HEIDELBERG
INSTRUMENTS

Design Guide


# µPG 101

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# Preface

This Design Guide is a document related to the User Guide for the µPG 101 system. In this manual you find data information and instructions on how to build up a design that is to be exposed on the µPG 101.

General design rules that have to be followed in order to get proper exposure results are given in the first chapter. Then special rules and instructions for each design type are outlined in the second chapter. The following design types can be exposed on the µPG 101:

- GDSII
- DXF
- CIF
- Gerber
- BMP

In the third chapter you find information on how to create a CIF, Gerber or a BMP design.Make sure that the designs are created with respect to the general and specific rules and instructions given in this guide. Otherwise, there will be failures in the exposed designs or the entire exposure will fail.

## *Related Documentation*

This document was issued as part of the documentation for the µPG 101 system. It is related to the following documents:

- ***Pre-Installation Guide*** — Environmental and electrical requirements, sizes and weights of components etc.
- ***User Guide*** — Instructions on how to perform the exposure procedure on the system

If you should need further assistance with design conversion or with handling the µPG 101 system in general, do not hesitate to contact Heidelberg Instruments Mikrotechnik GmbH (see section *Contact*).

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# 1 General Design Rules

The µPG 101 can expose designs defined in several different formats. Each of these formats is implemented for different purposes:

- **DXF, GDSII**: Standard formats for dense binary (2 dimensional) designs
- **CIF:** *Caltech Intermediate Form*, easy-to-use language for direct definition of binary (2D) structures in a text file. Good for fast definition of simple test structures without use of a special design program.
- **BMP** (only with grayscale option): Standard (Microsoft Windows) Bitmap format. This is the only format useable for grayscale exposures (3D resist structuring).
- **Gerber** (only with vector mode option): A common format in lithography. Required for vector mode exposures. Not usable for scanning exposures. The system shifts automatically to vector mode if a Gerber design is selected.

When creating a design, you have to follow certain rules to get correct exposure results. In the following, these rules are explained, and information about design creation is given.

## 1.1 Orientation

During your preparation work for the exposure procedure keep in mind that data view and stage view differ from each other. Your design will be exposed 90° counter-clockwise.

The coordinate system of the stage is oriented such that the x-axis corresponds to a backward-forward movement, while the y-axis corresponds to a left-right movement when standing in front of the machine.

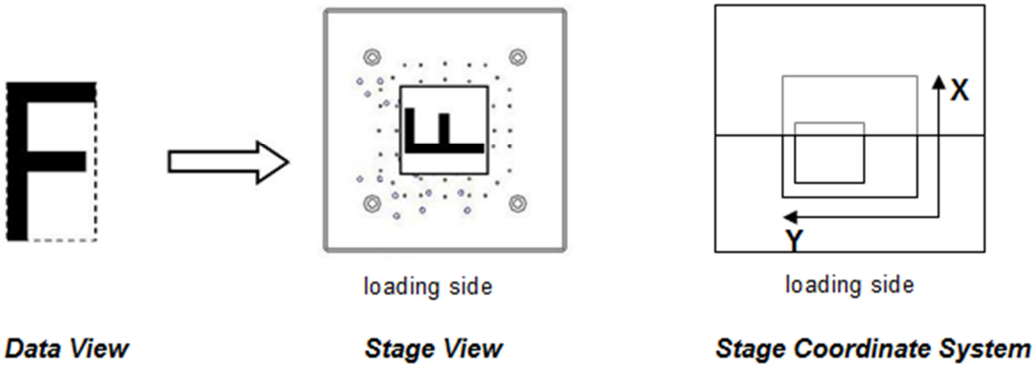



***Figure 1: Design orientation and stage coordinate system***

## 1.2 Filling Logic

In standard mode, the µPG 101 exposes all areas enclosed within structures defined by the design. If inverted exposure mode is selected, everything except the defined areas is exposed. When setting up a design keep in mind that the modes cannot be mixed.

- **Origin:** To make exposures fast and simple, the design coordinate origin has to be located in that point of the design that is to be exposed in the center of the substrate.
- **Areas:** Use only polygons/closed polylines and circles to define exposure areas. Lines cannot be used to define an area; only the outlines will be exposed.
- **Combination of structures:** Overlapping structures are combined with an OR function. This means also that any structures that lie completely within bigger structures are covered by these.

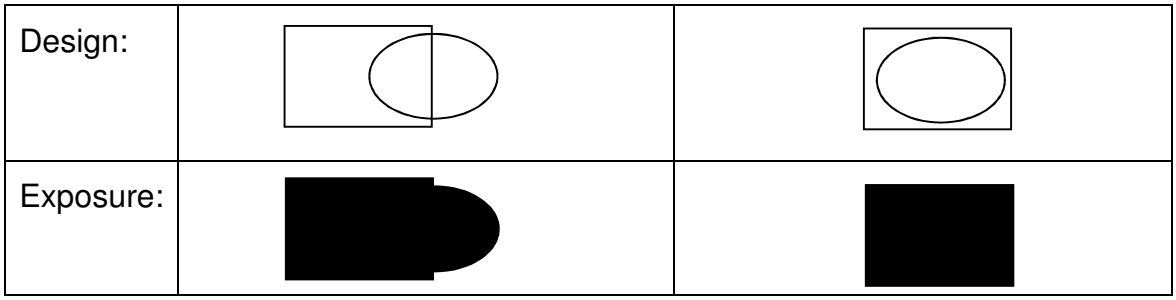
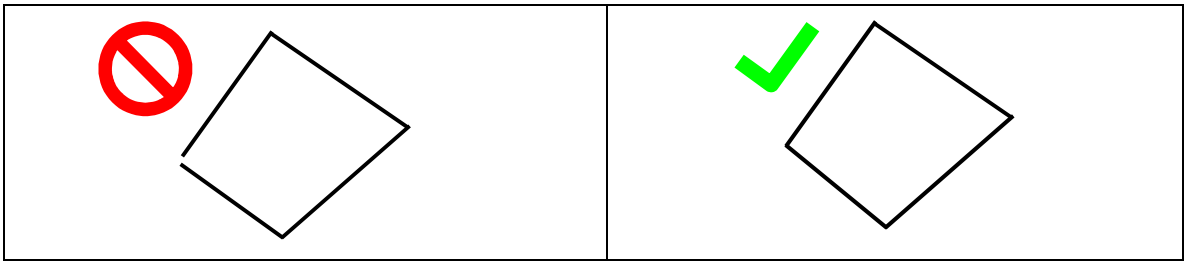



***Figure 2: Combination of structures***

- **Layers:** If possible, create the whole design in only one layer. If several layers are used, they will also be merged using an OR function (see above).
- **Lines:** Lines have to be defined with a fixed positive line width. Lines with width zero are ignored, as well as any line width changes within a line (tapered lines).
- **Polygons/Polylines:**
  - If using polylines to draw polygons, take care to **close all polylines** (last point has the same coordinates as first point). Otherwise, the complete design area is filled. When using a program with an automatic function to close polylines, use this.

