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## **AUTOMATING THREE-DIMENSIONAL (3D) MODEL CREATION OF CIRCUIT CARD ASSEMBLIES**

Joshua Stapp  
William Bartell

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U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND  
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## INTRODUCTION

Computer-aided design (CAD) software improves the efficiency of performing engineering design work. However, design activities require coordination of input across multiple engineering disciplines so that sharing information between different software suites becomes essential. This paper describes a process for sharing data between electrical and mechanical CAD software as it relates to the design of circuit card assemblies (CCA).

### Electrical Computer-aided Design

When developing a CCA, an electrical CAD (ECAD) software suite is typically used to perform the initial step of designing the electrical circuit. A schematic is generated that depicts electrical components using different symbols and depicts their electrical interconnections using lines between "pins" on the components. Once the schematic has been completed, the software generates a "netlist" that defines how the various components are interconnected. The netlist is imported into a separate application within the ECAD suite, which is used to design the physical printed wiring board design from the functional design created by the schematic. The board design software then exports industry standard files that describe to a manufacturer how the circuit boards are to be fabricated. The ECAD software can also be used to generate schematic and printed wiring board drawings but typically falls short when it comes to generating a drawing of the completed CCA.

### Mechanical Computer-aided Design

Mechanical CAD (MCAD) software is used to perform three-dimensional (3D) modeling and analysis. This is the preferred tool for visually verifying the correct placement and orientation of the components on a CCA. An MCAD model of a CCA can be used in higher assemblies to verify physical interfaces such as clearances, interconnects, and weights. The 3D MCAD model can also be used to create assembly drawings of the CCA containing a level of detail not available when the drawings are produced in the ECAD software. The refined level of detail allows visual confirmation of mechanical interfaces. Verifying these interfaces before boards are manufactured can reduce cost and scheduling by correcting any identified problems before fabrication begins.

### The Problem

Traditionally, CCAs are designed with ECAD software and, upon completion, are handed off to MCAD software for modeling. This handoff requires a significant duplication of work recreating the modeling details already generated in the ECAD software. For this reason, the handoff is typically a one-time transaction. This methodology restricts design collaboration between electrical and mechanical designers. Furthermore, manual duplication of the design by the MCAD user creates the potential for mistakes to occur. A process that automates the data transfer from the ECAD software to the MCAD software would eliminate duplication of work. A simpler process also allows for more collaboration between electrical and mechanical engineers throughout the design process.

## METHODS, ASSUMPTIONS, AND PROCEDURES

### Overview

The methods described in this paper follow a prescribed set of steps. The ECAD user designs a printed wiring board. When ready to generate a 3D model, the ECAD user exports the design and provides the files to the MCAD user. The MCAD user will create a conversion file to match ECAD component names to 3D model file names. The exported files from the ECAD software are then loaded and the model is created. At this point, the MCAD user can acquire/create any

missing 3D models. Note that this process can occur as the ECAD design is evolving rather than waiting until it is completed

## Software

The methods described in this document are specific to two software suites: the ECAD software Cadence OrCAD PCB Designer 16.6 and the MCAD software PTC Creo 2.0. Both software suites support the Intermediate Data Format (IDF) file format that makes the data exchange possible. A software tool, developed by the authors, automates some of the required conversion operations.

To further enhance the final graphical representation of the CCA, an image file is created that shows copper traces, solder mask, and silkscreen features. To produce this enhanced image, a Gerber File viewer is required that can generate an image using the manufacturing files generated by the ECAD software. One such viewer is an open source tool called “gerbv.”

## Electrical Computer-aided Design Steps

Perform the following sequence of steps in order:

- Open the completed circuit board file in OrCAD PCB Editor.
- From the top menu, select Export->MCAD->IDF.
- Select “PTC” from the File Name Type dropdown.
- Set the output file name.
- Define a default package height (this is an optional step that will create a rectangular prism of the given height if a 3D model of the component is not found).
- Click Export.
- Two files with extensions .emp and .emn will be created. Give these to the MCAD user.

