Integrated Passive Device (IPD) Modeling Enhancements

In order to reduce the board surface area and system cost associated with passive components, recent movements in the industry are focusing on alternative mounting methods for passives such as: on-chip, multiple value discrete passive components (arrays) mounted onto boards or substrates, passives fabricated with the board (embedded) and combinations of all of the above. One emerging method is the array or network approach earning the title "integrated passive devices" or IPDs. Integrated passives are simply collections of passive devices made using semiconductor of thin-film methods, packaged as an integrated circuit (IC).

In 2002, the modeling tool developed for assessing the board-level size and cost tradeoffs associated with the conversion of discrete passive resistors and capacitors to resistors and capacitors embedded within a board was extended to include the inclusion of IPDs. The objective of this effort was to support the conversion of selected discrete resistors and capacitors to integrated passive devices in addition to their conversion to embedded. The enhanced tradeoff analysis software was delivered on August 27, 2002 and supporting IPD libraries were delivered on September 30, 2002. The following summarizes the capability and use of these modeling enhancements.

Using IPDs in the Modeling Tool

An IPD can be selected for use with any existing passive component through the "Discrete Passives" portion of the modeling tool interface (Figure 1). To designate the component as an IPD, the "IPD-Integrated" choice must be made in the "State" column corresponding to the particular passive. A custom set of fields to the right of the State column will be enabled (note, you may need to click on another cell within the table to make the table update appropriately). Once a component is chosen to be an IPD, two additional pieces of information are necessary: First, how many of the existing discrete passive instances of the component do you which to replace with IPDs? This quantity is collected in the "Number in IPD" column. This quantity should be less than or equal to the total quantity of particular passive component in the design. The second piece of information is choosing a specific IPD to use. Clicking on the far right column in the table shown in Figure 1, produces a dialog box that allows the selection of an existing IPD[1] or the definition of a custom part.

Assembly information that is custom to IPDs can also be entered into the analysis tool. Figure 2 shows the interface (reached through the "Discrete Assembly" portion of the tool interface) for entering this information.

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[1] Currently 376 unique IPDs are included in the default library available with the tool. These are predominately resistor networks (however, some capacitor networks are included). These represent the complete Panasonic, Bourns, and CTS offerings through DigiKey as of September 2002.

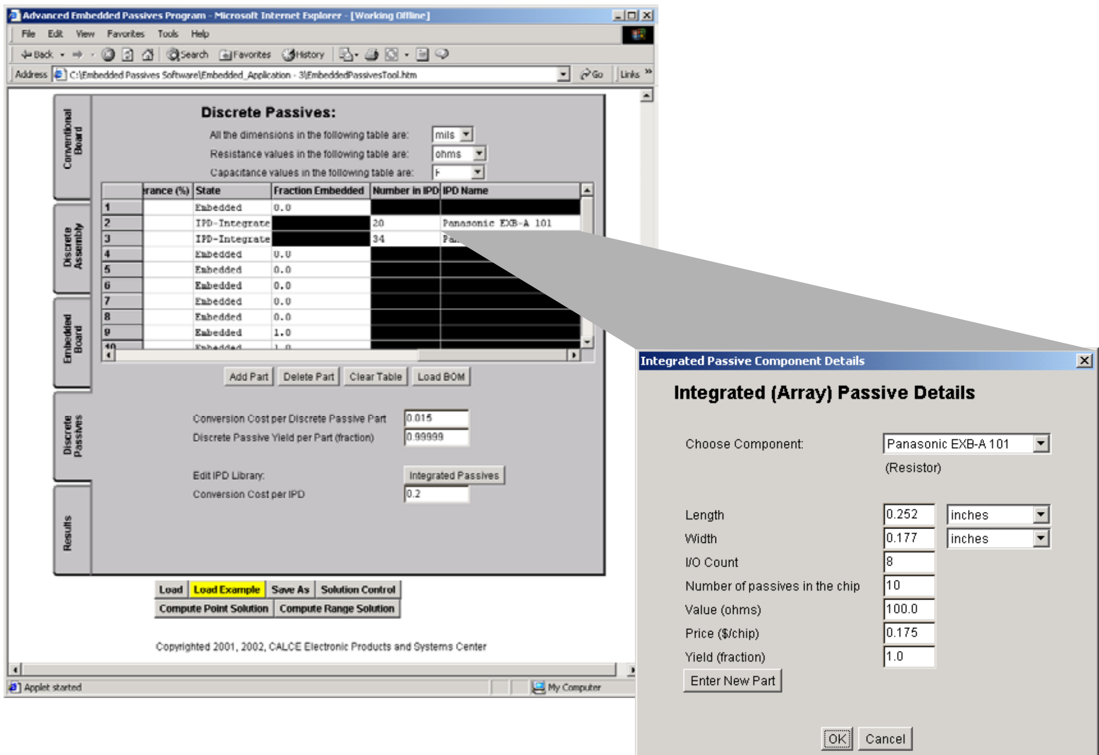

Figure 1 – Discrete Passives section of the embedded passive modeling tool showing the selection of IPDs.

