

Computer Aids for VLSI Design

Steven M. Rubin

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Appendix C: GDS II Format



In the design of integrated circuits, the most popular format for interchange is the Calma **GDS II** stream format (GDS II is a trademark of Calma Company, a wholly owned subsidiary of General Electric Company, U.S.A.). For many years, this format was the only one of its kind and many other vendors accepted it in their systems. Although Calma has updated the format as their CAD systems have developed, they have maintained backward compatibility so that no GDS II files become obsolete. This is important because GDS II is a binary format that makes assumptions about integer and floating-point representations.

A GDS II circuit description is a collection of cells that may contain geometry or other cell references. These cells, called **structures** in GDS II parlance, have alphanumeric names up to 32 characters long. A library of these structures is contained in a file that consists of a library header, a sequence of structures, and a library tail. Each structure in the sequence consists of a structure header, a sequence of **elements**, and a structure tail. There are seven kinds of elements: **boundary** defines a filled polygon, **path** defines a wire, **structure reference** invokes a subcell, **array reference** invokes an array of subcells, **text** is for documentation, **node** defines an electrical path, and **box** places rectangular geometry.

C.1 Record Format

In order to understand the precise format of the above GDS II components, it is first necessary to describe the general record format. Each GDS II record has a 4-byte header that specifies the record size and function. The first 2 bytes form a 16-bit integer that contains the record length in bytes. This length includes the 4-byte header and must always be an even number. The end of a record can contain a single null byte if the record contents is an odd number of bytes long. The third byte of the header contains the type of the record and the fourth byte contains the type of the data. Since the data type is constant for each record type, this 2-byte field defines the possible records as shown in Figs. C.1 and C.2.

File Header Records:	Bytes 3 and 4	Parameter Type
HEADER	0002	2-byte integer
BGNLIB	0102	12 2-byte integers
LIBNAME	0206	ASCII string
REFLIBS	1F06	2 45-character ASCII strings
FONTS	2006	4 44-character ASCII strings
ATTRTABLE	2306	44-character ASCII string
GENERATIONS	2202	2-byte integer
FORMAT	3602	2-byte integer

MASK	3706	ASCII string
ENDMASKS	3800	No data
UNITS	0305	2 8-byte floats
File Tail Records: Bytes 3 and 4 Parameter Type		
ENDLIB	0400	No data
Structure Header Records: Bytes 3 and 4 Parameter Type		
BGNSTR	0502	12 2-byte integers
STRNAME	0606	Up to 32-characters ASCII string
Structure Tail Records: Bytes 3 and 4 Parameter Type		
ENDSTR	0700	No data

FIGURE C.1 GDS II header record types.

Magnetic tapes containing GDS II files will have 2048 byte blocks that contain these records. The block size is standardized but has no bearing on record length or position. There is also a capability for circuits that require multiple reels of tape.

Element Header Records: Bytes 3 and 4 Parameter Type		
BOUNDARY	0800	No data
PATH	0900	No data
SREF	0A00	No data
AREF	0B00	No data
TEXT	0C00	No data
NODE	1500	No data
BOX	2D00	No data
Element Contents Records: Bytes 3 and 4 Parameter Type		
ELFLAGS	2601	2-byte integer
PLEX	2F03	4-byte integer
LAYER	0D02	2-byte integers
DATATYPE	0E02	2-byte integer
XY	1003	Up to 200 4-byte integer pairs
PATHTYPE	2102	2-byte integer
WIDTH	0F03	4-byte integer
SNAME	1206	Up to 32-character ASCII string
STRANS	1A01	2-byte integer
MAG	1B05	8-byte float

ANGLE	1C05	8-byte float
COLROW	1302	2 2-byte integers
TEXTTYPE	1602	2-byte integer
PRESENTATION	1701	2-byte integer
ASCII STRING	1906	Up to 512-character string
NODETYPE	2A02	2-byte integer
BOXTYPE	2E02	2-byte integer
FIGURE C.2 GDS II element record types.		

C.2 Library Head and Tail

A GDS II file header always begins with a HEADER record the parameter of which contains the GDS II version number used to write the file. For example, the bytes 0, 6, 0, 2, 0, 1 at the start of the file constitute the header record for a version-1 file. Following the HEADER comes a BGNLIB record that contains the date of the last modification and the date of the last access to the file. Dates take six 2-byte integers to store the year, month, day, hour, minute, and second. The third record of a file is the LIBNAME, which identifies the name of this library file. For example, the bytes 0, 8, 2, 6, "C", "H", "I", "P" define a library named "CHIP." Following the LIBNAME record there may be any of the optional header records: REFLIBS to name up to two reference libraries, FONTS to name up to four character fonts, ATTRTABLE to name an attribute file, GENERATIONS to indicate the number of old file copies to keep, and FORMAT to indicate the nature of this file. The strings in the REFLIBS, FONTS, and ATTRTABLE records must be the specified length, padded with zero bytes.

The parameter to FORMAT has the value 0 for an archived file and the value 1 for a filtered file. Filtered files contain only a subset of the mask layers and that subset is described with one or more MASK records followed by an ENDMASK record. The string parameter in a MASK record names layers and sequences of layers; for example, "1 3 5-7."

The final record of a file header is the UNITS record and it is not optional. The parameters to this record contain the number of user units per database unit (typically less than 1 to allow granularity of user specification) and the number of meters per database unit (typically much less than 1 for IC specifications).