The following steps can be performed if a graphic of the board surfaces is desired.

- Generate the board’s Gerber files for the top and bottom layers using OrCAD PCB Editor.
- Use a Gerber viewer application to import the outline, copper (top and bottom), solder mask (top and bottom), and silkscreen (top and bottom).
- Change the red, green, blue colors for the layers and background as described in table 1 and remove any transparency so layers completely cover the layers beneath them.
- Hide bottom layers and order top layers silk->soldermask->copper->outline.
- Export the current view as a high resolution “.png” or “.bmp” image.
- Repeat process for the bottom layers.
- Bottom layer must be mirrored along the vertical axis.
- Crop both image files to the shape of the board. An example of a prepared decal is shown in figure 1.



Table 1  
Gerber viewer layer colors

Silkscreen	255	255	255	255
Soldermask	190	180	180	255
Copper	10	100	50	255
Outline	255	255	255	255
Background	20	40	20	255

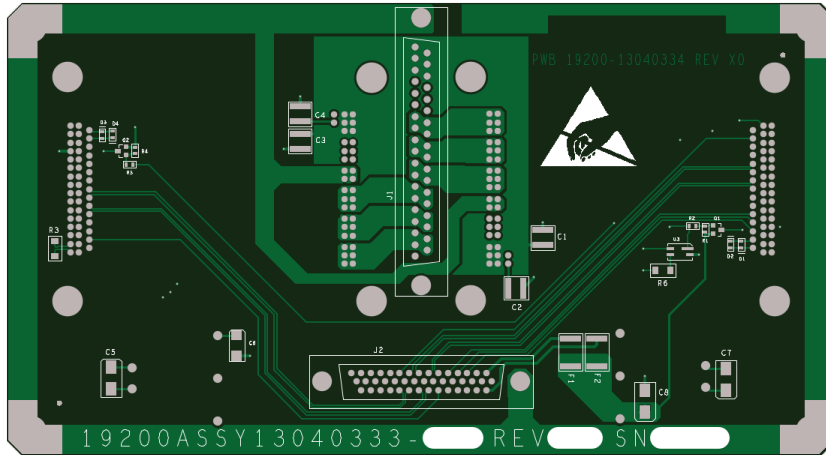


Figure 1  
Prepared decal example

**Transfer File Creation**

The ECAD design information is generated during the ECAD export process and stored in two text files. The emn file contains the dimensions of the board, the size and placement of all through holes, and the placement of all components. The emp file describes the individual components used on the board. The components used by the ECAD designer need to correlate to models possessed by the MCAD designer. The component names generated by the ECAD software are a composite of the schematic symbol name, the footprint name, and other component properties. However, there are many different parts that might use the same physical package (e.g., resistors, integrated circuits) but have different ECAD names. To streamline this process, a naming convention is followed that generates a simplified MCAD filename using the ECAD footprint to represent the 3D model for the various ECAD components involved.

A file (“ecad\_hint.map”) is used by the MCAD software to correlate the ECAD component names to the MCAD 3D model names. This file must be manually generated to facilitate the process of importing the ECAD data into the MCAD system. The following steps describe two different methods to generate the file.

**Manual steps to create file:**

- Create a text file and name it “ecad\_hint.map” and place it in the same location as the config.pro file in your Creo installation directory.
- Open the emp file in a text editor (i.e., Notepad). Each section between “.ELECTRICAL” and “.END\_ELECTRICAL” represents a unique electrical component. The following information is an example of an entry in an emp file.

```
.ELECTRICAL
C0805 CAPACITOR-NP_C0805_DISCRETE_10N THOU 57.00
0 -70.00 -30.00 0.000
0 70.00 -30.00 0.000
0 70.00 30.00 0.000
0 -70.00 30.00 0.000
0 -70.00 -30.00 0.000
.END_ELECTRICAL
```

