Extending the Gerber format with nested blocks. The goal is more efficient panel definitions.

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Please send your comments to gerber@ucamco.com

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1 Preface

Ucamco proposes extending the Gerber format to make it more efficient in handling fabrication and assembly panels. The proposed new features will no doubt have other applications.

Printed circuit boards are fabricated in panels. The PCB is repeated a number of times on a production panel. The image file representing a panel must represent all instances of the PCB. One way to represent the PCB instances is with a so-called 'flat' file: the objects representing the PCB are simply copied n times in the file, each time at the appropriate place. While this defines the correct image it blows up the file size and slows down processing the image in CAM and on the production equipment. A more efficient way is to store the PCB objects only once, and add an instruction to step and repeat the PCB over the image. The current SR command in Gerber exactly does that.

However, the assemblers, where the bare boards are populated with components, more and more works in panels themselves, often called an 'array', 'biscuit' or 'assembly panel'. The PCB fabricator then ships *arrays* to the assembler, *not single PCBs*. What he repeats in his bare-board production panel are the arrays. The efficient way to represent this image is by a nested step and repeat: the single PCB is stepped into an array, and the array is stepped into the production panel. With a nested step and repeat the PCB data is only once in a file. The problem with the SR in Gerber is that it supports only one level, no nesting. Thus one has to flatten either the array or the working panel. The resulting big files can become a problem when a small but complex piece of electronics such as a smartphone is fabricated.

To address this issue Ucamco will extend the Gerber language with nested step and repeat. Tests performed together with Via Mechanics in Japan indeed demonstrated dramatic productivity increases. To introduce this new feature in an easier and safer way Ucamco suggest not extend the capability of the existing SR command but to introduce new command, mainly AB. The reason is that legacy Gerber readers that do not yet support nested step and repeat, might overlook subtle changes in the SR command and produce the wrong image, without warning. A new command is safer. Indeed, the conformance section in the Gerber format specification states: “To prepare for future extensions of the format, Gerber file readers must give a warning when encountering an unknown command....”. When testing a file with the new command on the well-respected GC-Prevue Gerber viewer an error message duly appeared.

Another issue is that the step and repeat only allows a regular array. To allow more general repeats Ucamco introduces block aperture that that can be flashed in any location and orientation. The new AB command creates a block aperture. The new aperture options set by LM, LR and LS allow to mirror/rotate/scale the block apertures, and all other apertures for that matter.

Nested step and repeat and block apertures will make Gerber more efficient with panelized data. Furthermore, the block aperture is a powerful general construct with no doubt many other applications. Together, they are a powerful extension of the Gerber format.

Ucamco publishes a draft specification and sample file on its website to allow the Gerber user community to review and comment on the new feature before it is cast in concrete. Please send your comments and criticism to gerber@ucamco.com .

Karel Tavernier,
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2 Blocks Overview

A *block* is a set of graphics objects that can be added multiple times to the graphics objects stream. Blocks can be mirrored, rotated, scaled, shifted and polarity can be toggled. By using blocks sub-images that occur multiple times must only defined once, thus slashing file size, boosting processing speed and preserving the information that these sub-images are identical.

A block is *not* a macro of commands called repeatedly in the command stream. The command stream is processed sequentially in one pass, without procedure or macro calls. Gerber is not a programming language.

Blocks can contain objects with different polarities (LPD and LPC). Blocks can overlap.

Once a block is added to the graphics objects stream its objects becomes part of the overall stream. The effect of these objects does not depend on whether they were part of a block or not. Only their order is important. A clear object in a block clears *all* objects beneath it, not only the objects *not* contained in the block.

There are two commands dedicated to blocks: SR and AB. They open and close block statements, a sequence of commands that define blocks. A block statement can contain other block statements.

Warning: It is recommended to avoid overlapping blocks containing both clear and dark polarity objects. The order in which they are added to the object stream may affect the final image; that order is not always correctly implemented in Gerber readers. Overlapping blocks containing only dark objects are safe to use as the order does not affect the image.

