Cross-Section Viewer

Introduction

An integrated circuit is inherently a three-dimensional device, but in most CAD systems the third dimension is represented only by differences in color and/or fill pattern of areas on a two-dimensional screen. In university classrooms and in discussions between engineers, hand-drawn cross-section views are often used to communicate the relevant content of a design that may not be readily apparent from the usual top view.

Quick Access

Quick access to cross-section views provides an effective aid to understanding integrated structures for novice and experienced designers alike.

For example, students can immediately grasp the difference between Well and Select layers of a CMOS process with a tool that allows them to see the structure from a side view. From a top view, Well and Select appear similar. They both define mask layers that typically surround the two different types of Active area. A cross-section view makes it obvious that the Select is merely a qualifier on the Active implant while the Well corresponds to an actual structure that needs to be connected electrically.

Complex Designs

Experienced designers benefit from cross-section views when they move to more complex processes — a trend that is likely to continue for years to come.

For example, some of today's advanced CMOS-bulk processes provide double-poly, double-metal, base layer implant, and CCD implant. Engineers can create multigate transistors, JFETs, isolated bipolar transistors, CCD transfer structures, and a variety of floating gate structures.

Cross-section views are important even to the veteran chip designer when creating and communicating these more complex structures.

Geometrical Design Rules

Cross-section views are often useful for understanding the reasons for geometrical design rules.

For example, most CMOS processes impose a minimum distance between a Via and the edge of polysilicon. Vias may be entirely surrounded by or completely away from Poly, but they may not be near an edge. Although this rule may seem arbitrary to first-time designers, a cross-section view shows clearly the uneven metal terrain over Poly edges — and the fabrication problem that would arise from trying to place a Via there. Advanced designers who understand the motivation for design rules can violate selected rules under conditions that will not cause fabrication problems.

Implementation

L-Edit's implementation of cross-section views is intended to aid the circuit designer in conceptually understanding the vertical structure of integrated circuits in terms of the masks specified in the layout. This implementation does not provide the process engineer with a completely accurate representation of the physical reality. Actual chips have a variety of properties and process artifacts, such as smooth height transitions, bird's beak, and planarization, that are not modeled by L-Edit.

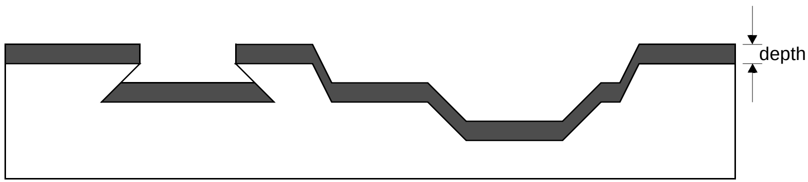
Cross-section views are generated from layout by simulating a set of process (fabrication) steps and building the diagram from the substrate up, one layer at a time. Our simplified process steps correspond only roughly to the process steps used by the fabricator to create the chip. The *process definition* is maintained in a separate text file and may be edited by the user (see XST Files).

The cross-section viewer simulates three types of process steps:

- *Grow/deposit* generates new material.
- *Etch* removes material.
- *Implant/diffuse* modifies the material nearest the surface.

Grow/Deposit

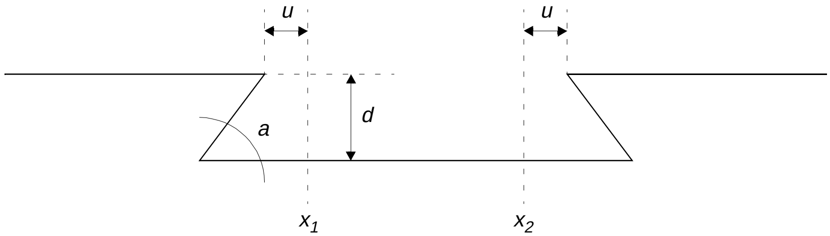
New material is generated uniformly in a grow/deposit step. The substance specified in the process step statement is grown/deposited vertically to the specified depth (measured in technology units) on all upward-facing surfaces. The following figure depicts new material deposited in a grow/deposit step. For more information on technology units, see Technology.