Eight-byte floating-point numbers have a sign at the top of the first byte, a 7-bit exponent in the rest of that byte, and 7 more bytes that compose a mantissa (all to the right of an implied decimal point). The exponent is a factor of 16 in excess-64 notation (that is, the mantissa is multiplied by 16 raised to the true value of the exponent, where the true value is its integer representation minus 64).

Following the file header records come the structure records. After the last structure has been defined, the file terminates with a simple ENDLIB record. Note that there is no provision for the specification of a root structure to define a circuit; this must be tracked by the designer.

C.3 Structure Head and Tail

Each structure has two header records and one tail record that sandwich an arbitrary list of elements. The first structure header is the BGNSTR record, which contains the creation date and the last modification date.

Following that is the STRNAME record, which names the structure using any alphabetic or numeric characters, the dollar sign, or the underscore. The structure is then open and any of the seven elements can be listed.

The last record of a structure is the ENDSTR. Following it must be another BGNSTR or the end of the library, ENDLIB.

C.4 Boundary Element

The boundary element defines a filled polygon. It begins with a BOUNDARY record, has an optional ELFLAGS and PLEX record, and then has required LAYER, DATATYPE, and XY records.

The ELFLAGS record, which appears optionally in every element, has two flags in its parameter to indicate template data (if bit 16 is set) or external data (if bit 15 is set). This record should be ignored on input and excluded from output. Note that the GDS II integer has bit 1 in the leftmost or most significant position so these two flags are in the least significant bits.

The PLEX record is also optional to every element and defines element structuring by aggregating those that have common plex numbers. Although a 4-byte integer is available for plex numbering, the high byte (first byte) is a flag that indicates the head of the plex if its least significant bit (bit 8) is set.

The LAYER record is required to define which layer (numbered 0 to 63) is to be used for this boundary. The meaning of these layers is not defined rigorously and must be determined for each design environment and library.

The DATATYPE record contains unimportant information and its argument should be zero.

The XY record contains anywhere from four to 200 coordinate pairs that define the outline of the polygon. The number of points in this record is defined by the record length. Note that boundaries must be closed explicitly, so the first and last coordinate values must be the same.

C.5 Path Element

A path is an open figure with a nonzero width that is typically used to place wires. This element is initiated with a PATH record followed by the optional ELFLAGS and PLEX records. The LAYER record must follow to identify the desired path material. Also, a DATATYPE record must appear and an XY record to define the coordinates of the path. From two to 200 points may be given in a path.

Prior to the XY record of a path specification there may be two optional records called PATHTYPE and WIDTH. The PATHTYPE record describes the nature of the path segment ends, according to its parameter value. If the value is 0, the segments will have square ends that terminate at the path vertices. The value 1 indicates rounded ends and the value 2 indicates square ends that overlap their vertices by one-half of their width. The width of the path is defined by the optional WIDTH record. If the width value is negative, then it will be independent of any structure scaling (from MAG records, see next section).

C.6 Structure Reference Element

Hierarchy is achieved by allowing structure references (instances) to appear in other structures. The SREF record indicates a structure reference and is followed by the optional ELFLAGS and PLEX records. The SNAME record then names the desired structure and an XY record contains a single coordinate to place this instance. It is legal to make reference to structures that have not yet been defined with STRNAME.

Prior to the XY record there may be optional transformation records. The STRANS record must appear first if structure transformations are desired. Its parameter has bit flags that indicate mirroring in x before rotation (if bit 1 is set), the use of absolute magnification (if bit 14 is set), and the use of absolute rotation (if bit 15 is set). The magnification and rotation amounts may then be specified in the optional MAG and ANGLE records. The rotation angle is in counterclockwise degrees.

C.7 Array of Structures Element

For convenience, an array of structure instances can be specified with the AREF record. Following the optional ELFLAGS and PLEX records comes the SNAME to identify the structure being arrayed. Next, the optional transformation records STRANS, MAG, and ANGLE give the orientation of the instances. A COLROW record must follow to specify the number of columns and the number of rows in the array. The final record is an XY with three points: the coordinate of the corner instance, the coordinate of the last instance in the columnar direction, and the coordinate of the last instance in the row direction. From this information, the amount of instance overlap or separation can be determined. Note that flipping arrays (in which alternating rows or columns are mirrored to abut along the same side) can be implemented with multiple arrays that are interlaced and spaced apart to describe alternating rows or columns.

C.8 Text Element

Messages can be included in a circuit with the TEXT record. The optional ELFLAGS and PLEX follow with the mandatory LAYER record after that. A TEXTTYPE record with a zero argument must then appear. An optional PRESENTATION record specifies the font in bits 11 and 12, the vertical presentation in bits 13 and 14 (0 for top, 1 for middle, 2 for bottom), and the horizontal presentation in bits 15 and 16 (0 for left, 1 for center, 2 for right). Optional PATHTYPE, WIDTH, STRANS, MAG, and ANGLE records may appear to affect the text. The last two records are required: an XY with a single coordinate to locate the text and a STRING record to specify the actual text.

C.9 Node Element

Electrical nets may be specified with the NODE record. The optional ELFLAGS and PLEX records follow and the required LAYER record is next. A NODETYPE record must appear with a zero argument, followed by an XY record with one to 50 points that identify coordinates on the electrical net. The information in this element is not graphical and does not affect the manufactured circuit. Rather, it is for other CAD systems that use topological information.

C.10 Box Element

The last element of a GDS II file is the box. Following the BOX record are the optional ELFLAGS and PLEX records, a mandatory LAYER record, a BOXTYPE record with a zero argument, and an XY record. The XY must contain five points that describe a closed, four-sided box. Unlike the boundary, this is not a filled figure. Therefore it cannot be used for IC geometry.

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