3 Block apertures NEW

3.1 Overview of block apertures

The AB command creates *block apertures*. The command stream between the opening and closing AB command defines a block aperture which is then stored in the aperture dictionary. Thus the AB commands add an aperture to the dictionary directly, without needing a template and an AD command. The effect of block apertures is governed by the LM, LR, LS and LP commands as any other aperture. When a block aperture is flashed the transformed –mirrored, rotated and scaled – objects are added to the graphics object stream.

While a standard or macro aperture always adds a *single* graphics object to the stream, a block aperture can add *any number* of objects, with different polarities. A block aperture is not a single graphics object but a set of objects. Standard and macro apertures always have a single polarity while block apertures can contain both dark and clear parts.

As with any other aperture, the flash operation updates the current point but otherwise leaves the graphics state unmodified. (The graphics state is *not* set to the value it had after the block statement defining the block. A block is not a macro command but simply a set of graphics objects.)

If the polarity is clear (LPC) when the block aperture is flashed the polarity of all objects in the block is toggled (clear becomes dark, and dark becomes clear). This toggling proceeds through all nesting levels. If the polarity is dark (LPD) then the block aperture is inserted as is. In the following example the polarity of objects in the flash of block D12 will be toggled.

```
%ABD12*%
…
%AB*%
….
D12*
%LPC*%
X-2500000Y-1000000D03*
```

3.2 AB - Aperture Block command NEW

The syntax for the AB command is:

<AB command> = AB[<block D-code>]*

Syntax	Comments
AB	AB for Aperture Block. Opens a block statement.
<block D-code>	The D-code under which the block is stored in the aperture dictionary.

Examples:

Syntax	Comments
%ABD12*%	Opens of the definition of aperture D12
%AB*%	Closes the current block statement.

The section between the opening and closing AB commands can contain nested AB commands. The resulting apertures are stored in the library and are available subsequently over the file, also outside the enclosing AB section.

AB statements can contain other AB or SR statements. See 6.

The AB command itself does not affect the graphics state. The names defined within an AB statement is not restricted to the AB statement but is global over the whole file.

3.3 Usage of block apertures

The first purpose of block apertures is to repeat a sub-image without copying the generating commands. It is a much more powerful concept than the SR command. The SR only allows repeats on a regular grid without mirror, rotate or scale, without nesting. Aperture blocks can be repeated at *any* location and *individually* mirrored, rotated and scaled. In PCB fabrication blocks are used to create panels without duplicating the data. Clear (LPC) objects are used to mask out underlying copper balancing patterns in the panel.

The second purpose of block apertures is to complement macro apertures. Blocks are simpler to create. However, macros can have parameters and blocks cannot. Macro outline primitives support linear segments only while blocks can contain contours with both linear and circular segments. A block aperture consisting of a single region creates a single object with one polarity– as with standard or macro apertures. Thus single object apertures of any shape can easily be created. In PCB design to fabrication data transfer block apertures can define pads. Such block apertures ideally consist of a single object (region). However, multi-object single polarity blocks can have a use. Pads are sometimes painted or stroked; such jobs are very hard to handle in CAM as pad locations must be reverse-engineered. Defining a block aperture with the painting of a single pad and then flashing it at the pad locations is a big step forward as the pad locations are now clear. Such a usage may be an intermediate step towards flashing pads with proper single object apertures.