Oxide growth and metal deposition are both simulated with this type of step. (In reality these fabrication layers and the substrate are manufactured with completely different procedures, but for cross-section-viewing purposes, the results may be modeled in the same way.)

Etch

An etch step removes material from all areas covered by the specified mask layer. The etch process model involves up to three parameters: the depth, the undercut offset, and the angle. Depths and offsets are measured in technology units; angles are measured in degrees. A cross-section surface resulting from an etch step with depth *d*, undercut offset *u*, and angle *a*, between points x_1 and x_2, is shown in the following figure.



Typically, many of the layers to be etched will not be simple drawn mask layers, but will result from logical operations such as AND, OR, and NOT combining several mask layers. Unlike a physical etch that may remove some materials but not others, the simplified etch step removes all materials uniformly. Although nonphysical, the simplified etch captures the important details of most semiconductor fabrication processes.

Implant/Diffuse

To simulate the ion-implantation or high-temperature diffusion process that modifies the type of semiconductor nearest the surface, an implant/diffuse step causes the color of the specified mask layer to replace the existing ones from the top surface down to the specified depth in all areas covered by the layer. The implant/diffuse process model involves the same parameters as in the etch model, except that the underlying material is replaced rather than removed.

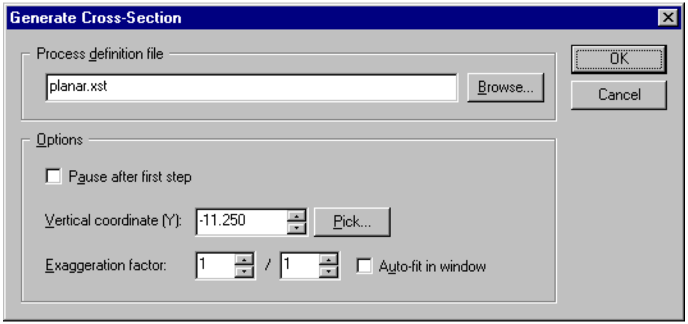
Again, the mask layer may be a logically derived one. For example, the self-aligned polysilicon gate structure requires a combination of the polysilicon and active mask layers to determine where to show the implanted active, which may be blocked by either field oxide (the NOT of active) or by polysilicon. (Operations on layers are specified with the **Setup > Layers** command. The derived layers are specified for cross-section views the same way as for DRC and extraction layers.)

Operation

A process definition file must exist prior to generating a cross-section. The layer names in the process definition must exactly match the layer names in the layout that you wish to view in cross-section. Sample process definition files are included with installation. They can be found in the tech directory located in your L-Edit install directory (**<install_dir>\tech**). These process definition files are described in readme files that are also in this directory (e.g., **readme.txt**).

The cell for which you wish to generate the cross-section must be open. Arrange the display such that a small region of interest (usually a few transistors) is centered in the upper portion of the layout view.

The **Tools > Cross Section** command presents a dialog requesting the name of the process definition file.



The dialog parameters are as follows.