  ***Note:*** Do not cross polygon lines or polylines, or create doubled vertices (vertices with no distance between them). This creates data errors.



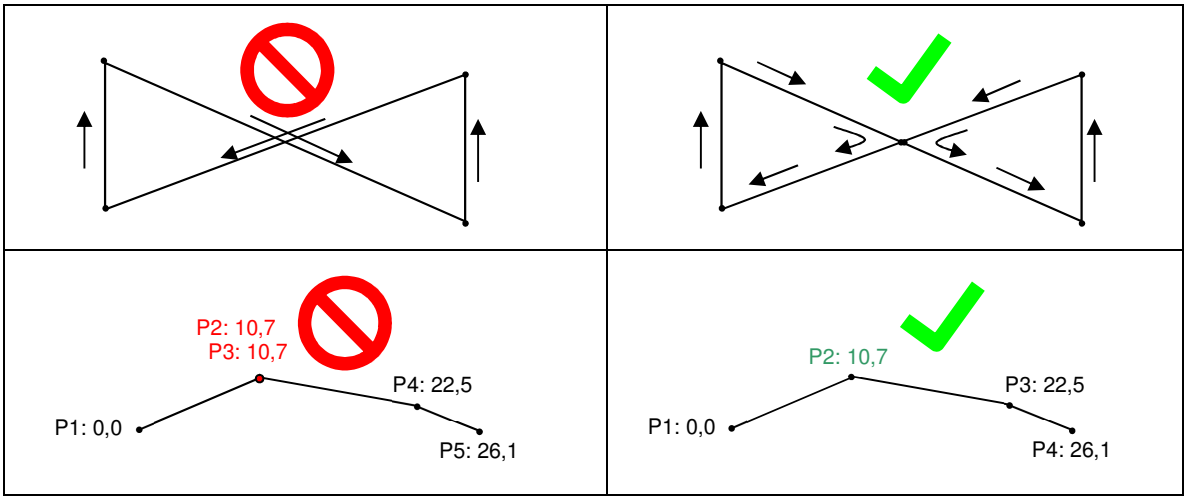



***Figure 3: Polygon/Polyline drawing rules***

- **Naming:**
  - Do not use special characters (spaces, punctuation marks, umlauts etc.) in the design name.
  - Do not use 'main' as name for a layer, cell or any structure.
- **Maximum design size:**
  - WM I: 90 x90mm
  - WM II: 125x125mm
  - WM III: 125x125mm
- **General size limits:**
  - 1,000,000 vertices/polygon (vertex = defined point)
  - maximum definition or reference depth: 16
  - maximum number of definitions or references: 100,000

***Note*:** There might be limits below these for specific formats!

# 2 Design Types

In this chapter you find the rules for each of the design types that can be exposed on the system. Read this chapter carefully and keep in mind the specific rules for each design when working on design creation. For the design types CIF, Gerber and BMP you find further instructions on how to set up a design in chapter *3 Design Creation*.

## 2.1 GDSII Designs

GDSII is a very common design format for layouts of integrated circuit boards. Numerous programs use it as standard output format, or offer it as export option. Rules for this format apart from the general rules above are few:

- **No Inclusions:** Do not include other GDSII files or text libraries, they will be ignored.
- **No nodes:** Node statements in GDSII are ignored.

## 2.2 DXF Designs

DXF is a common graphics design format, used by the well-known AutoCAD software. There is also other design software available that can export into DXF format, and software that can translate between different design formats (e.g., LinkCAD).

☝**Regardless of the design software you use, make sure the resulting file format is 100% AutoCAD R12 compatible**.

Create designs according to the software manufacturers instructions, taking into account the general plus the following additional rules.

### DXF SPECIFIC ADDITIONAL DESIGN RULES

- **Units:** The design has to be created in metrical units.
- **Structures:** Apart from the above listed structure types, for DXF, also “text” is supported. Any other advanced structure types are not supported. It is recommended to only use circles, polylines and text.
- **Text formatting:** Only one text font is provided (Courier-like typewriter font). This will replace any other font used in the design creation. The only supported text attributes are:
  - rotated
  - mirrored
  - scaled
- **Blocks:**
  - When inserting blocks, the same scaling has to be used for x and y.
  - External blocks are not supported

- **Lines:** Lines with width must not change their linewidth (tapered lines not allowed). Linewidth changes within a line will be at best ignored, at worst they can cause conversion errors.
- **Polygons:** Polygons have to be defined as closed. Open polygons will be ignored.

## 2.3 CIF Designs

The Caltech Intermediate Format (CIF) is a design format for direct creation of designs in a text editor. For complex structures, it is recommendable to use a professional CAD software that can create e.g., AutoCAD R12 compatible DXF design files. If only small test structures are set up, they can be easily defined and varied in a CIF design file.

There are a few rules that have to be taken into account in addition to the general rules when setting up a CIF design for a µPG 101:

### CIF SPECIFIC ADDITIONAL DESIGN RULES

- **Layers:** Use only one layer. If several layers exist in a design file, only the layer with the maximum number of structures is written.
- **Calls:** Maximum reference depth is 50, meaning that not more than 50 subroutine calls may be nested into each other.
- **Main structure definition:** The subroutine with the highest number (= routine 'name') will be taken as main routine.

For instructions on how to set up a design refer to *3.1 Setting up a CIF Design*.

## 2.4 Gerber Designs

The Gerber format is used for vector mode exposures. A vector mode exposure is recommendable for designs with only a few line structures, where a scanning of the full area would take longer than a direct writing of the structures. Also, it improves the edge quality of lines written under an angle, but exposure time increase significantly.

In Gerber format, structures are described via apertures and a path across the design field. The opening and closing of the aperture along the path, and the selection of aperture types, create the final structure.

The vector mode conversion program of the µPG 101 supports only a limited subset of Gerber statements and definitions. The most important limitation is that aperture size and shape are restricted to the writing beam size and shape. Each segment that is defined in the design file is written once with the fixed spot diameter of the laser beam. The spot diameter depends on the selected write mode. In order to achieve thick lines, the segment must be repeated several times using a specific displacement of one spot diameter.