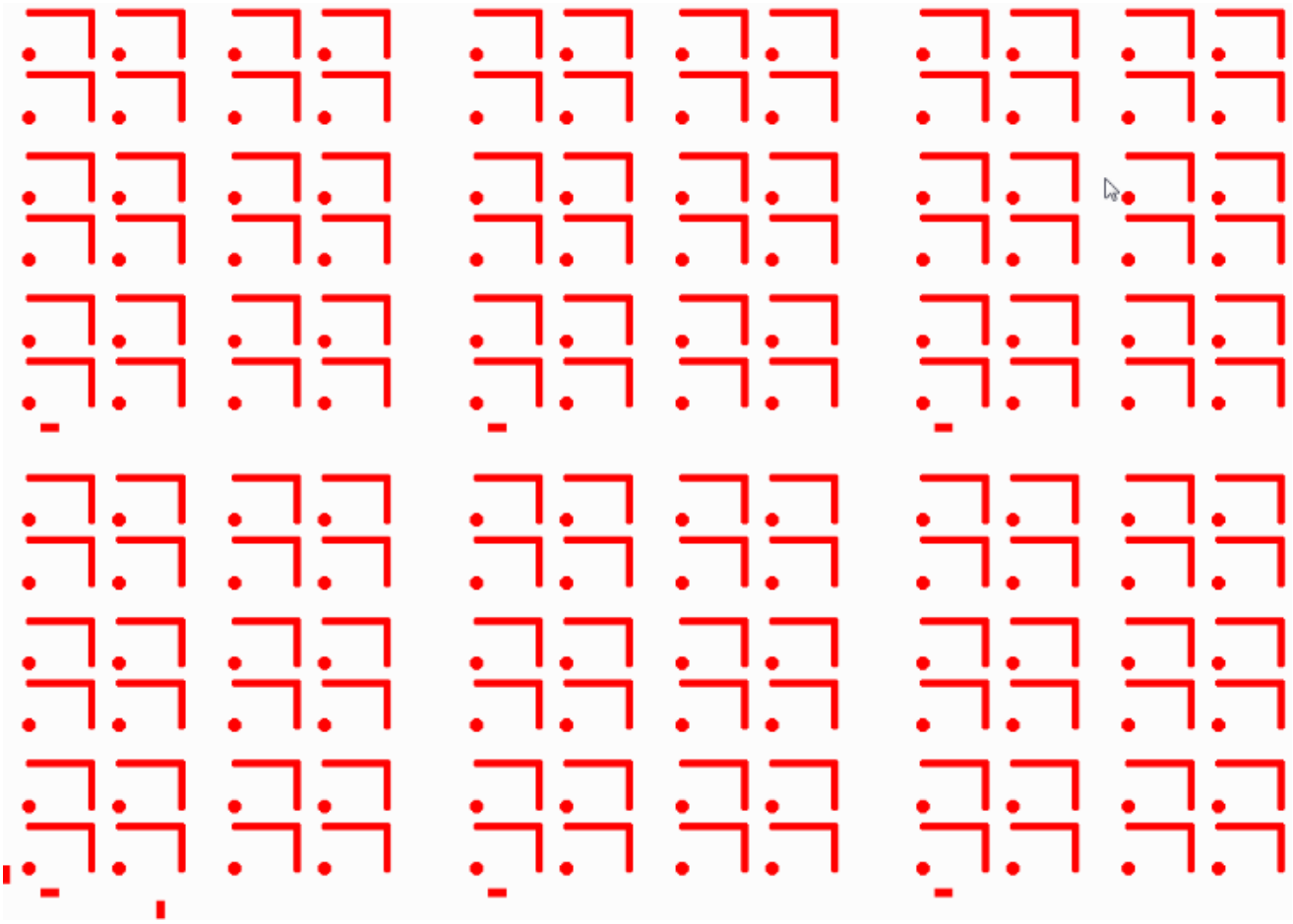
Do not use blocks – or macros - when a standard aperture is available. Standard apertures are built-in and therefore are processed faster.

