Design Rules for Drawing Masks using AutoCAD

Artwork Conversion Software, Inc

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Setting Up the AutoCAD Drawing Environment

Introduction

AutoCAD is often used to draw masks for microelectronic circuits because it is widely available and gives the experienced user many tools for laying out unusual shapes. However no mask making machine is controlled directly by AutoCAD's DXF file. Instead the DXF file is translated in one or more steps into a data file that controls the mask making machine. The most common types of machines are:

Figure A-1. An example of a mask drawn in AutoCAD.

Photoplotters	Gerber data controls these machinese
Pattern Generators	PG data controls these machines
Electron Beam	MEBES data controls these machines
LaserWriter	Proprietary formats control these machines

One does not even convert directly from DXF but goes through an industry standard mask data format known as Calma GDSII stream, or GDSII for short.

To get the mask right you need to understand quite a lot about the nature of the mask making machine, the nature of GDSII and the nature of the translation software used to move from DXF to GDSII to the mask database. What you need to know about good drawing practice is summarized in this document.
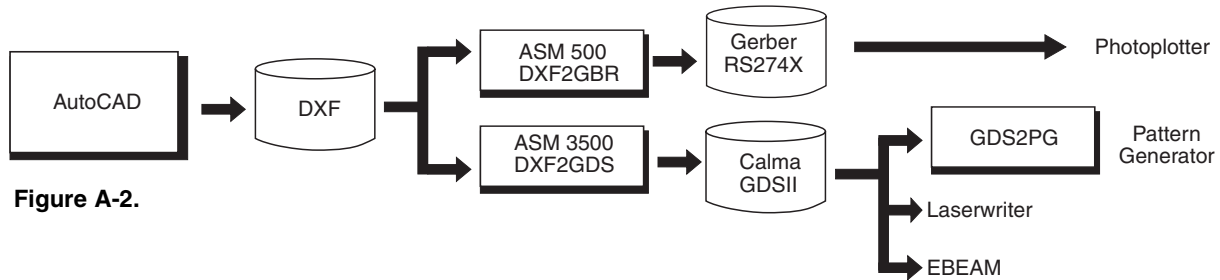
Figure A-2.

Research

Before you put pen to paper learn something about the process that will produce your mask. I've sketched out below a couple of typical worksheets for different types of machines.

Pattern Generator

```
Glass Size:         5 x 5
Margin:             0.25 inch
Machine:            PG Mann 3600
Paint & Scratch:    NO
Re-entrant Polys:   YES
Arcs/Circles:       Avoid if possible
Units to Draw In:   MILS
Min Line Width:     0.2 mil
Data Coordinates:   Center on 0,0
Data Grid: 0.1 mil
```

TI LaserWriter

```
Glass Size:         10 x 10
Margin:             0.25 inch
Machine:            TI Laswerwriter
Paint & Scratch:    YES
Re-entrant Polys:   YES
Arcs/Circles:       OK
Units to Draw In:   UM
Min Line Width:     2 um
Data Coordinates:   Center on 0,0
Data Grid:          0.5 um
```

Units and Grid Snap

All mask making machines and their databases including GDSII are integer or grid based; AutoCAD uses a double precision database that is not grid based. To prevent round off approximations from messing you up during translation you should set a grid snap in AutoCAD and make sure everything you draw is snapped to grid.

A typical grid value if you were drawing a semiconductor mask would be 0.25 or 0.1 or even 0.01 um. Most GDSII databases are in units of microns. Other units are acceptable but we recommend that you try to draw in units of um, mils or mm as appropriate. Never scale your mask to fit to a page border; always draw your mask at 1:1.

One reason we recommend that you avoid arcs is that the vertices of the approximation may be snapped to grid in an ugly or unacceptable fashion.

Polygon properly snapped to grid.

Same polygon after 45 degree rotation and re-snapped to grid.

0.5
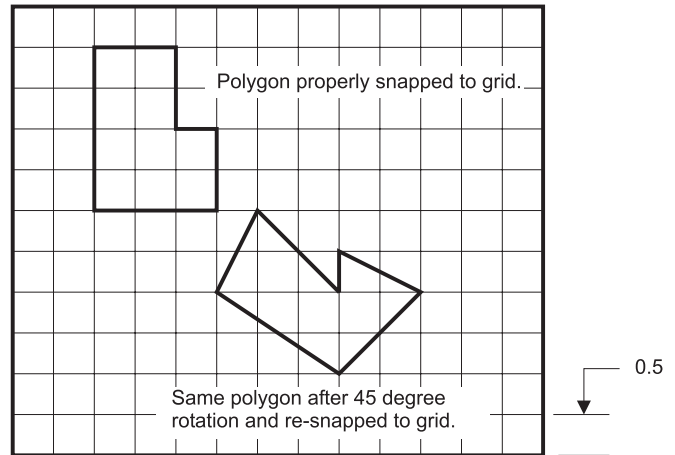
Figure A-3. In this example the user was careful to snap his polygon to the 0.5 um grid of the machine. But he forgot that 45 degree rotation would pull his vertices off of the grid. The resulting polygon didn't look very good on the mask!.

