

Most designs contain line items that affect PCB design but do not require component purchase or placement. Additional line items might represent parts which are either not stuffed or they require hand placement. Attributes to control these operations can be placed in CAD tool libraries or maintained outside the schematic using a database. Index Designs selected the database scheme and incorporated placement control flags in its BOM Builder application.

Value [.01UF]	<input checked="" type="checkbox"/> InBOM
Package [0603]	<input checked="" type="checkbox"/> InPCB
PCB Decal [0603]	<input checked="" type="checkbox"/> InSCH
	<input checked="" type="checkbox"/> Top Side Part
	<input type="checkbox"/> Bottom Side Part
	<input checked="" type="checkbox"/> Stuffed
	<input type="checkbox"/> Hand Place

Placement Control Flags in BOM Builder

4. Part Feeders

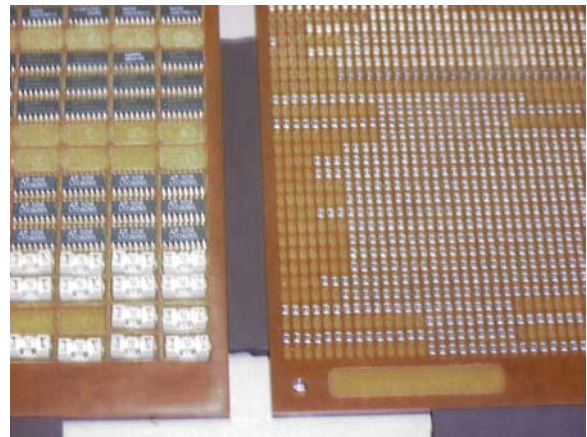
The single greatest task involved with assembly machine setup is the logical and physical setup of the part feeders. Logical setup refers to the dividing of BOM line items into groups as required by machine feeder hardware. Physical setup refers to the placing of the physical components into the mechanical feeders. With the feeders selected and loaded the machine operator must identify to the machine software which feeder locations contain which part types. When a board placement list is transferred to the machine and all part types are programmed and loaded then assembly can start.

The TM8C reel feeders used by Index Designs require 4 minutes to load, trim and unload. If a job requires only 2 parts from a reel the cost per part is very high. Most jobs contain many 1, 2 or 3 part line items. It is common for a job setup to require the removal or addition of special feeder types. These feeders are often very expensive and their mounting increases setup time. When building only one or two boards machine setup quickly exceeds the time required to hand place and solder components.

To reduce setup time an array of customized trays was designed to hold components. Small quantities of loose components are easily placed in trays and short pieces of tape are placed on trays with tooling pins. A software "Tray Compiler" is used to take a BOM and map the components into trays. Additional software logic creates magazine definition files for the trays and these are downloaded to the assembly machine. A MyData TP12-UFP was equipped with a large "Tray Wagon" and tooling has been added to hold trays in know positions.

Information associated with parts can be kept with standard CAD attribute fields or within a parallel database. While storage within attributes is easy to implement the storage within a database simplifies the writing of management software. A database was constructed that contains the definitions of standard trays. Tray definitions consist of arrays of holes located in X and Y. Each hole has an associated depth. Multiple trays of the same size and shape can exist and each tray is given a serial number.

Multiple BOMs are merged as part counts are multiplied by the number of boards being built. As the count of a single part exceeds a threshold then, as feeding information permits, feeding varies from loose parts to strips of tape to reels. The goal of this process is to minimize job setup time.



Parts in Trays



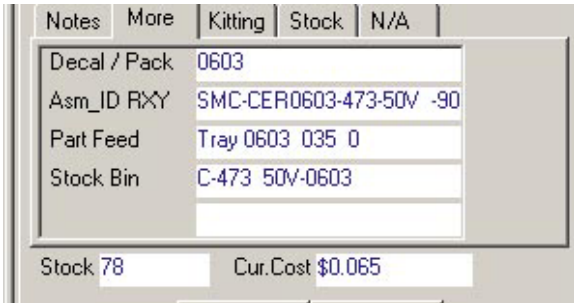
Multiple Trays Loaded on Tray Wagon

5. Details of Part Feeding Attributes

While the software required to compile a BOM into a set of tray definitions becomes complex the attribute set is fairly manageable. For each in house part number 4 lines of text have been setup in a Parts & Vendors database. These lines define:

- PCB Decal and Package Type
- Assembly ID and Placement Offsets
- Part Feeding Information
- Part Storage and Bin Location Data

While PowerPCB attributes can contain this data Index Design favor the uses of database techniques as this simplifies the writing of processing software.



User Fields in Parts & Vendors

The first line is used to define the PowerPCB decals associated with Part Number. If a single string exists (as in the above example) then the decal for PCB design and for placement verification have the same name.