***Note***: Keep in mind that the effective line width also depends on system parameters and processing.

For a list of the supported statements and instructions on how to create a Gerber design for a µPG 101 refer to *3.2 Setting up a Gerber Design.*

## 2.5 BMP Designs

3D exposures require a file format where for each pixel within the design area, a depth can be defined in the form of a grayscale value. This is given in the bitmap format. The µPG 101 offers 100 different intensity levels that can be addressed by the grayscale values 0-100 in an 8-bit grayscale format.

The bitmap format also has some specific rules that have to be taken into account in addition to the general ones when setting up a design.

### BMP SPECIFIC ADDITIONAL DESIGN RULES

- **Grayscale Format:** For grayscale exposures, use ***8-bit grayscale format***, and only values ***0-100***. All values above 100 will be interpreted as 100. 0 has to be used for areas with no exposure, 100 means maximum exposure dose and thus maximum depth. For designs that require only 16 or less gray values, also 4-bit grayscale can be used. This has the advantage that a bigger area can be covered, as the file size is smaller (see next bullet point).
- **File size:** The maximum possible image file size in BMP is ***4 GB***. In the above recommended setting for µPG 101 designs (8-bit grayscale), this corresponds to 4 billion pixels, or a size of e.g., 63000 x 63000 pixels. The physical size of such a design depends on the configuration of the µPG 101.

  ***Note*:** In 32 bit systems, the maximum BMP file size that can be viewed is ***3 GB***. You can create bigger files if you have the necessary tools, but you will not be able to load them into any viewer. However, the µPG 101 does not have this limitation and will expose the design.

  For instruction on design creation refer to *3.3 Setting up a BMP Design*.

# 3 Design Creation

This chapter informs about how to create a design. You find examples and explanations on the specific creation commands for the design types CIF, Gerber and BMP. When creating a design, keep in mind the general design rules (*1 General Design Rules*) and the specific ones for each design type (*2 Design Types*).

## 3.1 Setting up a CIF Design

CIF designs are composed of several routines and subroutines. The lowest subroutines contain the geometrical shapes to be used. These subroutines can then be combined and multiplied in higher routines. The higher routines then call these initial subroutines and combine them with position information. Several routines may call the same subroutines. Subroutines may be called several times in the same routine. Subroutine calls may be combined with definitions of geometrical structures in the same routine.

### Structure

This is an example for the structure of a CIF file:

```
<Routine 1000>
     <Call of Subroutine 100>
     <Call of Subroutine 200 in Position X1,Y1>
     <Call of Subroutine 200 in Position X2,Y2 with mirroring
on y axis>

<Subroutine 100>
     <Call of Subroutine 10 in Position X4,Y4>
     <Call of Subroutine 10 in Position X5,Y5 with rotation>
     <Description of geometrical structure at X6, Y6>

<Subroutine 200>
     <Description of geometrical structure at X7,Y7>
     <Description of geometrical structure at X8,Y8>

<Subroutine 10>
     <Description of geometrical structure at X9,Y9>

E;
```

Here, the µPG 101 identifies 1000 as the main routine, as it is the routine with the highest name definition. The final ‘E’ denotes the end of the file.

Routines and subroutines consist of statements. Each of these statements can be combined with parameters, and is closed with a semicolon. Start and end of a routine is denoted by the statements ‘Definition Start’ (DS) and ‘Definition Finish’ (DF). With the start of a definition, the scaling has to be defined. The basic unit of the CIF format is centimicrons (10nm). As only integers are allowed, a scaling factor has to be used

to define structures in smaller increments than this unit. At the same time, for large structures, the scaling can be used to avoid large numbers. To reach both aims, a multiplier and a divider have to be introduced, by which the basic scaling unit of 10nm is modified.

The general subroutine structure looks like this:

```
DS <definition name> <scale divider> <scale multiplier>;
     <statements>;
DF;
```

In the example:

```
DS 10 1 10;
     <statements>;
DF;
```

all coordinates and sizes within routine 10 have the unit 100nm instead of 10nm, allowing to drop one zero from all numbers.

Anywhere within a CIF design file comment lines may be added by putting the text within brackets:

```
(this is a comment);
```

### Statements

All statements have necessary parameters and optional parameters. In the description of available statements necessary parameters are listed between curly brackets {…}, optional parameters between square brackets […].

The statement that interlinks routines is the CALL (or just C) statement:

```
C {routine identification number} [T XT YT] [R XR YR] [MX]
[MY];
```

- **T:** If no options are used, the structures of the subroutine will be arranged around the origin of the routine from which the call is made. Alternatively, the subroutine structures can be shifted with the ‘T’ranslation option combined with a set of offest coordinates XT YT (written with just a space in between).
- **R:** With the ‘R’otation option, the structure set of a subroutine can be rotated. The coordinates define a vector with origin at 0,0. The x axis of the routine will be rotated until it is parallel to this vector and points in the same direction. A rotation R 0 -1 is therefore a clockwise rotation by 90°, while R 2 1 will lead to a ccw rotation of 30°. The coordinate set 1,0 is without effect (vector along x axis).

  ***Note*:** The turning point for rotation is not the origin of the subroutine, but that of the routine in which the call is issued!

- **MX / MY :** These are options for mirroring at the x- or y-axis. The mirroring is done with respect to the coordinate system of the calling routine, not the internal axis of the called subroutine.

In subroutines containing geometrical statements, a definition is usually required to which layer these structures belong. This is defined with the LAYER (L) statement. Although the µPG 101 ignores layer information and merges all layers using an OR operation, for viewer compatibility, the information has to be given before any geometrical statements.

```
L {layer name};
```

Layer names are generic usually denoting technology and layer e.g., CM for CMOS Metal.

The geometrical statements available for design structure definition are:

- BOX (B),
- WIRE (W),
- ROUNDFLASH (R)
- POLYGON (P)

`B {XSize YSize XPos YPos} [XRot YRot]` – defines a filled square.

- **XSize** / **YSize:** Defines the box size (width in X, height in Y)
- **XPos** / **YPos:** Defines the position of the box center within the current routine
- **XRot** / **YRot:** The mechanism of defining a rotation for the box is the same as in the CALL command: A vector with origin at 0,0 is defined by the coordinates of the end point, and the structure will be rotated around 0,0 until the x axis is parallel to the vector, and points in the same direction.

`W {Width X1 Y1 X2 Y2} [X3 Y3 …]` – defines a polyline of fixed width.

- **Width:** Defines the width of the line. Lines with width 0 are ignored. To make sure that lines are really drawn they should be larger than the spot size specifies for the write mode to be used (see specifications in *Appendix A*).
- **X# Y#:** Coordinate sets defining the path drawn. Lines between coordinates are always straight.