Data Origin

You should select one of two locations for your mask origin:

[a] locate 0,0 at the lower left extents of your data

[b] locate 0,0 at the center of your data.

A   B   C
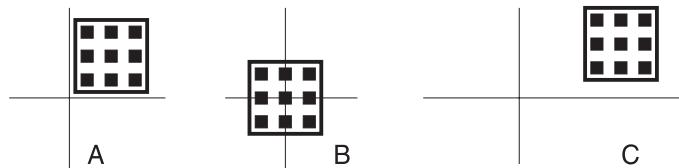
Figure A-4.

Avoid drawing your mask so that it is far away from the origin [c] - this could cause problems later on. Do not draw any data outside of the normal extents of your mask. If you must have data outside of the mask area, such as a title border, make sure it is on a separate layer and purge that layer prior to running a translation to DXF.

Construction Lines

Prior to starting a layout create a construction layer that contains the glass outline, margins and other lines you may help you align your data.

In the example below, the glass outline, margin and center lines were drawn on a layer called construct. Don't draw these entities on your actual mask layers however.
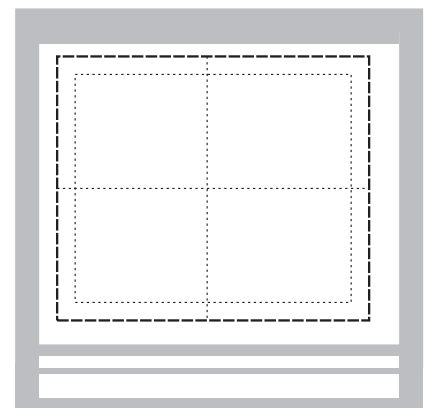
Figure A-5.

Setting up the AutoCAD Drawing Environment cont....

UCS and VPOINT

Make sure that you set UCS (user coordinate system) to WORLD and that you do not modify the vpoint. AutoCAD modifies the coordinates of entities entered while a different UCS is in effect. The translator may not map these to GDSII database correctly.

Layer Names

GDSII uses layer numbers from 0-63. We suggest that you do the same with your AutoCAD layer naming scheme so that there is less chance for confusion. DXF2GDS and GDS2DXF translators do include a method of controlling AutoCAD name to GDSII layer number mapping if needed.

No Hatching

 Some designers think that they should use AutoCAD's hatch command to indicate filled areas on the mask. No! Erase all hatching blocks wherever possible. Hatching is stored in the DXF file as lines contained in unnamed blocks. These lines will end up on GDSII layer 0 and are of no value in the GDSII stream file. GDSII has no hatch entity. GDSII boundaries are always considered filled so adding hatching to simulate a filled boundary is unnecessary and redundant.

Drawing Boundaries Using the Polyline

One of the two basic entities in GDSII is the boundary.

Closed -A boundary consists of a series of straight segments forming a closed area. The first and last vertex must be the same. The inside of the boundary is solid.

Number of Vertices - A boundary may have no less than 3 vertices and no more than 200 vertices.

No Self Intersection - A boundary may not overlap on itself nor self-intersect. However it may touch itself. A boundary that touches itself is called a re-entrant boundary.

AutoCAD has no boundary entity so the closest entity that matches a closed filled area is the zero width closed polyline. This can be directly translated into a GDSII boundary or into a fillable polygon.

self intersecting
(clearly illegal)

two polygons
(legal)

one polygon
(non-intersecting)
legal????