- The “ecad\_hint.map” file must contain a separate entry for each “.ELECTRICAL” entry found in the emp file. Entries are separated by a “#” symbol with the fields in quotes reflecting information from the emp file. The following information is an example map file entry reflecting the CAPACITOR-NP emp entry example shown previously.

```
#
map_objects_by_name->
ECAD_NAME "C0805"
ECAD_ALT_NAME "CAPACITOR-NP_C0805_DISCRETE_10N "
ECAD_TYPE ""
MCAD_NAME "ECAD_ C0805"
MCAD_TYPE "part"
END
```

- ECAD\_NAME is the name of the footprint used by the ECAD software. It is the first set of text on the first line after “.ELECTRICAL” (in the emp file).
- ECAD\_ALT\_NAME is the text immediately following the ECAD\_NAME text.
- ECAD\_TYPE is left blank.
- MCAD\_NAME is the same as ECAD\_NAME with the prefix “ECAD\_” added.
- MCAD\_TYPE is typically “part” but can be changed to “assembly” if the desired import component is an assembly of multiple parts (this can be useful for connectors but is rarely used).

Automated steps to create file:

- The authors of this paper have created a program to automatically create the ecad\_hint.map file from an .emp file. This program is named “Hint File Generator.exe” and can be obtained by contacting the authors. A screenshot is shown in figure 2.

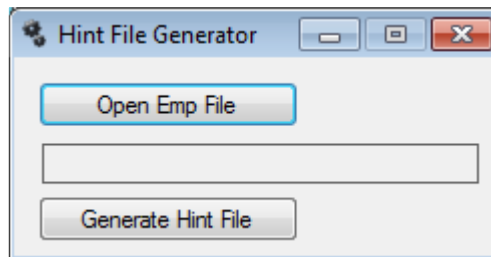


Figure 2  
Hint file generator tool

- To use this tool, either “drag and drop” an emp file onto the program window or click the “Open Emp File” button and locate your file.
- Once the file has been selected, click the “Generate Hint File” button to create the file.
- In some cases, the text may need to be modified. For instance, if the model is an assembly, the MCAD\_TYPE field will need to be manually changed from “part” to “assembly.”

**Mechanical Computer-aided Design Steps**

Before this process can be implemented, the MCAD software must be configured to operate with the ECAD software files. To do so, open the Creo configuration editor and add/change the following parameters to the values shown in table 2.

Table 2  
Creo configuration parameters

Parameter	Value
Ecad_board_csys_def_name	Ecad_default
Ecad_comp_csys_def_name	Ecad_default
Ecad_load_filtered_holes_to_ui	Yes
Ecad_mapping_file	C:\Program Files\PTC\Creo 2.0\Common Files\M130\text\ecad_hint.map
Ecad_pin_hole_import	yes
Template_ecadpart	...\startpart_metric.prt *

\*Replace this directory location with the full file path to your intended start part.

The first step is to create a model of the printed wiring board without components. To do so, perform the following steps:

- Open the .emn file from within the Creo software.
  - Creo will open an “Import New Model” window. Select “part” as the type and enter the part number (e.g., 19200\_12345678) for the printed wiring board in the name field.
  - Enter the board thickness in the unit systems used by the default start part.
  - Ensure the “use default template” box is checked. This will use the start part defined by the configuration parameters set previously.
  - Creo will import the board outline, hole locations, and hole sizes into a 3D solid model that represents the printed wiring board.
- Apply graphics to the front and back of the board.
  - Select the entire model by clicking the “19200\_12345678.prt” at the very top of the feature tree, and change the appearance to one solid color. This color will represent the green edge color seen around the perimeter and inside the through holes.
  - Select the front (top) face of the board and change its appearance to a different color than chosen previously.
  - Select the back (bottom) face of the board and change its appearance to another unique color.
  - Open the model appearance editor, and select the nongreen color that represents the top of the board.
  - Select the Map tab and then decal.

