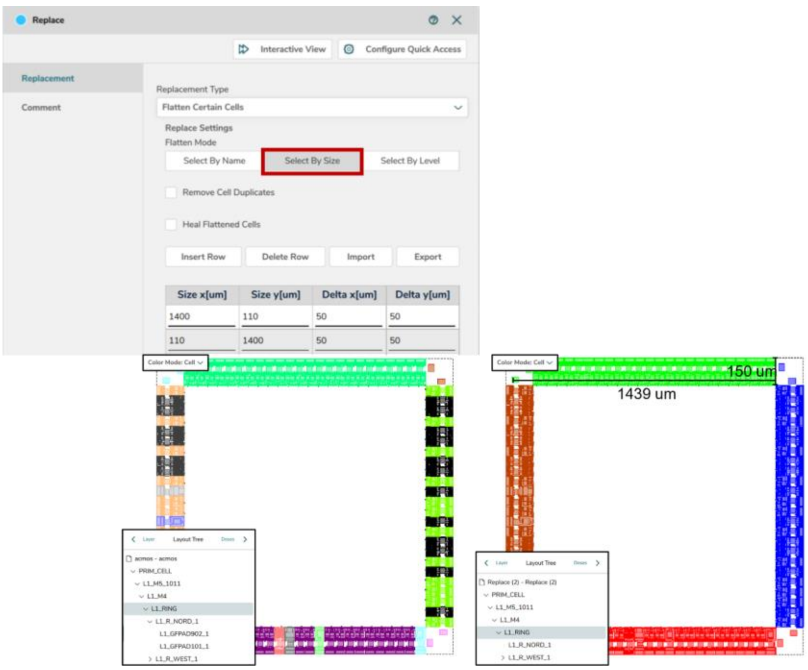


*Figure 18. (Left) 'L1_RING' cell in a CMOS layout composed by several cells and (Right) cell 'L1_RING' flattened according to the sizes introduced in the module.*

- *Select By Level*: For a layout with several hierarchy levels, the '*Level to Flatten*' establishes an upper limit to simplify the design. In the figure, the level is chosen to 3; therefore, the replace module takes the cells up to a third hierarchy level and flattenens the cells above that limit (lower hierarchy level). This means that cells of fourth, fifth and so on hierarchy levels are united to their third level cell forming a single base pattern (see Fig. 19).

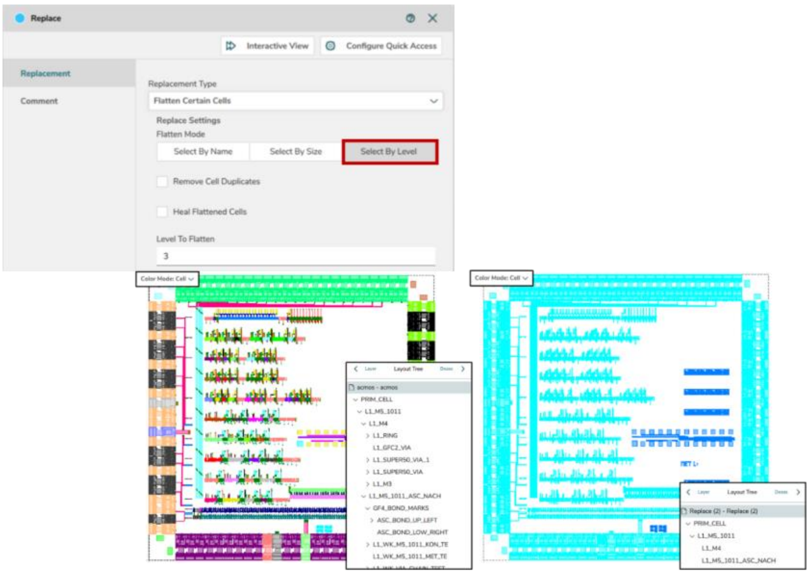


*Figure 19. (Left) CMOS layout composed by several cells and (Right) CMOS layout flattened up to third hierarchical level.*