How a re-entrant polygon is legal.
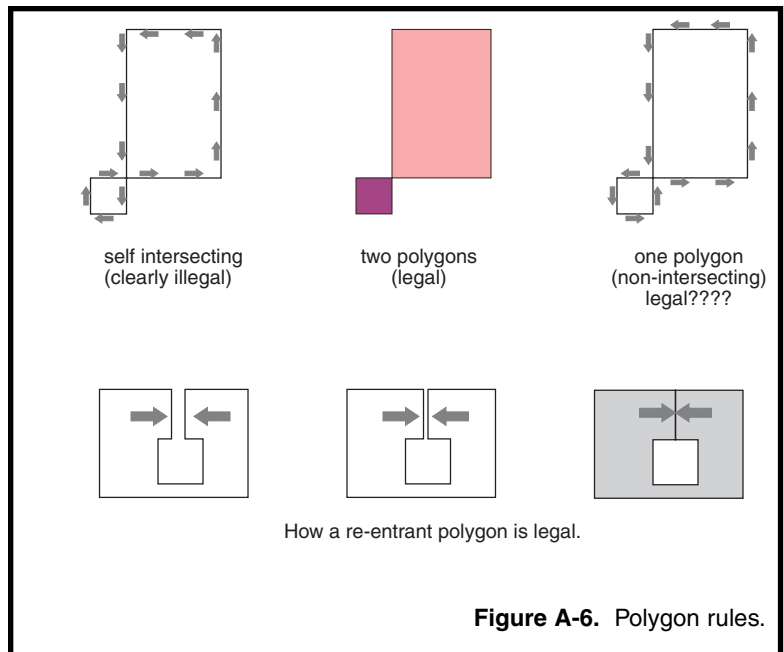
Figure A-6. Polygon rules.

If at all possible use the zero width closed polyline (ZWCP) to form all of your regions.

Q. Can I use arcs as part of my ZWCP?

A. Yes, the ZWCP in AutoCAD supports arcs as part of the boundary definition. However you may wish to use some caution:

Mask making machines don't directly support arcs so they will be fractured into small segments. For critical applications this may be a problem. Also when the arcs are fractured the boundary may have too many segments.

Q. What is the maximum number of vertices per closed polyline?

A. It depends on the target machine or postprocessing software. Older GDSII based tools have a limit of 200 verices per boundary. Newer software has a much higher limit - 2048 or even 5000 sides. Before starting your design you should check with the mask shop to see what the limit is.

Q. Can I close a polyline with width to form a frame?

A. No don't do this. At the start/end vertex you will normally get a self intersecting boundary because this is first converted to a polygon. Either you will get no mask data at all or you will get a small unfilled area. See illustration to right.

Figure A-7. Left = Closed polyline with width drawn in Auto CAD. Right = Mask data with notch due to self intersection.

Polylines with Width - You can also use an AutoCAD polyline with width. The width may vary from vertex to vertex with the following exceptions:

- do not start or end with a zero width vertex.
- do not use an arc section that changes width.
- do not close a polyline with width.

Solids - The AutoCAD solid entity may be used as long as you do not accidentally draw a bow-tie solid.

Lines and Arcs - Lines and arcs may be used to form closed boundaries, but the designer must take great care to make sure that the endpoints snap together and that there are no hidden lines under lines. An Autolisp program called BBPRO is available from Artwork that will interactively convert lines and arcs into zero width closed polylines.

It is also possible to accidentally draw self-intersecting boundaries when using lines and arcs since the linking routine may come to a point where the correct path to follow is ambiguous.

The Re-entrant Polyline

Re-entrant boundaries should only be drawn using zero width closed polylines; never use lines.

200 vertex limit

If you recall, a polygon may never intersect itself - i.e. never fold back over itself. There is a special case of polygon that does fold back to touch itself but doesn't actually overlap. This is called a re-entrant polygon and is often drawn when working with mask making machines that don't support clear or empty polygons.
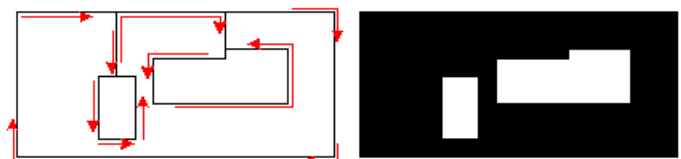
Figure A-8.

The 200 vertex limit is an artificial one imposed by the GDSII definitions. Many software developers have found this limitation too restrictive and have developed programs that support more than 200 vertices.

For example, if you are generating GDSII data to be sent to a MEBEs fracturing software, such as CATS by Transcription Enterprises, you may find that this fracturing software supports boundaries with vertices up to 2048 sides.

If you verify that the end user can accept more than 200 vertices, then you can go ahead and

1] draw more complicated boundaries and

2] configure Artwork's translators to support more than 200 vertices.