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- This will open a browser. Navigate to the top image generated from the ECAD user and select it.
- After selecting open, the image may not appear. To correct this, first select the eye dropper in the upper right corner of the model appearance editor, select the front face of the board selected previously, and then select the “edit decal placement” icon.
- Repeat these steps so that both the front and rear decals are applied.
- If done correctly, both decals will now appear with the proper orientation, verifiable by the proper alignment of the through holes to decal.
- Figure 3 shows a properly aligned graphical decal of the solid board model.

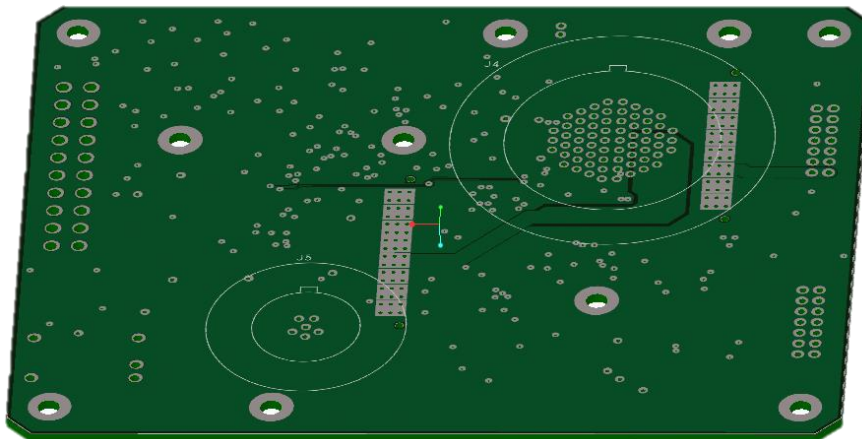


Figure 3  
Printed wiring board with decal

Now that a model of the board exists, the individual components can be added. Follow the following steps to do so.

- The MCAD user must either model or locate models that will represent each component. Models can often be found on manufacturer’s websites. Another good source for generic 3D models is <http://www.3dcontentcentral.com/default.aspx>.
- Once the model exists, create a new coordinate system with the name “ecad\_default” as shown in figure 4.
  - The orientation of this coordinate system must follow the following rules listed:
    - The z-axis must face away from the board and into the part.
    - The x-y plane must coincide with the surface of the printed wiring board that the component is mounted to.
  - The location of the coordinate system must match the origin of the footprint created by the ECAD user.

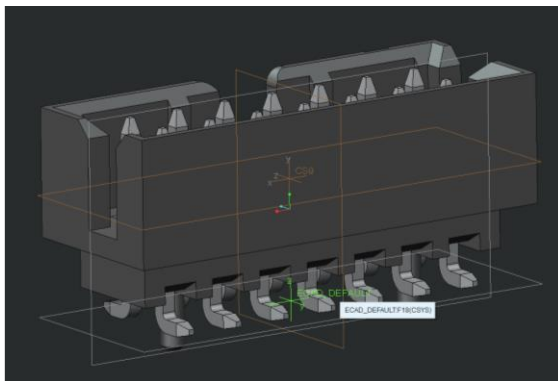


Figure 4  
Component model with coordinate system

- Save the model with a file name that corresponds to the “MCAD\_NAME” created in the “ecad\_hint.map” file as explained in the
- Transfer File Creation section.
- Continue this process, creating parts for all components that will be imported into the CCA.

With the printed wiring board and all the components modeled, an assembly of the entire circuit card can now be created.