Line 2 (Asm_ID RXY) identifies the assembly machine ID for this component along with the Rotation, X and Y offsets. These offsets are used to translate from PCB design files to assembly machine formats. MyData machines use Unix based file systems and the legal character set is small. A lookup table is constructed from the Parts & Vendors data as to allow third parties to setup and maintain their own translation tables.

Line 3 (Part Feed) identifies this part as being feed in a tray using a 0603 hole size that is 050 mils deep. The part is located in the tray at 0 degrees. Code in the BOM to tray "Compiler" uses this line to place the part into an inventory of predefined trays. Additional code takes the hole size name (0603 in this case) and drives a laser cutter that creates cardboard component trays. Cardboard trays are very useful as they are very space efficient and they make it easy to visually verify that all parts for a job exist and are ready for placement. The hole depth field allows machined tray holes to be adjusted to match component height. Having small parts in controlled depth holes simplifies the packaging of loaded trays and simplifies transport.

Line 4 drives component bin marking and locating functions. When gathering material for prototype assembly a significant amount of time is spent locating parts. Index Designs has set up a system where standard resistor and capacitors are stored in a loose form. It is much faster to reach for a small marked "Pill Box" and extract two or three loose parts than it is to locate a reel and extract 2 parts from tape.

Locating parts from inventory is a significant task. While reels are the most common form of individual part storage reels are difficult to store in an easy to locate and access manner. Index designs strips down a portion of its common reel components into pill boxes and sorts these into carriers based on size and type. A single carrier might carry 0603 capacitors while another might carry diodes.

The goal is to reduce the time it takes to load components for a job. Tray loading from loose parts in pill boxes averages about 350 parts per hour or about \$0.09 per part. Loading of tape strips results in a loading rate of 2000 parts per hour. A medium sized board might contain 250 parts, which results in a worst-case setup of \$18.00 per board. The threshold for moving from loose to tape strips is about 10 or 15 parts.



Pill Box with Label and Bar Code

The BOM Compiler arranges the parts into trays such that loading errors are minimized. Experience shows that most part errors are generated as components are selected from storage. Bar Codes have been added to storage container bottoms to allow software verification of the selected component. In addition to bar codes laser cut trays are marked with component identifiers.

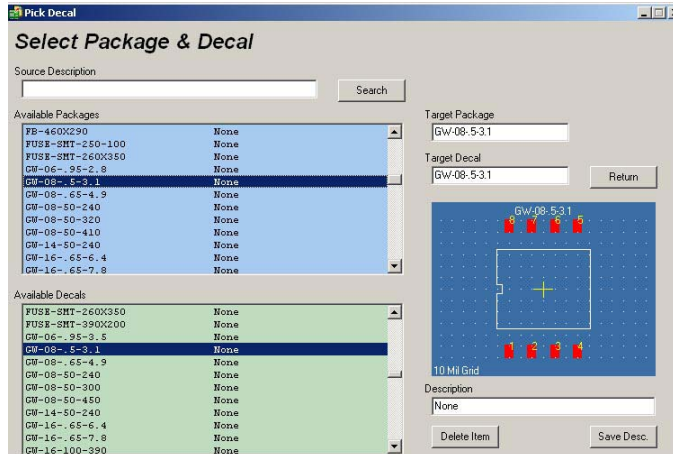
While the loading of trays is tedious it is actually much faster than loading bare boards and the loading of reels is also a very tedious process. The goal is to minimize setup time. Whichever scheme prepares the assembly machine fastest is preferred.

Small parts typically load at 400 pieces per hour. Since all parts of one type are loaded at one time in a single row stuffing errors are practically eliminated. The small shallow holes in the tray surface allow parts to "Click In Place" which greatly speeds loading.

6. Schematic to PCB Tools

Once an external database is used to manage part placement it is relatively simple to expand this scheme to include Part Number to PCB Decal assignment. Index Designs provides PCB design services for a number of customers who use a variety of schematic capture tools. In these schematics it is very common to find passive components with VALUES defined and some parts with incomplete manufacturer part numbers. Prior to PCB design the schematic items must be linked to PCB package styles as defined in the Index Designs library. Once all schematic items are mapped to physical packages the PowerPCB netlist is modified with the package assignment from the database. The resulting netlist is simply imported into PowerPCB.

The advantage to this scheme is that the schematic need not be changed to modify decal assignments and additional components (such as mounting holes) are easily added. Part value and reference designators from the original schematic are retained and BOM compare function can detect changes in values, reference designator, pick and place setup, part location, rotation or side. These checks are very useful in detecting changes between revs. In many organizations a schematic BOM drives the generation of various supporting documents. The ability to detect and report a BOM change simplifies the task of updating these documents and improves their accuracy.