`R {Diameter XPos YPos}` – defines a filled circle.

- **Diameter:** Sets the circle diameter.
- **XPos YPos:** Defines the position of the circle center.

`P {X1 Y1 X2 Y2 X3 Y3} [X4 Y4 …]` – defines a filled polygon.

- **X# Y#:** At least three coordinate sets are required to define a polygon. The polygon will be closed automatically.

## Example

Example for a CIF design:

```
(A CIF sample smiley file);

DS 10 10 1;
L CM;
(eye circle);
R 4 0 0;
DF;

DS 100 100 1;
C 10 T -1 0;
DF;

DS 200 10 1;
L CM;
(nose box);
B 1 4 0 0;
DF;

DS 300 40 1;
L CM;
(mouth triangle);
P -2 0 2 0 0 -1;
DF;

DS 400;
L CM;
(wire frame positive quadrant);
W 1 200 0 200 40 170 113 113 170 40 200 0 200;
DF;

DS 1000 100 1;
(putting together the parts);
C 100 T 0 1;
C 100 T 0 1 MX;
C 200;
C 200 R 0 -1;
C 300 T 0 -1;
C 400;
C 400 R 0 -1;
C 400 MX;
C 400 R 0 -1 MX;
DF;

E;
```

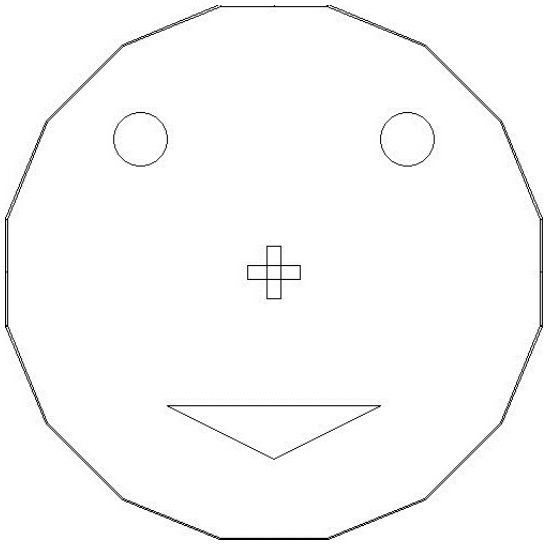


*Figure 4: Sample CIF Design*

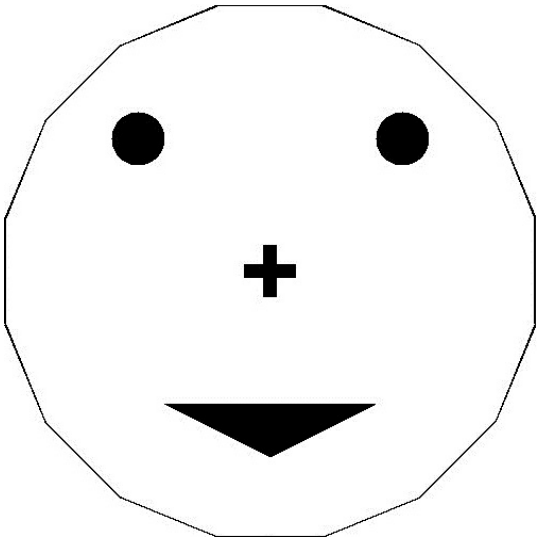


*Figure 5: Exposed CIF design*

## 3.2 Setting up a Gerber Design

A Gerber design describes a continuous path on the substrate, plus the information where on this path the beam should be on, leading to the exposure of the path onto the substrate. The file consists of a header with general format instructions, and a body with the description of the path.

Several different commands are required to define the path .Commands are written together with options and parameters in one uninterrupted string. Not always a full set of parameters is required. To mark the end of each Gerber command, an asterisk (*) is used. All general format commands are set between percentage signs (%).

For explanation of the setup of a Gerber design file, as an example, the drawing of the following structure is explained (for full code see next page):