3.4 Example

Example 2: a complete Gerber file with nested blocks

```
G04 Ucamco copyright*
%TF.GenerationSoftware,Ucamco,UcamX,2016.04-160425*%
%TF.CreationDate,2016-04-25T00:00;00+01:00*%
%FSLAX36Y36*
%MOMM*%*
G04 Define standard apertures*
%ADD10C,7.500000*%
%ADD11C,15*%
%ADD12R,20X10*%
%ADD13R,10X20*%
G04 Define block aperture D100, consisting of two draws and a round dot*
%ABD100*%
D10*
X65532000Y17605375D02*
Y65865375D01*
X-3556000D01*
D11*
X-3556000Y17605375D03*
%AB*%
G04 Define nested block D101, consisting of 2x2 flashes of D100
%ABD101%*
D100*
X-30000000Y10000000D03*
X-30000000Y10000070D03*
X-29999900Y10000000D03*
X-29999900Y10000070D03*
%AB*%
G04 Define nested block D102, consisting of 2x3 flashes of D101 and 1 flash of D12*
%ABD102%*
D101*
X-30000000Y10000000D03*
X-30000000Y10000160D03*
X-30000000Y10000320D03*
X-29999770Y10000000D03*
X-29999770Y10000160D03*
X-29999770Y10000320D03*
D12*
X19500000Y-10000000D03*
%AB*%
G04 Flash D13 twice outside of blocks*
D13*
```

```
X-30000000Y10000000D03*
X143000000Y-30000000D03*
G04 Flash nested block D102 3x2 times
D102*
X-30000000Y10000000D03*
X-30000000Y10000520D03*
X-29999500Y10000000D03*
X-29999500Y10000520D03*
X-29999000Y10000000D03*
X-29999000Y10000520D03*
M02*
```



4 Aperture State Parameters

4.1 Overview

The commands LP, LM, LR and LS load the aperture graphics state parameters:

Aperture parameter commands	
Command	**Aperture Parameter**
LP	Polarity
LM	Mirroring
LR	Rotation
LS	Scaling

The aperture parameters transform the current aperture when used in a D01 (interpolate) or D03 (flash) operation command. The operation is performed with the aperture as it is áfter the transform is applied.

Aperture parameters become effective immediately after loading and remain in effect until a new value is loaded. Selecting a new current aperture, or any other command, does not reset the aperture parameters. The parameters do not change the aperture definition or D-code in the aperture dictionary; when a current aperture is selected its original definition is taken, and the current aperture parameters are applied to the original when used. An example:

`D123*`	Select D123
`X5000Y7000D03*`	Flash D123
`%LR90.0*%`	Set aperture rotation to 90 degrees
`X6000Y8000D03*`	Flash D123 rotated 90 degrees
`D124*`	Select D124
`X6000Y8000D03*`	Flash D124 rotated 90 degrees
`%LR0.0*%`	Reset aperture rotation to 0 degrees
`X7000Y9000D03*`	Flash D124, not rotated
`D123*`	Select D123
`X1000Y2000D03*`	Flash D123, this is the original, not rotated

Attributes are attached to the D code and are not affected by the aperture commands.

The aperture parameters affect only the apertures, not the coordinate data.

The defaults are defined in the graphics state table:

Graphics state parameter	Value range	Fixed or changeable	Initial value
Unit parameters			
Coordinate format	See the FS command in xxx	Fixed	Undefined
Unit	Inch or mm - See MO command in xxx	Fixed	Undefined
Drafting parameters			
Current point	Point in plane	Changeable	Undefined
Current aperture	Aperture used by the operations D01 and D03.	Changeable	Undefined
Interpolation mode	Linear, clockwise circular, counterclockwise circular See the G01/G02/G03 commands in and xxx	Changeable	Undefined
Quadrant mode	Single-, multi-quadrant See G74/G75 commands in xxx	Changeable	Undefined
Aperture parameters			
Aperture polarity	See the LP command in xxx	Changeable	Dark
Aperture mirroring	See the LM command in xxx	Changeable	No mirror
Aperture rotation	See the LR command in xxx	Changeable	No rotation (=0 degr.)
Aperture scaling	See the LS command in xxx	Changeable	No scaling (=1.0)
Region parameter			
Region mode	On/Off - See G36, G37 commands in **Error! Reference source not found.**	Changeable	Off

4.2 Load Polarity (LP)

The LP command sets the *aperture polarity*. This command can be used multiple times in a file. The aperture polarity applies to all subsequent apertures used until changed by another LP command.

Polarity can be either *dark* or *clear*. Its effect is explained in xxx. Section xxx gives an example of its use.

The syntax for the LP command is:

<LP command> = LP(C|D)*

Syntax	Comments
LP	LP for Load Polarity
C|D	C – clear polarity D – dark polarity

4.3 Load Mirroring (LM) NEW

The LM command sets the *aperture mirroring*. This command can be used multiple times in a file. The mirroring applies to all subsequent apertures used until changed by another LM command.