- Create a new assembly with the CCA part number as the name. Assemble the printed wiring board modeled earlier into the default location.
- On the model tab, select the get data drop down and select import.
- Browse to the emp file and select open. An “ECAD Input - Assembly” dialog box will open. If a part model exists in the current session with the same component name as specified in the “ecad\_hint.map” file, the get from column will say “existing.” If the model does not exist, the get from column will say “new.” A component listed as new will use the component definition in the emp file for dimensions of a rectangular prism. This value comes from the ECAD software’s footprint model for the specified component.
- After the emp file is loaded, Creo will request the corresponding emn file that specifies the location of each component. Once selected, the 3D models of the components are assembled to the circuit board at the locations defined by the ECAD software.

As a comparison, a CCA model was generated with and without detailed component models. Figure 5 shows the CCA without detailed models. All components were created with the length, width, and height as defined in the ECAD software. Figure 6 shows the same CCA with detailed 3D models of all components.

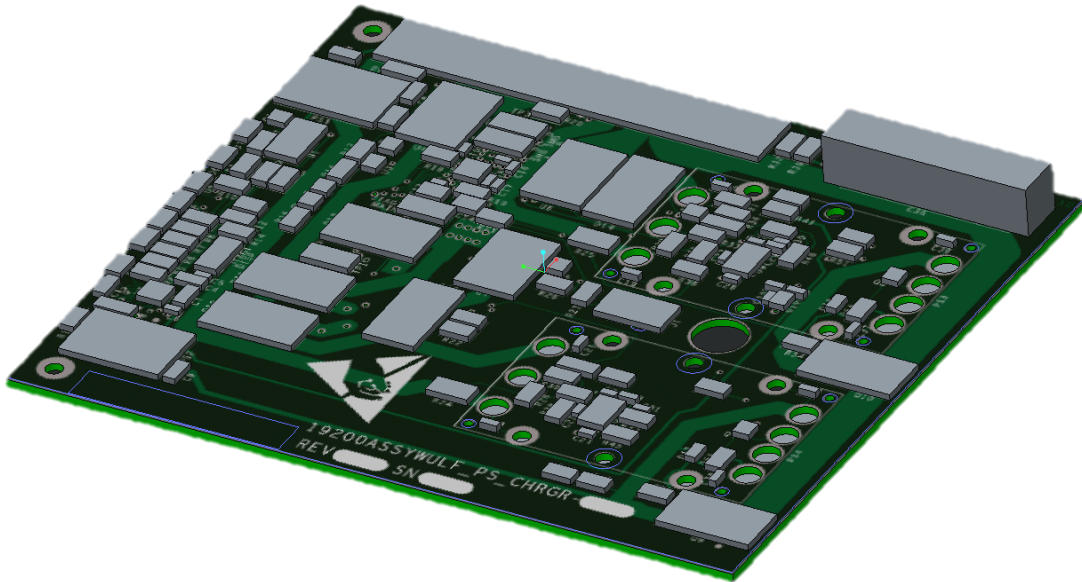


Figure 5  
Model without detailed 3D components

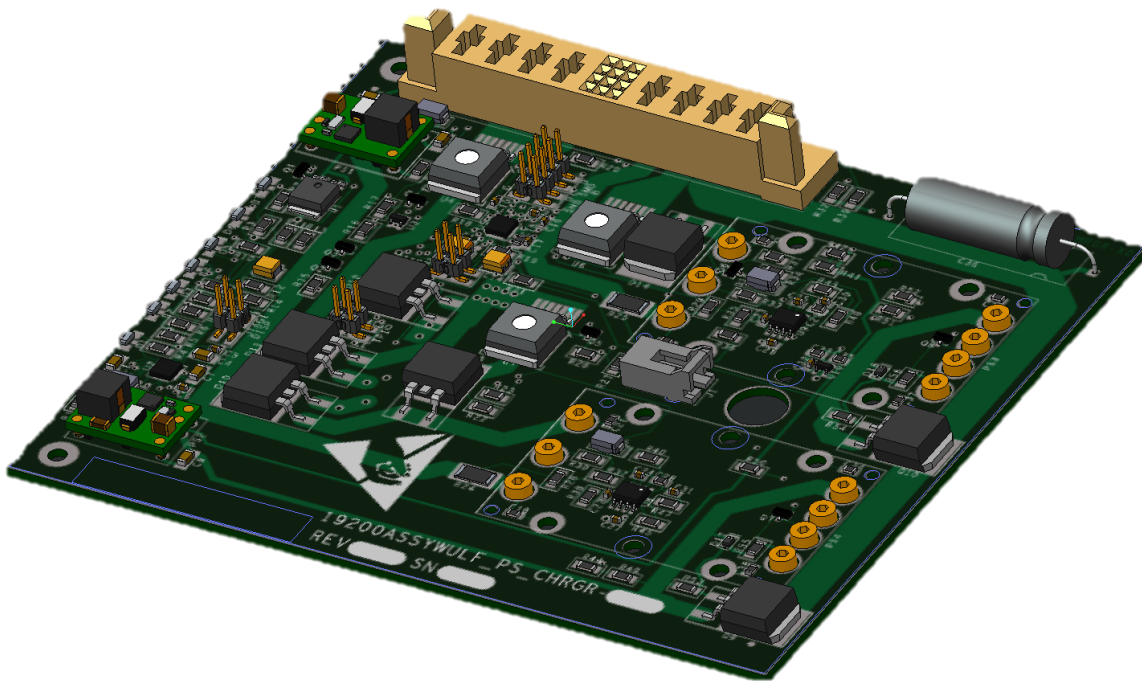


Figure 6  
Model with detailed 3D components