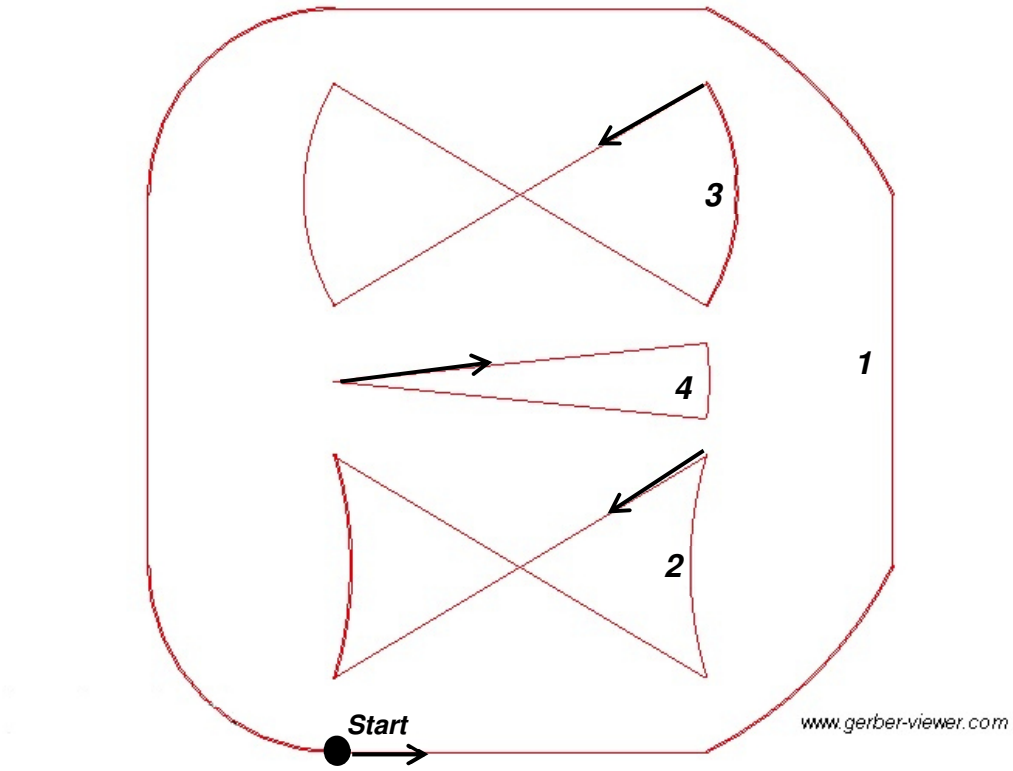



*Figure 6: Sample of Gerber file in viewer*

The full code for this design is:

```
%FSLAX32Y32*%
%MOIN*%
%IPPOS*%
G71*
%ADD10C,0.00*%
G54D10*
G75*
G01X750Y500D02*
X1250D01*
G03X1500Y750I-250J500D01*
G01X1500Y1250D01*
G03X1250Y1500I-500J-250D01*
G01X750Y1500D01*
G03X500Y1250I0J-250D01*
G01X500Y750D01*
G03X750Y500I250J0D01*
G01X1250Y900D02*
G01X750Y600D01*
G03X750Y900I-500J150D01*
G01X1250Y600D01*
G02X1250Y900I500J150D01*
G01X1250Y1400D02*
G01X750Y1100D01*
G02X750Y1400I250J150D01*
G01X1250Y1100D01*
G03X1250Y1400I-250J150D01*
G01X750Y1000D02*
G01X1250Y1050D01*
G74*
G02X1250Y950I400J50D01*
G75*
G01X750Y1000D01*
M02*
```

Some of the commands in this example are added only for Viewer compatibility and are ignored by the µPG 101. These are marked in red, and will not be explained.

Each Gerber design starts with some general statements about number formats and scaling. Within the commands, only integer numbers are allowed as parameters. To get the correct results, the position of the decimal point has to be defined, as well as the scaling between design units and the system unit (1mm in µPG101).

After these initial settings, the path is defined segment by segment.

**Detailed command explanations:**

`%FSLAX32Y32*%`
is a **format statement** (FS). The following characters and numbers denote the options that are defined in this statement, and give the parameters for each option:

- **L** (following the FS characters) indicates skipping of **l**eading zeros. Skipping trailing zeros (**T**) is not supported.
- **A** / **I** (following the **L** statement) tells the conversion if coordinates are given in **a**bsolute (A) or relative (=**i**ncremental) (I) values.
- **X<n><m>** and **Y<n><m>** gives the number of digits in front of (**<n>)** and after (**<m>)** the decimal point for the X or Y coordinate respectively.

In the given example, leading zeros are skipped, and absolute coordinates are used. The decimal point has to be set between the 2nd and the 3rd character from the end of a number (e.g., 1250 -> 12.5, 750 -> 7.5).

`%MOIN*%`
is a **mode statement** (MO). It defines the scaling between Gerber units (the base unit within the design file) and metric units:

- **MOIN** sets the scaling factor to 25.4 (inch units are used for coordinates)
- **MOMM** sets the scaling factor to 1.0 (metric units are used for coordinates)

`%IPPOS*%`
added for viewer compatibility only.

`G71*`
This is a G code, the so called preparatory function code, which are the codes that are used to select modes of writing for the following coordinate set(s). They specify how the coordinate data should be interpolated (shape of the path in between), and set various options concerning the interpretation of the given coordinates. In this case, the code selects the size of the unit value used from this command on:

- **G70** - Specify inches (All coordinates following this statement are read as inch values)
- **G71** - Specify millimeters (All coordinates following this statement are read as millimeter values)

Other G code types will be explained further down.

`%ADD10C,0.00*%`
`G54D10*`
Aperture definition code and preparatory function code for the aperture definition, added for viewer compatibility only. As the µPG 101 has only one writing beam, any aperture codes are ignored when a Gerber design is translated into the machine code. However, Gerber viewers need at least one aperture definition at design start.

From this point on, the structures are defined.

`G75*`
G code for setting of the interpolation mode used in circular interpolation (definition of curves):

- **G74** - Disable 360° circular interpolation (single quadrant mode)
- **G75** - Enable 360° circular interpolation (multi quadrant mode)

In this case, the multi quadrant mode is defined. This means a circle can be drawn in one stroke. Single quadrant mode is required for systems that can not handle signed coordinates for the circle center definition. The µPG 101 however can handle these, so there is usually no reason to use a different interpolation mode than multi quadrant mode (G75).

`G01X750Y500D02*`
This command is a standard command sequence for a straight line:

- **G01** – a G code denoting that movement should be done in a straight line (linear interpolation between current position and target coordinate).
- **X<x>Y<y>** – target coordinates for the movement. Only the coordinates that change have to be listed.
- **D01** / **D02** – A code that denotes if the path should be exposed (01 = shutter open), or if it is just a stage movement (02 = shutter closed). Subsequent D02 coordinates are combined by the conversion software to just one movement statement.

In this case, the stage moves in a straight line (G01) to the start point of the frame around the structure (X750Y500 → X=7.5mm, Y=5.0mm), without writing.

`X1250D01*`
This is the command for the first written line (bottom line of the frame). The G01 code is still active, so linear interpolation is used again. It does not have to be repeated. Only the X coordinate changes, so only this has to be mentioned. The D01 sets the system to writing mode (open shutter) for this movement. The stage moves from (X=7.5mm, Y=5.0mm) to (X=12.5mm, Y=5.0mm) with open shutter, exposing a straight line on the way.

`G03X1500Y750I-250J500D01*`
Command sequence for an arc.

- **G02** / **G03** – a G code denoting that movement should be done in an arc. The number denotes the direction of the bow: 02 – clockwise movement, 03 – counterclockwise movement.
- **X<x>Y<y>** – target coordinates for the movement. Only the coordinates that change have to be listed.
- **I<x>J<y>** – coordinates of the arc center, relative to the starting point, defining the curvature of the arc.
- **D01** / **D02** – Shutter code.

Here, he stage moves in a counterclockwise arc from the previous position (X=12.5mm, Y=5.0mm) to the new one (X=15.0mm, Y=7.5mm), around a center point at a relative position of –2.5mm in X and 5mm in Y. During movement, the shutter is open (D01), so the arc is exposed.

The following commands:

```
G01X1500Y1250D01*                  (line)
G03X1250Y1500I-500J-250D01*        (ccw arc)
G01X750Y1500D01*                   (line)
G03X500Y1250I0J-250D01*            (ccw arc)
G01X500Y750D01*                    (line)
G03X750Y500I250J0D01*              (ccw arc)
```

draw the rest of the frame.

```
G01X1250Y900D02*
```

Movement to the start of the next structure, without writing (upper right corner of the lowest structure).

```
G01X750Y600D01*                    (line)
G03X750Y900I-500J150D01*           (ccw arc)
G01X1250Y600D01*                   (line)
G02X1250Y900I500J150D01*           (cw arc)
```

Exposure of the bow tie with inward curvature.

```
G01X1250Y1400D02*
```

Movement to start point of upper structure.

```
G01X750Y1100D01*                   (line)
G02X750Y1400I250J150D01*           (cw arc)
G01X1250Y1100D01*                  (line)
G03X1250Y1400I-250J150D01*         (ccw arc)
```

Exposure of the bow tie with outward curvature.

```
G01X750Y1000D02*
```

Movement to the start point of the center structure

```
G01X1250Y1050D01*
```

Exposure of the first straight line of the center structure.

```
G74*
```

Change to single quadrant mode for circular interpolation, meaning that no signs are required for the center coordinate.

```
G02X1250Y950I400J50D01*
```

Clockwise arc.

```
G75*
```

Switch back to multi quadrant mode for circular interpolation.