The aperture mirroring defines the mirroring axis. The current aperture is mirrored around its *origin* (which may not be its geometric center). Mirroring is performed on the original aperture as defined in the aperture dictionary, it is not cumulative.

The syntax for the LM command is:

<LM command> = LM(N|X|Y|XY)*

Syntax	Comments
LM	LM for Load Mirroring
N|X|Y|XY	N – No mirroring X – Mirroring *along* the X axis; mirror left to right; the signs of the x coordinates are inverted Y – Mirroring *along* the Y axis; mirror top to bottom; the signs of the y coordinates are inverted XY – Mirroring *along* both axes; mirror left to right and top to bottom; the signs of both the x *and* y coordinates are inverted

Mirroring is performed *before* the rotation.

4.4 Load Rotation (LR) NEW

The LR command sets the *aperture rotation*. This command can be used multiple times in a file. The aperture mirroring applies to all subsequent apertures used until changed by another LR command.

The rotation defines the rotation angle. The current aperture is rotated around its *origin* (which may not be its geometric center). Rotation is performed on the original aperture as defined in the aperture dictionary, it is not cumulative.

The syntax for the LR command is:

<LR command> = LR<Rotation>*

Syntax	Comments
LR	LR for Load Rotation
<Rotation>	The rotation angle is specified by a decimal, in degrees. A positive angle is a counterclockwise rotation.

Mirroring is performed *before* the rotation.

4.5 Load Scaling (LS) NEW

The LS command sets the *aperture scaling*. This command can be used multiple times in a file. The current scaling applies to all subsequent apertures used until changed by another LS command.

The scaling defines the scale factor applied to apertures. The current aperture is scaled from its *origin* (which may not be its geometric center); in other words the origin remains in the same position, whatever the scaling. The scaling is performed on the original aperture as defined in the aperture dictionary, it is not cumulative.

The syntax for the LS command is:

<LS command> = LS<Scale>*

Syntax	Comments
LS	LS for Load Scaling
<Scale>	The scale factor is specified by a decimal.