## RESULTS AND DISCUSSIONS

These techniques have been used numerous times to create high quality models of CCAs. The use of these models has been instrumental in resolving several mistakes prior to fabrication both at the CCA level and as part of larger assemblies. Issues identified using these models include: mismatch of component to its footprint, physical interference between CCA components and features of other CCAs or parts, insufficient clearances with CCA enclosure, misaligned mounting holes, incorrectly sized mounting holes, etc.

Initial setup can be labor intensive, but as a library of MCAD components models grow, the level of effort quickly diminishes. Once this ECAD-MCAD conversion process is established, new CCA models typically only require a handful of new components to be modeled and can be completed faster than legacy methods. This automated process yields highly detailed models that are both visually appealing and accurate. As an example, figures 7 and 8 show a 3D model and a photograph of the same CCA. In this case, all 3D models already existed as they had been used previously. The initial export of the IDF files in the ECAD software to the final 3D model being completed in the MCAD software took less than 15 min.



Figure 7  
3D model of CCA

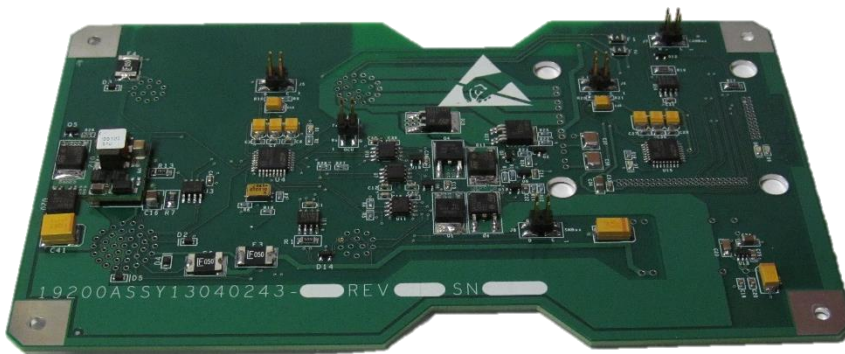


Figure 8  
Photograph of CCA

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## **CONCLUSIONS**

By using the methods described in this document, detailed three-dimensional models of circuit card assemblies can be created with a minimal amount of effort. The end result is better models, additional error checking prior to fabrication, and the data needed to make high quality technical drawings.



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