G01X750Y1000D01*
Exposure of closing straight line.

M02*
M (miscellaneous) code, identifying the end of the file. M01, M02 or M03 may be used without difference. In the µPG 101, any statement containing the letter M will terminate the parsing of a Gerber file.

## CHECKING AND PREVIEWING GERBER CODE

In order to check a Gerber design file, in principle, any Gerber viewer can be used, as long as above mentioned compatibility additions have been made. Still, some viewers might still have difficulties with the restricted file format the µPG 101 requires. Best results were achieved using LinkCAD or the Online Gerber Viewer (http://www.gerber-viewer.com/).

## 3.3 Setting up a BMP Design

There are numerous different programs available for BMP design creation. However, most options required for creation of BMP design files for the µPG 101 are similar in all programs. As an example, the setup of a BMP greyscale design with GIMP is explained in the following. GIMP is a freeware software available at http://www.gimp.org .

The example shows the creation of a five-step pyramid using GIMP 2.8:

1. Start **GIMP**.
2. From the menu bar, choose **File ➔ New**.
3. The **Create a New Image** window opens. Here, you select certain properties for the new image:
   - Edit image size to 1000 x 1000 pixel.
   - Open **Advanced Options** by clicking on the **+** button.
   - From the **Color space** dropdown list select **Grayscale.**

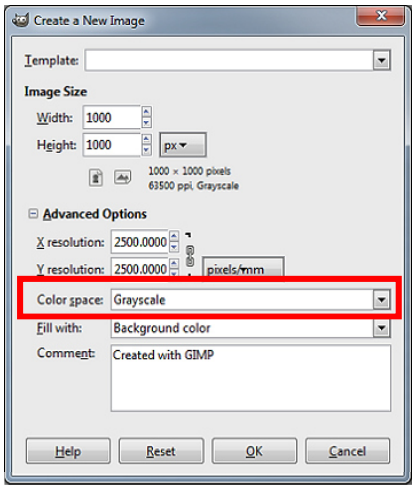



***Figure 7: BMP image setup (GIMP)***

- Optional: To get real dimension information, edit X/Y resolution to 2500 pixel/mm at WM I ,1000 pixel/mm at WM and 500 at WM III .

4. Click **OK**. The editor frame opens. Here you create the design.
5. If the **Toolbox** is not open yet, from the menu bar choose **Windows➔New Toolbox ➔ Rectangle Tool** .
6. From the menu bar choose **Windows➔Dockable Dialogs ➔ Tool Options.** Here you can select the tool options.


***Figure 8: Toolbox (GIMP)***

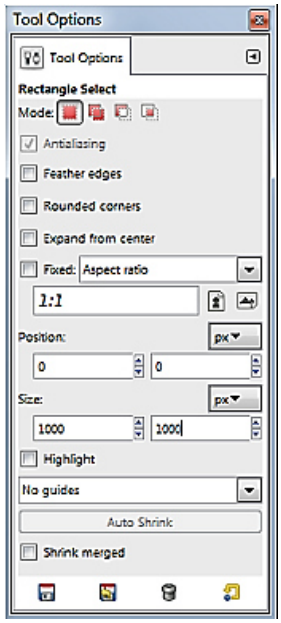



***Figure 9: Rectangle tool settings (GIMP)***

7. In the lower part of the **Tool Options** window, you find a listing of properties for the rectangle you are about to draw. Adjust the checkbox settings e.g., de-select **Rounded Corners**.

8. Click into the editor frame and keep the left mouse button held down while you draw an arbitrary rectangle into the editor frame.

9. In the **Tool Options** window, edit rectangle **Position** to 0,0 and **Size** to 1000,1000. Now, the rectangle fills the complete editor frame.

10. In the **Toolbox** you find a **Foreground & Background Colors** icon (Figure 10). Click on the black rectangle. The ***Change Foreground Color*** editor frame opens (Figure 11).

***Figure 10: Color settings (GIMP)***

11. At **R**, **G** and **B** enter value 20.

12. Click **OK**

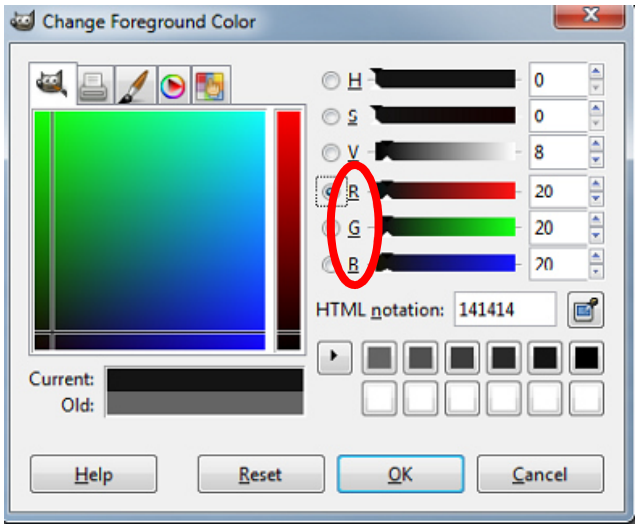



***Figure 11: Gray tone adjustment (GIMP)***

13. In the **Toolbox** window select the **Bucket Fill Tool**  and click into the drawn rectangle in the image editor window. The rectangle is now filled with gray value 20.

14. Repeat step 7 to 13, but this time use **Position** 100,100 and **Size** 800,800 as rectangle properties. **R**, **G**, and **B** value 40.