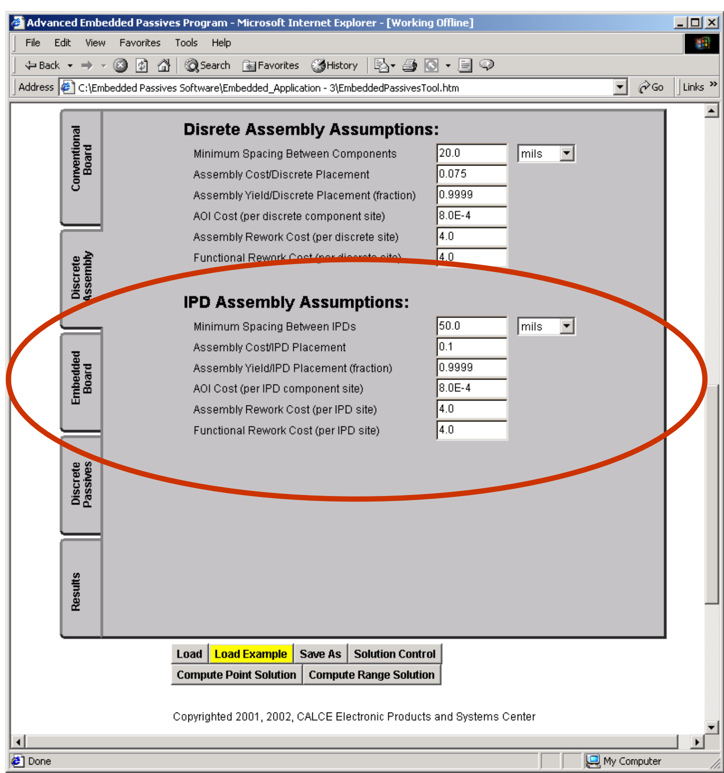

Figure 2 – IPD assembly inputs in the Discrete Assembly section of the embedded passives modeling tool.

Analysis of boards containing IPDs is identical to the normal operation of the embedded passives analysis tool. Discrete, embedded, and integrated (IPD) passives can be mixed in the same design. Note, if there is a difference between the number of passive components in IPDs and the total number in the design, the balance are treated as discrete passives.

<u>Example Tradeoffs Including IPDs</u>
In this section the results for three applications are considered. A detailed description of the applications can be found in [1].

Figure 3 shows results for the NEMI hand held emulator. This application has a very high density of passive components and is assumed to be very high volume. Including IPD resistors increased passive procurement costs from $1.26/board to $1.91/board, however, assembly costs dropped from $25.64/board to $22.90/board resulting in a net 7% drop in cost[2] for the system. In this case, the board size did not change when IPD resistors were used. An applicable IPD capacitor network was available for replacement of one of the discrete capacitor types, however, use of this IPD increased the board size thus reducing the number of boards fabricated on a panel and adding cost.

	Size	Cost*
IPD Resistors	1% ↑	7% ↓
IPD Resistors and Capacitors	9% ↑	3% ↓
Embedded Resistors (MacDermid)	5% ↓	55% ↓
Embedded Resistors (Ohmega Ply)	5% ↓	48% ↓
Embedded Capacitors (C-Ply)	3% ↓	3% ↓

*Cost = <u>only</u> costs associated with passive procurement and assembly + board price