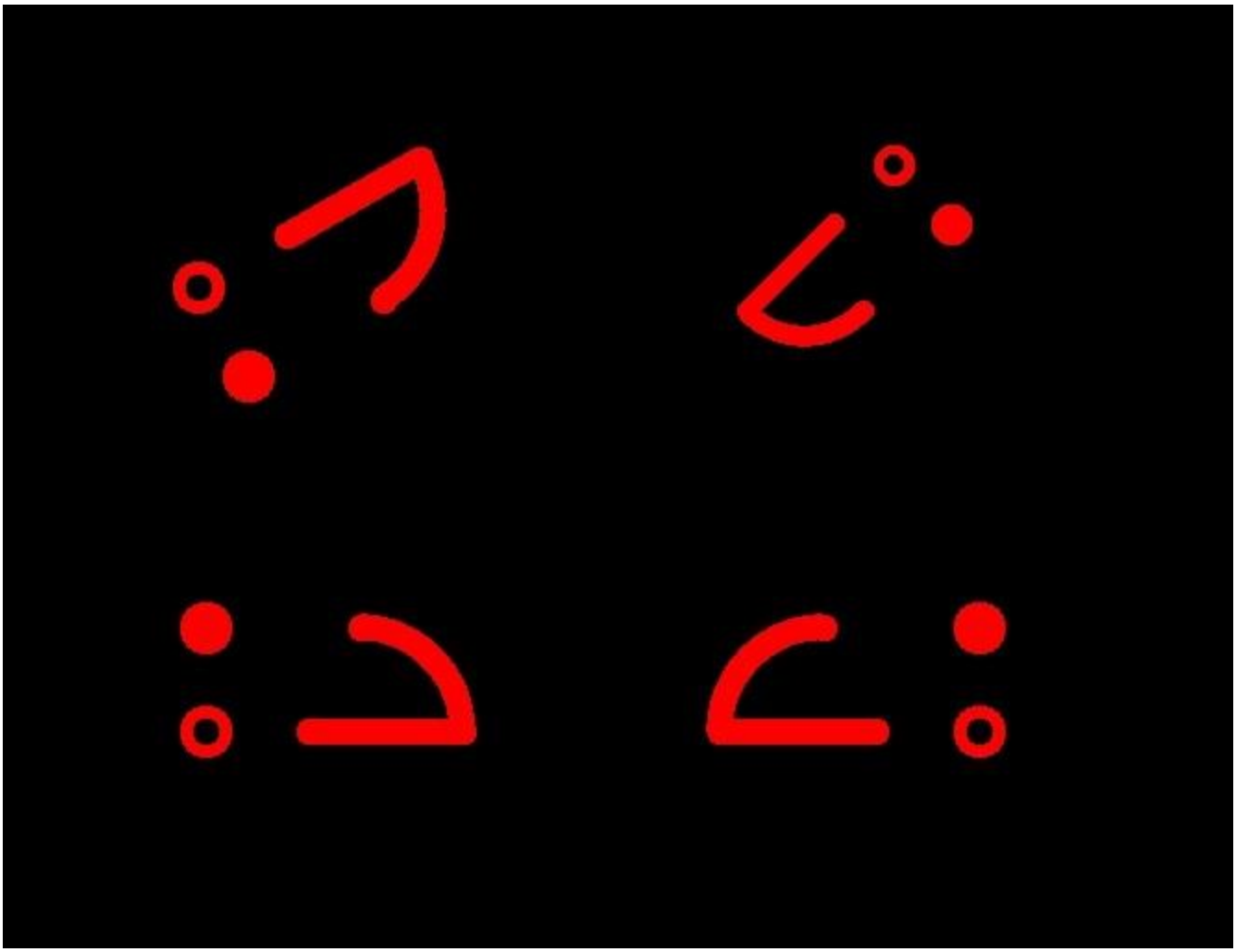
4.6 Examples

Syntax	Comments
%LPD*%	Sets the aperture polarity to dark
%LPC*%	Sets the aperture polarity to clear
%LMX*%	Sets aperture mirroring to mirroring along the X axis
%LMN*%	Sets aperture mirroring to no mirroring
%LR45.0*%	Sets aperture rotation to 45 degrees counterclockwise
%LR-90*%	Sets aperture rotation to 90 degrees clockwise
%LS0.8*%	Sets aperture scaling to 80%

Example of a block flashed in different orientations

```
G04 Ucamco copyright*
%TF.GenerationSoftware,Ucamco,UcamX,2016.04-160425*%
%TF.CreationDate,2016-04-25T00:00;00+01:00*%
%FSLAX26Y26*%
%MOMM*%
%ADD10C,1*%
%LPD*%
G04 Define block aperture D12
%ABD12*%
%ADD11C,0.5*%
D10*
```

```
G01*
X-2500000Y-1000000D03*
Y1000000D03*
%LPC*%
D11*
X-2500000Y-1000000D03*
%LPD*%
X-500000Y-1000000D02*
X2500000D01*
G75*
G03*
X500000Y1000000I-2000000J0D01*
G74*
G01*
%AB*%
G04 Flash D12 four times, in different orientations
D12*
X0Y0D03*
%LMX*%
X10000000D03*
%LMY*%
%LR30.0*%
X0Y8000000D03*
%LMXY*%
%LR45.0*%
%LS0.8*%
X10000000D03*
M02*
```



5 SR –Step and Repeat

X1

The SR command generates a step and repeat of a block.

The syntax for the SR command is:

<SR command> = SR[X<Repeats>Y<Repeats>I<Step>J<Step>]*

Syntax	Comments
X<Repeats>	<Repeats> defines the number of times the block is repeated along the X axis. It is an integer ≥ 1.
Y<Repeats>	<Repeats> defines the number of times the block is repeated along the Y axis. It is an integer ≥ 1.
I<Step>	<Step> defines the step distance along the X axis. It is a decimal number ≥ 0, expressed in the unit set by the MO command.
J<Step>	<Step> defines the step distance along the Y axis. It is a decimal number ≥ 0, expressed in the unit set by the MO command.