15. The image should now look like this (Figure 12):

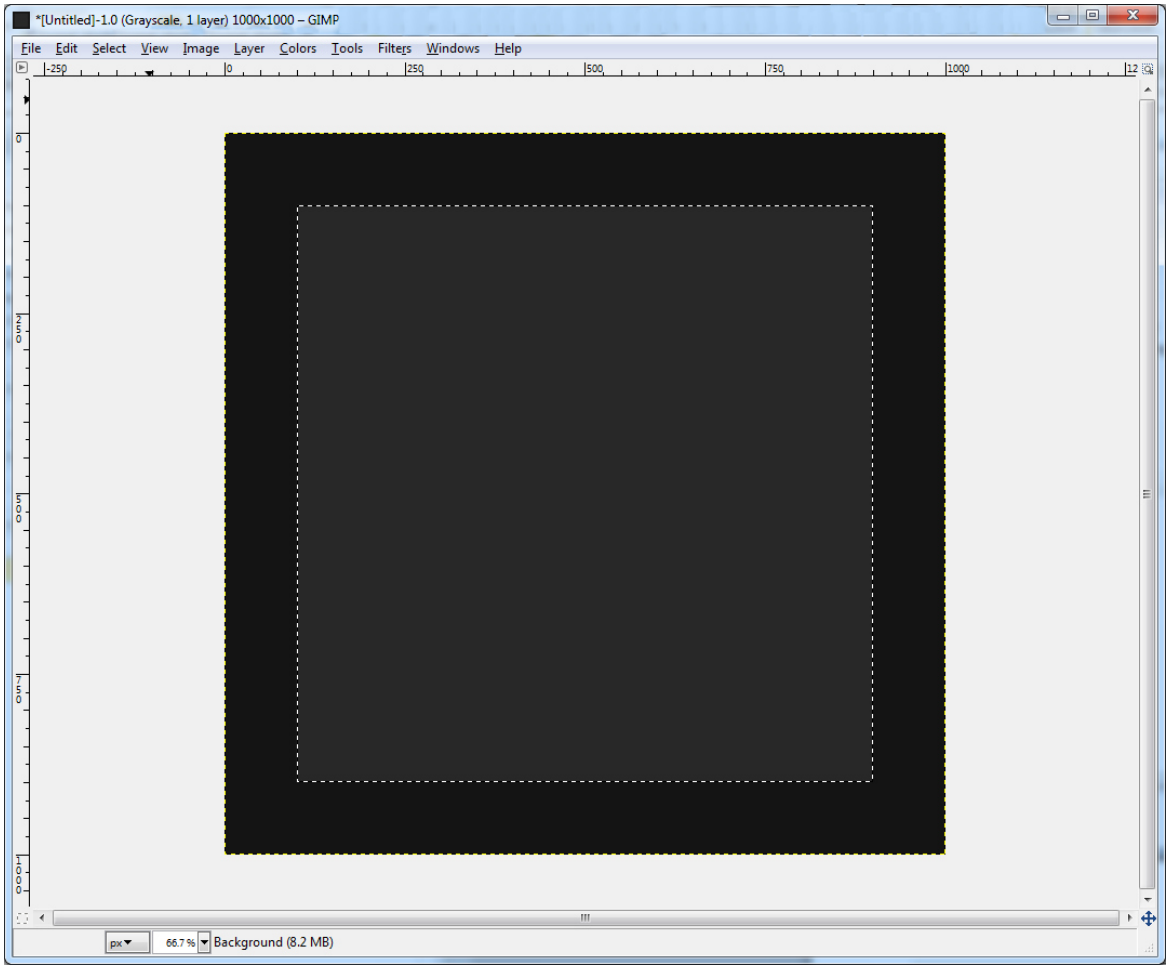



***Figure 12: Second pyramid gray level (GIMP)***

16. Repeat steps 4 to 9 with following rectangle properties and color settings:

- Position (200,200), Size (600,600), RGB = 60
- Position (300,300), Size (400,400), RGB = 80
- Position (400,400), Size (200,200), RGB = 100