Select Package and Decal Screen

A second advantage of this scheme is the insertion of “attributes” into schematic libraries is eliminated. Only a single resistor symbol is required in the schematic symbol library. Design engineers can concentrate on schematic “Connectivity” with “BOM Annotation” saved as a final process.

The use of a reference schematic from vendors or schematics from consultants is simplified since write access to the schematic is not required. Consultants often have their own schematic tools and libraries and

most library data servers are not accessible through company firewalls. Given the wide acceptance of the PowerPCB netlist format it is relatively simple to accept input from most any schematic capture program and map the designer part requirements to existing inventory parts

Many schematics will incorporate new parts and these present the greatest challenge to design processing. New parts require that a job “Place Holder” be created that can be used to collect decal, package, description and a full company part number. Index Designs designed its parallel BOM such that components without part numbers are maintained and design information can be collected through the process. The state of each BOM line item is identified using color.

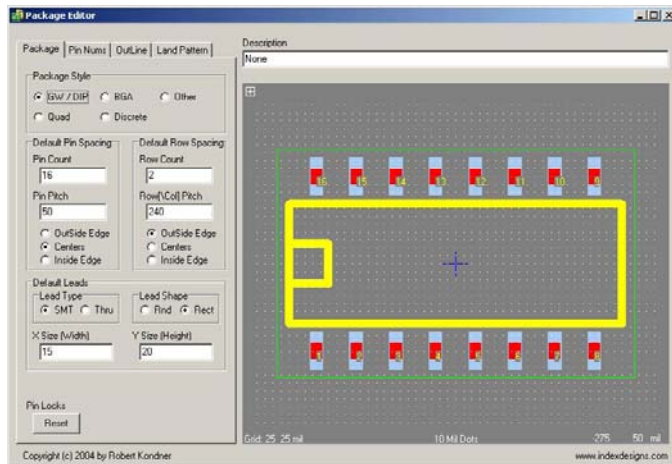
The logic by which BOM items are color-coded depends on the view selected by the user. Having the data to drive a PCB design process does not imply the data exists to drive the assembly process. Jobs from external customers might be annotated to where they can be assembled but not to the degree required to drive PCB assembly.

7. Additional Functions

Probably the most unique and useful piece of code in the Index Designs library is a custom electronic component indexing and lookup engine. This engine uses several techniques to reduce a BOM line item description to an in house part number. A very common task is to convert microfarads to Pico farads. Line items such a 0.001uf are matched to 1000pf. The indexer is driven from any data source that contains a Company Part number and a description. Additional code was required to synchronize indexer tables with a company database in a time efficient manner.

The second major requirement was a tool that allows a complete machine setup to be saved, recalled and changed. During the course of preparing a job for assembly it is common to get “Changes”. Either an existing part must change or a new part must be added. In either case existing trays might already be stuffed and the new or changed component must be worked into the job setup.

The third major function that Index Designs has recently added is a Package Wizard. The current scheme required two PowerPCB libraries, one for land patterns and another that identifies package shapes and contact areas. A Package Wizard has been added that allows parts definitions to be constructed outside of the PowerPCB library editor. These package definitions are applied against a IPC-7351 rule sets and generates PowerPCB land patterns. This new scheme reduces the number of libraries and allows quick and accurate generation of land patterns.



Package Wizard with IPC-7351 Rules

is to laser cut stencils using data from the new Package Wizard.

Quality assembly starts with getting the correct amount of solder paste in the correct position. Lead contact areas define the correct position of paste. Solder paste files that are received from customers tend to be based on land patterns and for from optimal. If Index Designs can generate custom laser cut stencils from package data it should be able to improve the quality of the assembled product and reduce costs.

8. Summary

While Index Designs has developed a significant amount of code to automate this process (42K lines in Delphi at last count) much of this has been added to expedite the assembly of external jobs. If only in house schematics and PCB designs are to be assembled then several processes can be simplified.

- Only rotational data is required to map from PowerPCB rotation to machine rotation. A very simple script can adjust the CAM outputs.
- No search engine is required if schematic library attributes are used to store rotation and part feeder information. The search engine is a powerful technique but most engineering groups already live with extensive library attributes.
- Trays are very useful for feeding all types of loose parts but the code to “Compile” a BOM into tray configurations is very complex. Strips of tape placed on pin trays might be able to simplify assembly machine setup. Much of what is possible depends on assembly machine software.

The current scheme at Index Designs has reduced part setup to 1 hour for two medium sized boards with remaining machine setup at about 30 minutes. Much of this setup is preformed “Off Line” from the assembly machine and does not affect other jobs. Stencil setup and tear down requires another 30 minutes. Hand placing of these boards is 4 to 6 hours each.

The remaining area where costs can be reduced is in stencil costs. Stencil costs are currently about \$150 per side and there are shipping costs and delays. Our plan