Using CAD Data in Assembly - Advantages and Pitfalls

For years, electronic engineers and circuit board designers have shared information between their computer-aided-engineering (CAE) and computer-aided-design (CAD) systems. This has enabled them to cut development time, reduce design errors, and produce better products. Unfortunately, this flow of information usually does not continue into the board assembly and test area. Manufacturers have not had tools to take advantage of the data produced by CAD, or have not been able to get the right data. Instead, circuit manufacturers spend considerable time and energy recreating the layout design data by hand.

Industry trends today are forcing companies to make use of CAD design information in manufacturing: higher component pin counts and smaller part footprints make it imperative to place components with greater accuracy. Businesses want to develop manufacturing programs and documentation faster, to cut manufacturing cycle times. Manufacturers seek ways to reduce errors to improve manufacturing quality.

CIM, or computer-integrated-manufacturing, provides a way to meet some of these goals. Reliable CAD data is the starting point for CIM. When combined with information from a business' MRP system, CAD data contains all of the information needed to help manage the manufacturing process. CAD data can reduce manufacturing preparation time by eliminating the need to manually define placement information with a digitizer or vision camera. It also eliminates human errors introduced when generating this data. Finally, CAD data provides absolutely accurate information to manufacturing. Using the original CAD data, engineers can get the exact component coordinate position.

One of the reasons that CAD has not been used in manufacturing is a lack of knowledge about what kind of information is available from the CAD system. There are different types of CAD data, and confusion about what each contains and is designed for. This article seeks to explain some of the advantages of using CAD, what information is available from CAD systems, how to obtain the correct type of data, and how it can be used reliably.

Four main types of CAD data

Broadly speaking, there are four basic types of data available from a CAD system: component centroid data; Gerber data; CAD interface data; and the CAD binary database. The first three data types are ASCII, which simply means they can be loaded into a text editor and be read by a user. The CAD binary database is used internally by the CAD system and has no value for manufacturing.

Component centroid data is a list of the components in the circuit that contains an X-Y location for each component, the component rotation, and a unique component identifier. Every CAD system creates a unique centroid file format, but they are all text files and can easily be read and understood.

Gerber data is named after a leader in the photoplotter industry, Gerber Scientific Instruments, and is the data output by a CAD system for creating the film artworks used to fabricate the circuit. Today all photoplotters and CAD systems support this format. It is the most important fabrication output from CAD; other fabrication data includes drill files and board profiling files.

CAD interface data is a complete description of the design. It includes board shape, fiducials, test pads, traces, and component geometry information. These files are provided by CAD vendors to allow other software applications to read design information, and each CAD system has a unique file format.

The CAD binary database is the internal file for the CAD system. Its format is proprietary, and it cannot loaded into a text editor to be read or understood by other applications,

Most manufacturers who work with CAD data are using either Gerber data or component centroid data. The reasons for this are straightforward- Gerber data is readily available because circuit designers must create it for fabrication, and component centroid data contains much of the information needed for assembly. However, there are real problems in using both Gerber and centroid data- they lack important information needed for manufacturing, or appear to have more information than they really do.

Gerber data lacks key information

Gerber data is a numerical control (N/C) program for controlling the operation of a film photoplotter. The Gerber data for a single circuit is contained in multiple computer files, with one or two files for each artwork layer. Each file consists of a series of line draws (D01 commands), pad flashes (D03 commands), and aperture commands (D10-D1000). The aperture commands select the aperture used to draw each line or pad, but do not describe the aperture. For example, the Gerber data may specify that D10 is used to draw a line, and a separate report, called the aperture listing, would identify D10 as a .012” round aperture. A very small extract from a file follows:

```
D11*
X06296D01*
X06377Y14572D01*
X06458Y14605D02*
X06382Y14574D01*
X06535Y14657D03*
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Gerber data is a de facto standard that grew out of the PC board fabrication industry’s need for a common photoplotter control language compatible with all photoplotters and CAD systems. It became an actual standard when the IEEE defined RS-274-D around Gerber data . It has long been recognized that there are weaknesses in the format- the aperture definitions are external, and there is no description of the units in the data. A new standard, RS-274-X, addresses the shortcomings in the original format. A few CAD companies now support this format.

Gerber data represents a *picture* of the circuit, so it is well suited for making artwork films, which are simply pictures of circuit layers. It is also useful in creating artwork data for SMT stencils. However, Gerber data is not appropriate as a data source for component assembly and test. This is because Gerber data contains no component or trace information- it is a picture of the board, with no “circuit intelligence”. To place the components on the board, you need circuit intelligence- the location of component U1, the rotation for component C4, etc. This information is totally missing in the Gerber data.

In order to use Gerber data for placement and test, you need a conversion tool to convert Gerber data into component data. There are a several Gerber conversion tools on the market that work in a similar fashion. They begin by scanning the Gerber data for pad occurrences, recognize patterns in the pads, and identify components from these patterns. After components are found, the tools try to determine the net list by connecting the trace lines in the Gerber data. In effect, the conversion tools attempt to recreate the circuit intelligence that has been eliminated from the Gerber data.

This is a time consuming process, and generally requires a user to manually verify each instance of each component, assign component names, and check for incorrect rotation information. Errors are often introduced during the component identification process that are difficult to find, and attempting to create net list information for ATE is almost impossible to do without mistakes. It is always better to use original CAD data where it is available, to avoid making mistakes.

Centroid data offers less than meets the eye

The most widely used CAD data type in component assembly is a component centroid file. Assembly machines that boast of the ability to read “ASCII” files from CAD, are actually referring to centroid data files. Engineers also easily interpret them because the data formats are simple to understand. One fundamental weakness of this data is due to its simplicity- centroid data does not provide netlist information for test, or graphical data for documentation, and is limited in use to component placement.

Centroid files will contain a record for each component that include a unique component identifier as well as its location relative to the CAD zero point. The format will depend on the CAD system, but a typical file will look like this:

```
C53    102-0007.00     4875  4850    0.0   T
C52    102-0007.00     5350  5275    0.0   T
U97    102-0007.00     2750  2175  180.0   B
R174   108-0099.00     2500  600     0.0   B
```

At first glance, this would seem to be enough information to accurately place components, - component name, part number, location, rotation, and board side. However there are some problems with this data.

First, the X-Y coordinate in the file may not be the centroid location, but can easily refer to the location of pin 1 or another user defined origin in the component. CAD systems output different locations, depending on how the data is originally defined. The same CAD system used by different designers will output different locations. Even when the centroid coordinate is supposed to be the part center, the centroid is based on a calculation done by the CAD system, which may use features other than pin locations to determine the center. The accuracy of the centroid can vary from component to component, and cannot be verified without going to the placement machine.

Even if the centroid X-Y position is correct, the component rotation information in a centroid file will be incorrect 75% of the time. This is because the rotation values in the centroid file are relative to the CAD library, which is not linked to manufacturing. For example, if a CAD designer defined his 1206 capacitor shape vertically, when this component is placed on the board in a horizontal position, it will appear in the component centroid file with a rotation of 90 or 270. This means that the rotations in the centroid file will need to be individually checked and edited prior to assembly.

Third, while the locations may be accurate for the top of the board, they are wrong for parts on the bottom side. Most CAD systems record all part locations as if the are on the top side, even when the component is on the bottom of the circuit. Engineer need to convert all bottom side component locations to a different frame of reference.

A final problem with component centroid data is that it will generally not include fiducials and other non-electrical parts in the circuit. These must be taught by hand.

To overcome these problems, manufacturing engineers who use centroid files generally have developed elaborate spreadsheet applications to correct the data. These are based on experience, and require substantial manipulation by skilled users.

CAD interface data offers ability to extract necessary information

The third type of data produced by CAD systems, the CAD interface file, is the most complete. Almost every PCB CAD system outputs a complete circuit description file in ASCII format. The format of these files is wildly different, and there is no format standard among files produced by different CAD systems. Different CAD vendors call their interface file a different name. For Mentor, the data is called the Neutral file; for Zuken-Redac, the CADIF file; PADS Software calls their interface file the ASCII file, while Protel names theirs the PCB ASCII file.

The main advantage for manufacturers in working with the interface file is that every item in the design - component locations and graphics, pin size and locations, fiducials, vias, test points, traces, board outline, mounting holes, etc., is in the file. With this information, it is possible to get a complete and accurate description of the design CAD data can be automatically merged with a bill of materials to create a single database that completely defines the manufacturing process, and this file is the normal starting point for a CIM tool. Manufacturers clearly benefit when they have access to real CAD data and incorporate it into their engineering process:

- Single database to control entire manufacturing process. Data from CAD can be used in test, repair, quality, and other process areas.
- Engineering changes can be made faster, with less change of error, by simply loading the latest design revision.
- More accurate placement information. The data in the CAD file is exactly correct, with no rounding errors or tolerance problems. Component rotations can be exactly computed as well.
- Fewer engineering errors. Because the manufacturing engineer simply reads in the CAD file, errors that arise from handling data are eliminated.
- Reduced engineering time and cost. Creating test and placement data from any source other than real CAD files takes a lot of time to do and check. When you use real CAD data, the time to read in the CAD file is only a few 5 minutes.

Problems with real CAD data

The main difficulty with CAD data is file size- the complete CAD files usually exceed 1 megabyte and sometimes approach 20 megabytes. Also, although they are text files, they are meant to be parsed by a software program, not read, and information is difficult to find and interpret without the aid of a special software tool.

Another problem with this data is that the file formats are unique for each CAD system. There is a project sponsored by the IPC to define a common CAD data file for assembly and test, and in the next few years this effort will bear fruit, but in the mean time manufacturers who need to interface to multiple CAD systems face a difficult task.

In the 1980's many of the largest manufacturing companies in the U.S. recognized the importance of getting accurate CAD data into the manufacturing process, and wrote software to read a CAD interface file directly.

This was fine for large manufacturers, who had the resources to write custom engineering software and need to deal with only one or two CAD system formats, but is difficult for smaller manufacturers and contract assembler who need the ability to support every CAD system. To solve this problem, several CIM companies have developed software applications that translate virtually any CAD file into useful manufacturing information.

Another problem with using real CAD data is being able to get the original file from the design engineer (or the customer in the case of contract manufacturers). The key is to show them how using CAD data benefits them as well as you, because you will be able to use their data directly with a minimum of errors or manual intervention.