17. In the end, the image looks like this (Figure 13):

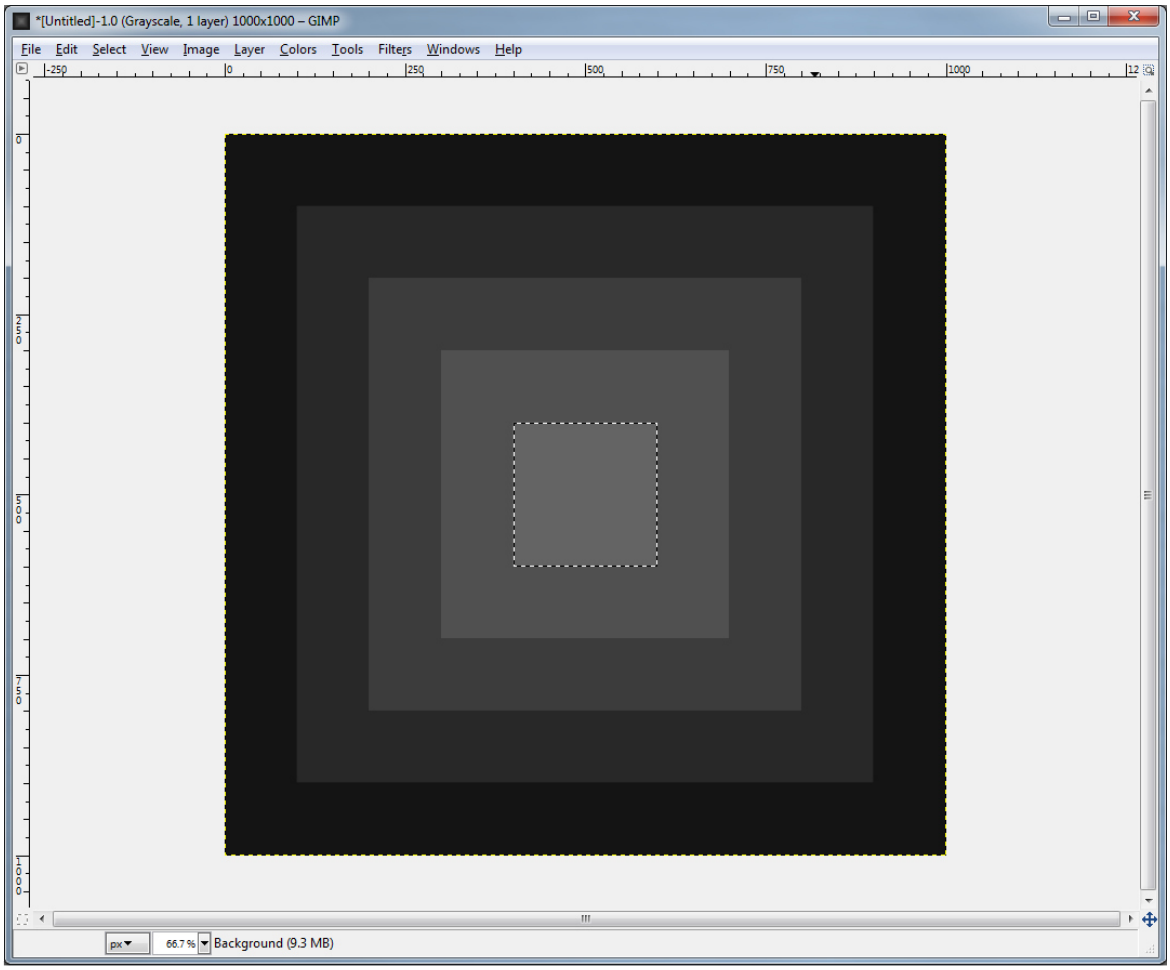



***Figure 13: Five-level gray scale pyramid (GIMP)***

18. Select **File ➔ Export As** (Figure 15).

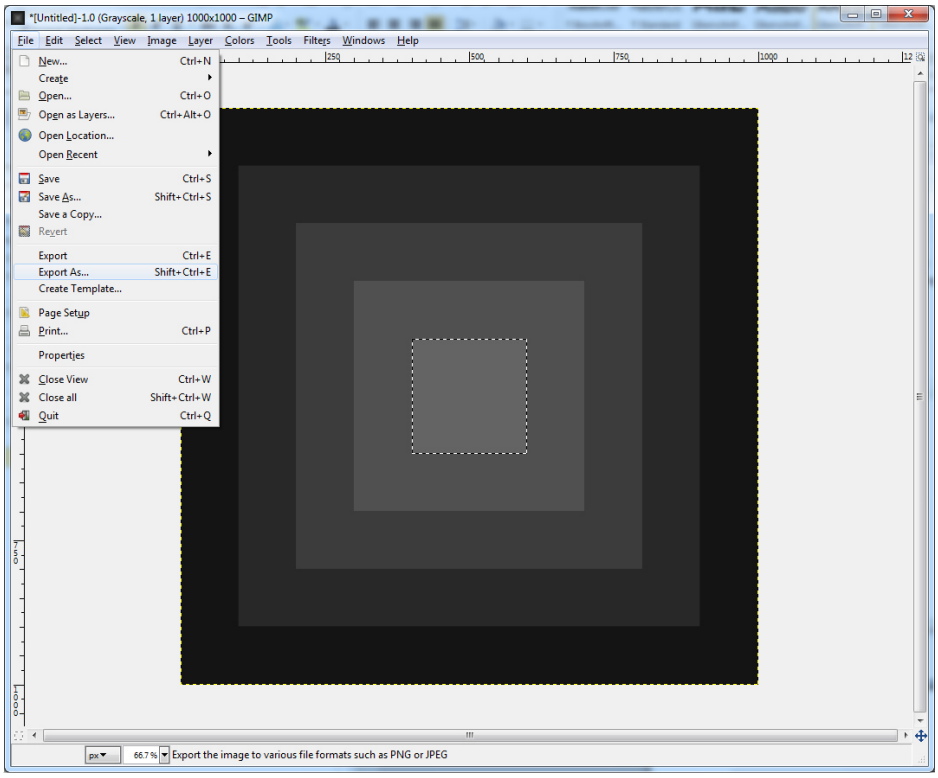



*Figure 14: Export As (GIMP)*

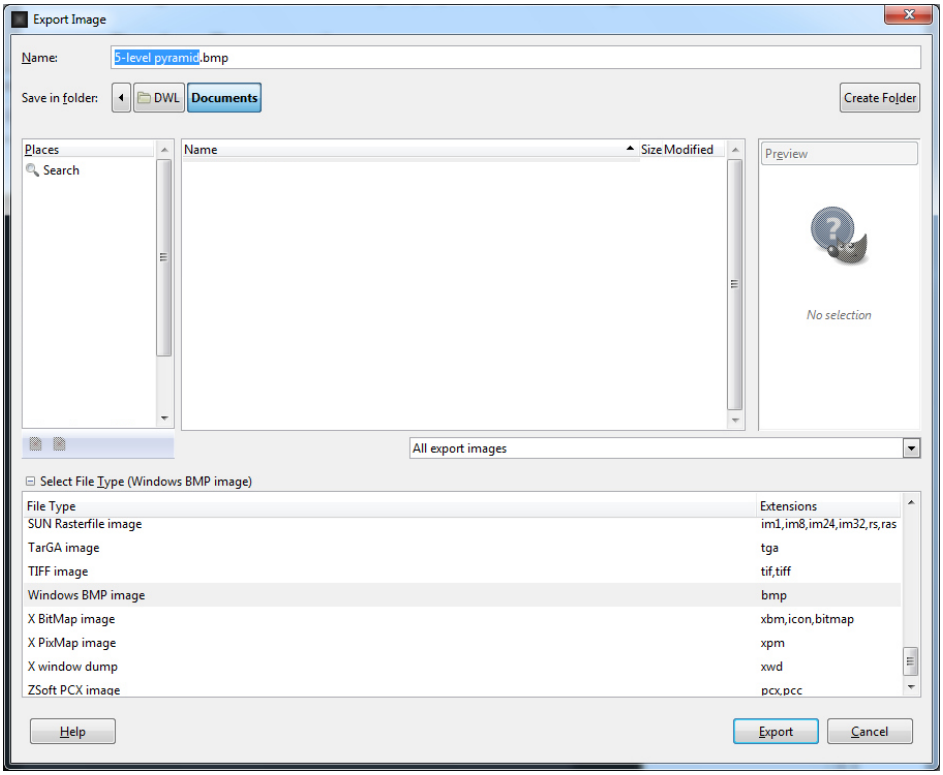



*Figure 15: Save image as BMP-file (GIMP)*

19. In the ***Export Image*** window, enter a name and choose a place where the file is to be saved.

20. Expand frame at **Select File Type** and choose **Windows BMP image**.

21. Click **Export**.

22. In the following dialog window, **do not** select **Run-Length Encoded** compression. Click **Export**.

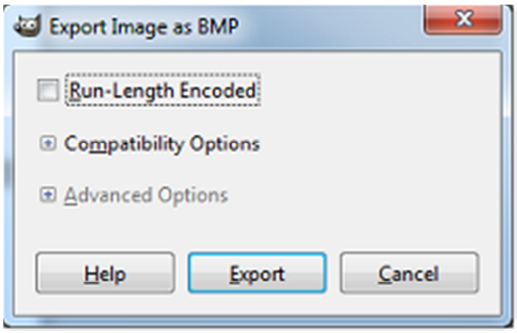



***Figure 16: Deselect Run-Length Encoded (GIMP)***

23. Close GIMP with **File ➔ Exit** from the menu bar.

# Notes

# Notes