Drawing Paths using Polylines

In addition to the boundary, GDSII also has a PATH entity. (Some CAD systems call a path a WIRE). These are often used in IC's to interconnect boundaries representing metal pads. There are three types of PATHS.

Figure A-9.

 ASM 3500 always generates PATHS of type 0.

Figure A-10.
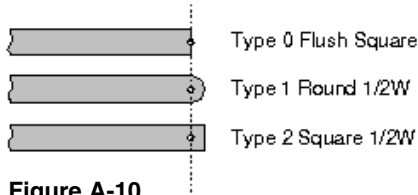
Type 0 Flush Square
Type 1 Round 1/2W
Type 2 Square 1/2W

Characteristics of PATHS

■ The GSDII path has constant width.

■ It must have at least two vertices and no more than 200 vertices

■ If a path bends through more than 90 degrees the corners may be mitered - however there is no GDSII specification on the mitering rules.

Drawing PATHS in AutoCAD

Always use the AutoCAD polyline with width. Width should be constant. You can force a polyline to have a constant width by using the PEDIT command and setting the width.

Path Mitering

AutoCAD does not miter polylines that bend through more than 90 degrees but most CAD systems that import GDSII data automatically apply some type of mitering. This is not under control of the translation software.

Drawing Islands and Isolated Areas

Islands are clear field areas surrounded by a dark field on the mask. They cannot be drawn in the same manner as you would for controlling a plotter or cutting machine. AutoCAD and GDSII have no way to determine that a particular polygon interior should be clear.

In the drawing to the right, the designer drew one boundary inside of another [a]. Instead of getting the mask he desired [b], he got the black mask shown in [c].

Figure A-11.

This is because GDSII fills each boundary solid independent of its relationship to other boundaries. There is no such thing as an empty boundary in GDSII.

There are a couple of ways to work around this:

Two mating boundaries

You can use two separate boundaries that butt up against each other to form the frame. Only use a closed polyline - if you use lines, most likely they will be linked incorrectly to form a self intersecting boundary.

Figure A-12. These actually touch but are shown separated for clarity.

Re-entrant Boundary

Another method to realize an island is to go into the interior of your polygon and out again via the same path. This is called a re-entrant boundary. This is best done using a closed zero width polyline.
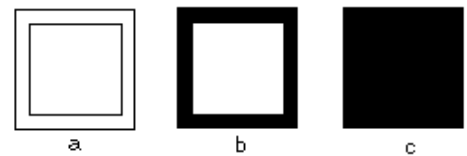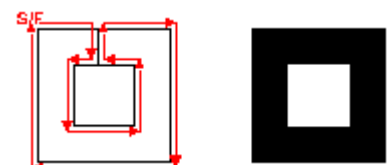

Figure A-13.

Text

ASM 3500 supports text but cannot pass the actual font information. You should not rely on fancy or special text fonts as many mask making machines don't support GDSII text at all.

Supported Text Functions:

- Rotation
- Mirroring

n Height

- Upper Case Numbers and Characters and period, comma, dash, space and slash 1234567890 ABCDEFGHIJKLMNOPQRSTUVWXYZ .,- _ /

Unsupported Text Functions

- Obliquing
- Vertical
- Dynamic (i.e. fitted or where width factor not equal to 1)
- Special Characters
- Special Fonts

Notes

Just because ASM 3500 supports text and text is a valid entity in GDSII, it does not mean that all target systems will correctly read text. Some GDSII postprocessors do not support text. Check with the mask vendor.

If you know that your target does not support text, the dxf2gds translator offers a special option called PG Text. This option converts your strings of text into GDSII boundaries automatically so you don't have to do it.

[a] AutoCAD txt.shx

[b] PG font generated by ASM 3500
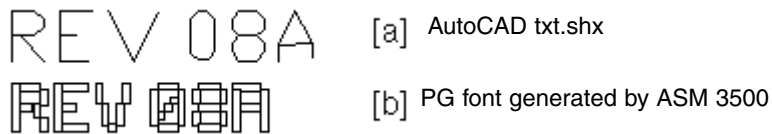
Using Blocks and Inserts

Blocks are very useful for repetitive data - you can nest blocks inside of blocks to minimize your drawings size.

Insertion Scale

Insert blocks at scale=1 if possible. Although GDSII and dxf2gds support blocks inserted with scale, some GDSII postprocessors may not support structures inserted at scale other than 1. Never insert a block with x scale different from y scale. GDSII does not support this.

Insertion Layer

Insert all blocks on layer 0. While this is not mandatory you should note that unlike DXF, GDSII does not mark on which layer structures are inserted.