A new SR command closes the current SR command. Used without any parameters (or with both repeats equal to 1 it simply closes the opening SR command. Used with a specification of a number of repeats and step distance it ends the current SR command and immediately starts a new one. In other words an SR command always terminates the current SR block. After terminating an SR block the current point is at the position after the last command in the block definition.

An opened SR block must be closed before the end-of-file command (M02) is encountered.

The number of repeats and the steps can be different in X and Y. The number of repeats along an axis can be 1, which is equivalent to no repeat. If the repeat number is 1 it is recommended to set its step value to 0.

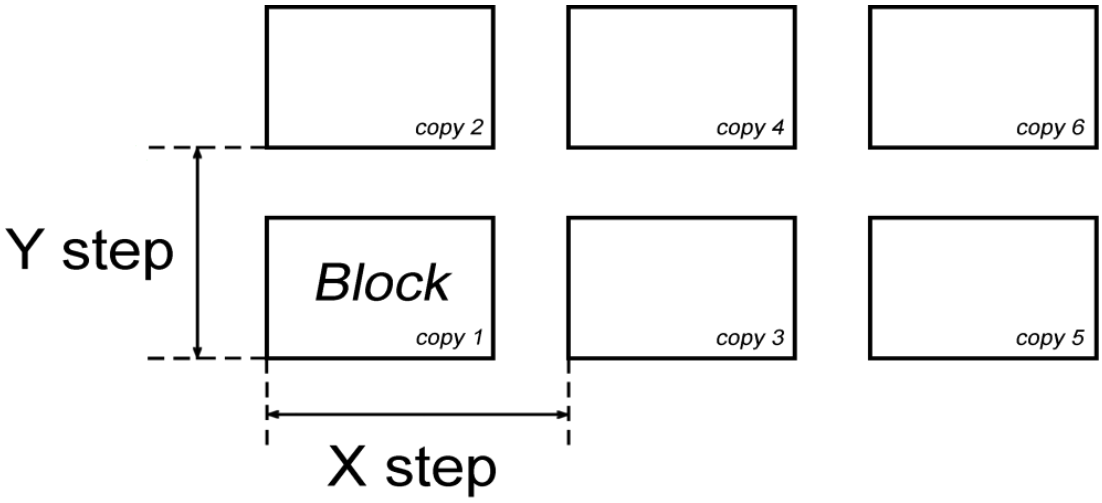
Blocks are copied first in the positive Y direction and then in the positive X direction.

The SR commands step-repeats (copies) blocks in the image plane when closed according to the parameters in the opening SR command. Each copy of the block contains identical graphics object. Blocks are copied first in the Y and then in the X direction.

The SR command itself does not affect the graphics state. The names defined within an SR statement are not restricted to the SR statement but is global over the whole file.

Example

```
%SRX3Y2I5.0J4.0*%
...
%SR*%
```



Step and Repeat (SR blocks)

Other examples:

Syntax	Comments
%SRX2Y3I2.0J3.0*%	Opens an SR block that is repeated 2 times along the X axis and 3 times along the Y axis. The step distance between X-axis repeats is 2.0 units. The step distance between Y-axis repeats is 3.0 units.
%SRX4Y1I5.0J0*%	Opens an SR block that is repeated 4 times along the X axis with the step distance of 5.0 units. The step distance in the J modifier is ignored because no repeats along the Y axis are specified.
%SRX1Y1I0J0*%	Close the previously started SR block. If no block is opened, this does nothing.
%SR*%	Close the previously started SR block. If no block is opened, this does nothing.

6 Syntax of SR and AB nesting

We first informally define three variables:

<single command> = all commands except the block commands SR and AB

<sr parameters> = X<Repeats>Y<Repeats>I<Step>J<Step>

<D-code> = D<integer ≥ 10>

Now we are ready to specify the block commands:

<AB open> = %AB<D-code>*%

<AB close> = %AB*%

<AB statement> = <AB open><section><AB close>

<SR set> = %SR<sr parameters>*%

<SR close> = %SR*%

<SR statement> = <SR set><section>{<SR set><section>}<SR close>

<block statement> = <AB statement>|<SR statement>

<section> = {<single command>}|{<single command>}<block statement>{<single command>}

7 Block related attributes

7.1 The .FlashText aperture attribute 

Gerber intentionally does not contain fonts or typographic text – this would introduce a complexity out of proportion to its benefits. The image of any text can be represented with the available graphic constructs, especially by contours. However, loses the information which text string they represent; this is sometimes a disadvantage.