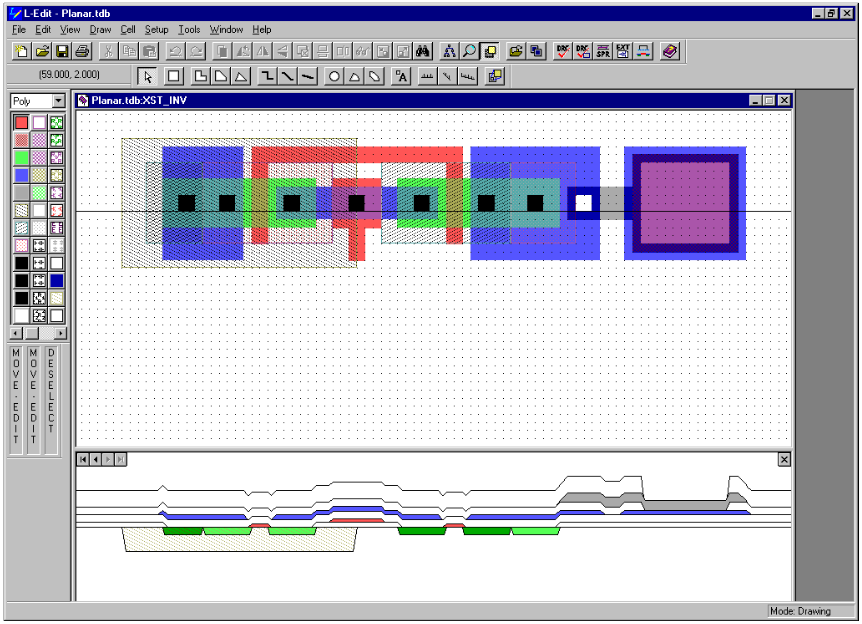
Process definition file	Type in the name of the process definition file, or use the **Browse** button to select the file.
Pause after first step	Cross-section generation pauses after the first step in the process if this box is checked.

Vertical coordinate(Y)	Sets the vertical coordinate along which the cross-section is generated. If you click on the **Pick** button, you can select the vertical coordinate directly from the layout.
Exaggeration factor	Sets the magnification factor for the cross-section along the *z* axis in terms of a ratio.
Auto-fit in window	Sets magnification along the *z* axis for maximum visibility.

After you have set your parameters, click **OK** to generate the cross-section.

In normal mode (not single-step), L-Edit reads the process file, constructs the cross-section view, and displays it in the lower portion of the Layout Area. A sample cross-section view is displayed on the next page.

Since process depths are measured in technology units, the displayed thicknesses of layers in cross-section scale with the current layout magnification. At very large or very small magnifications, it may be impossible to display cross-section views effectively at a 1:1 horizontal-to-vertical aspect ratio. The two numbers (numerator and denominator) under **Exaggeration factor** specify the ratio by which to compress or expand the vertical axis of the cross-section.


L-Edit - Planar.tdb
File Edit View Draw Cell Setup Tools Window Help
(59.000, 2.000)
Poly
Planar.tdb:XST_INV
MOVE-EDIT
MOVE-EDIT
DESELECT
Mode: Drawing

Click the **Close** button in the upper right of the cross-section window to remove the cross-section view and continue normal editing.

Where there is a cross-section window in a file:

- You cannot pan, zoom, or edit in the cross-section window.
- You cannot perform an editing operation in other windows associated with the file.
- You cannot resize the layout window.

The split line separating layout from the generated cross-section can be dragged into another location. Double-clicking on this line removes the cross-section.

Single-Step Display

You can see the cross-section view developed one process step at a time. To do so:

- Check the **Pause after first step option**. The cross-section view is displayed as it would appear after the first process step.
- Click the **Next Step** button (the right-facing arrow) in the upper left of the cross-section window. The second process step is displayed.
- Click the **Next Step** button once for each succeeding step in the cross-generation. The succeeding process steps will be displayed.

A tool tip with a description of the next step is presented when you place the pointer over the **Next Step** button. The step that has just been completed is displayed in the Status Bar.

There are three other buttons in the cross-section window.

Previous Step	A left-facing arrow. Clicking this button displays the previous process step.
First Step	A left-facing arrow pointing at a vertical line. Clicking this button displays the first process step.
Last Step	A right-facing arrow pointing at a vertical line. Clicking this button displays all of the process steps.

Single-step mode is useful for learning the steps involved in fabrication. For instruction in real fabrication processing, a much more detailed process definition could be used.

Single-stepping through a fabrication cross-section that includes all the photoresist and other intermediate processing steps would better communicate the full complexity of today's fabrication processes. For designers who only want to view final cross-sections, simpler process definitions (such as the example in this chapter) are sufficient and easier to maintain.