Insertion Rotation

Do not insert blocks with rotation unless absolutely necessary. Many CAD systems that import GDSII only support rotations of 90, 180 and 270 degrees - some don't support rotation at all.

Block Names

It is good practice to use only upper case characters and numerals for block names. Many CAD systems that import GDSII have difficulty with lower case block names - some reset the names to upper case and some fail on importation. GDSII allows up to 32 characters maximum per name.

Block Attributes

Block attributes are not passed to GDSII.

MINSERT FOR ARRAYS

AutoCAD's MINSERT command (multiple insertion of blocks) is translated to a GDSII AREF (array reference). This is a very useful command for inserting large arrays of cells and it keeps both the DXF and GDSII database small. We suggest that if you use this command that you:

1. Never rotate the MINSERT
2. Always make the row and column distance positive values

Although both the translator and GDSII database support both rotation and negative step sizes we have found that many other GDSII based programs do not implement these transformations consistently. You may spend many hours chasing down weird effects at the other end.

Circles/Arcs

Avoid using circles and arcs if possible. Although the dxf2gds translator can convert circles and arcs into GSDII data, it is not a perfect translation because GDSII does not include an arc or circle entity. The translator will approximate your arc or circle with a series of short segments. You have some control over this approximation. If you have many circles of the same diameter you may want to convert your circle(s) into a block. This will reduce the size of the GDSII file.

ARCRES (Arc Resolution)

Arcres is a value in degrees that determines how many segments are generated per curve. Typical values range from 2 degrees up to 15 degrees.

ARCSAG

Arcsag is the maximum error between the ideal arc and the segmented arc. This value always occurs at the center of each chord as shown in the illustration. dxf2gds will then calculate the number of segments required to produce the desired maximum error. A zero value of arcsag causes the translator to ignore the setting.

Figure A-14. Examples of arcsag and arcres.

Combining Arcsag and Arc Res

The two parameters can be used together - the one that results in the more precision will take effect.
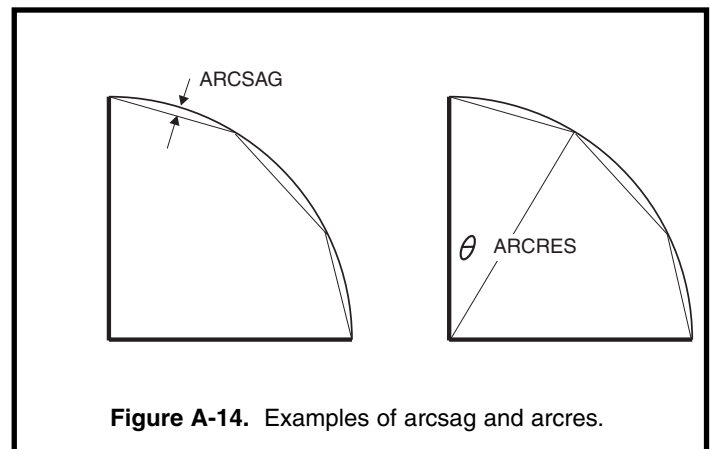
Creating the DXF File

This step may seem simple but we often see many customer errors in simply creating the DXF file from AutoCAD.

Purge the Database

ASM 3500 translates all entities and blocks in your DXF file whether or not the layer is on, off or frozen. To minimize translation time, and to reduce the ultimate GDSII file size you should clean and purge your drawing prior to running the DXFOUT command.

1. Erase all data on layers you do not wish to translate to GDSII.

2. Save your drawing. Open the drawing and use the Purge All command to eliminate unused layers, blocks and fonts.

3. Repeat the preceding step over and over until no more items can be purged.

An alternative approach to purging is to use AutoCAD's WBLOCK command to create a new file containing only the entities you wish to translate to GDSII.

DXFOUT Command

■ Always DXFOUT the entire file. Never select DXFOUT "entities" as the header is not included. Without the header dxf2gds will not run correctly.

■ Do not DXFOUT binary data (DXB) - the translator cannot read this format.

■ Make sure the number of significant places is enough. The default of 6 places is normally fine. However there are exceptions where 6 places may not be enough.

Example

A typical error is creating an AutoCAD drawing in units of inches with very small dimensions - say on the order of 0.000001 inch. If you accept the standard 6 places accuracy when creating the DXF file you may have errors in your GDSII data - due to the fact that AutoCAD stores the data internally to about 14 places but is only writing out 6 places to the DXF file.