The .FlashText aperture attribute defines this lost information. Bar codes are handled as text – one can view a barcode as a special font. .FlashText assumes is designed for text image created with a flash, typically with a block aperture.

Syntax and semantic of the attribute value is as follows:

<Text>,(B|C),[(R|M)],[<Font>],[Size],[<Comment>]

.FlashText fields	Usage
<text>	The text string represented by the aperture image.
(B|C)	Indicates if the text is represented by a *barcode* – B -or by *characters* - C.
(R|M)	Indicates if the text is readable or mirrored. Optional.
<Font>	Font name. Content not standardized. Optional.
<Size>	Font size. Content not standardized. Optional.
<Comments>	Any extra information one wants to add. Optional.

An empty field means that the corresponding meta-data is not specified.

Examples:

```
%TA.FlashText,L1,C,R,Courier,10,Layer number (L1 is top)%
```

Text: L1
B|C: Characters,
(R|M): Readable
Font: Courier
Size: 10
Comment: Layer number (L1 is top)

```
%TA.FlashText,XZ12ADF,B,,Code128,,Project identifier *%
```

Text: XZ12ADF
B|C: Barcode
(R|M) Not specified
Font: Code128

Size: Not specified
Comment: Project identifier

8 Revisions

Final	Draft is final and closed.
Rev 12	Amended .FlashText attribute. Removed .AperFunction value Part; while such information is no doubt valuable it is not yet clear how best to specify it; it is probably that a construct with a similar function will be added in the future. Text corrections.
Rev 11	Retract the new SN statement – the set of AB/LM/LR/LS commands is now so general and powerful that SN is not needed anymore.
Rev 10	Mirror/rotate/scale was completely overhauled based on a suggestion by Masao Miyashita. Blocks are now defined directly as apertures rather than as templates with mirror/rotate/scale parameters. The new commands LM, LR and LS hander mirror/rotate/scale for all apertures. This is more powerful, more consistent with the LP command and more according to the Gerber style. The .FlashText attribute was adapted accordingly. Specify the effect of flashing a block aperture on the graphics state; this was triggered by Mark Sims. Add image of AB example.
Rev 9	Added EBNF syntax of mixing and nesting of AB, SN and SR. Copy-edits.Rev 8 Added words on proper use of the block aperture triggered by comments from Paul Wells-Edwards – see 3.1. Specified the effect of flashing a block aperture under clear polarity – see 3.2Replace name .AperText by the more specific .FlashText to avoid future name clashes and clarified the convention for “unspecified” in .FlashText –see 7.1
Rev 7	Corrections after input from Helmut Mendritzki. Add barcode/character field to AperText after discussion with Bruce McKibben. BlockPart becomes part of the .Aperfunction value Part rather than a new attribute see 7.
Rev 6	Added text attribute and made clarifications as suggested by Bruce McKibben. Cleaned text and formatting.
Rev 5	Clarified aperture attributes and %SN and %SR Corrected errors in examples indicated by Helmut Mendritzki Added preface
Rev 4	Added .Blockpart attribute as suggested by Filip Vermeire Rewrite/reorganize overviews Clarified order of mirror/rotate as suggested by Remco Poelstra
Rev 3	Added AB command
Rev 2	Simplified SN syntax as suggested by Remco Poelstra
Rev 1	Initial version, SN command only. This draft was developed with the assistance of Thomas Weyn

9 Copyright

The information contained herein is subject to change without prior notice. Revisions may be issued from time to time. This document supersedes all previous versions. Users of the Gerber Format®, especially software developers, must consult www.ucamco.com to determine whether any changes have been made.

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