- 2.17 in^2
- 107 applicable (replaceable) capacitors
- 174 applicable resistors

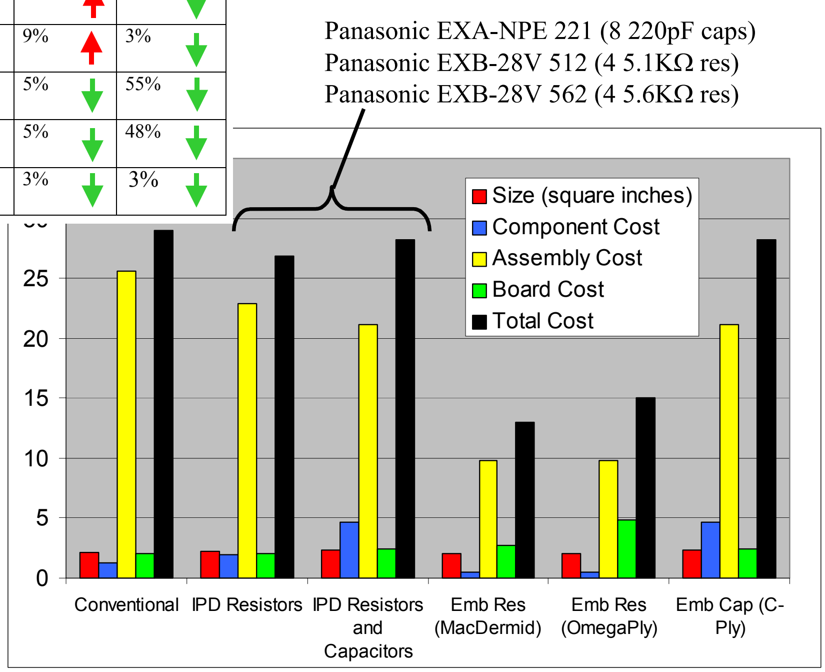

Figure 3 – NEMI hand-held emulator, note, costs only include the price of passives, the assembly of passives and the board price, all other costs are assumed to be equivalent between the cases and not included.

	Size	Cost*
IPD Resistors	1% ↓	7% ↓
IPD Resistors and Capacitors	NA	NA
Embedded Resistors (MacDermid)	2% ↓	46% ↓
Embedded Resistors (Ohmega Ply)	2% ↓	3% ↑
Embedded Capacitors (C-Ply)	1% ↓	12% ↑

*Cost = only costs associated with passive procurement and assembly + board price

- 2.27 in^2
- 43 applicable (replaceable) capacitors
- 70 applicable resistors

Panasonic EXB-B 562 (8 5.6KΩ res)
Panasonic EXB-A 471 (8 470Ω res)
Panasonic EXB-28V 510 (4 51Ω res)

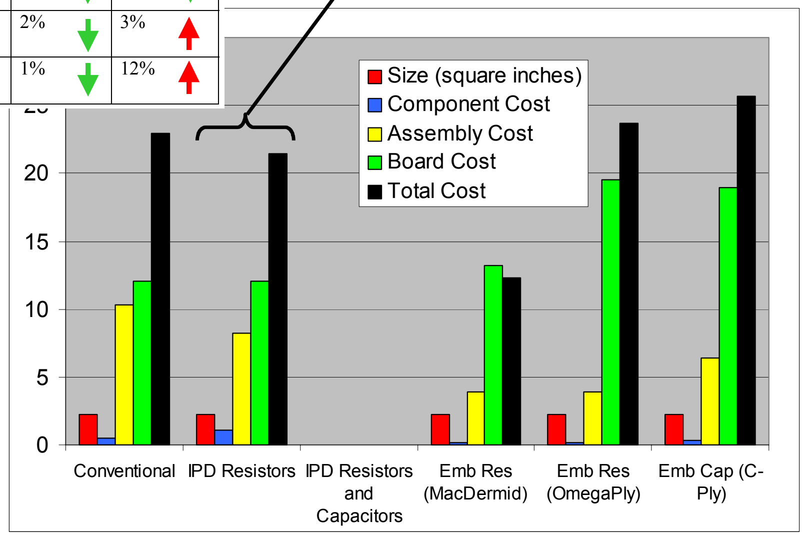

Figure 4 – Picocell telecommunications board, note, costs only include the price of passives, the assembly of passives and the board price, all other costs are assumed to be equivalent between the cases and not included.

Figure 4 shows results for a picocell telecommunications board. This application has a lower density of passive components than the NEMI hand held emulator and is assumed to be medium volume. Including IPD resistors increased passive procurement costs from \$0.53/board to \$1.12/board, however, assembly costs dropped from \$10.31/board to \$8.24/board resulting in a net 7% drop in cost for the system. In this case, the board size decreased slightly when IPD resistors were used, but not enough to change the board price. No applicable IPD capacitor network was available for replacement of any of the discrete capacitor types. Note, that the IPD resistor case for this application results in a lower cost than the Omega-Ply embedded resistor solution.

The last example is a fiber channel card, Figure 5. This application has the lowest density of passive components of the three examples presented. This application is also very large (12 x 18 inches). Including IPD resistors decreases the board size (but not enough to decrease the board price), increases passive procurement costs from \$3.83/board to \$7.05/board, and decreases the assembly costs from \$77.74/board to \$68.33/board resulting in a net 2% drop in cost for the system. No applicable IPD capacitor network was available for replacement of any of the discrete capacitor types. As with the picocell board, the IPD resistor case for this application results in a lower cost than the Omega-Ply embedded resistor solution.

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[2] This system cost is only the cost of passive procurement, passive assembly, and the board (it does not include the cost of procuring non-passive parts or assembling them, or the cost of functional testing).

	Size	Cost*
IPD Resistors	1% ↓	2% ↓
IPD Resistors and Capacitors	NA	NA
Embedded Resistors (MacDermid)	1% ↓	14% ↓
Embedded Resistors (Ohmega Ply)	1% ↓	17% ↑
Embedded Capacitors (C-Ply)	No change	33% ↑

*Cost = only costs associated with passive procurement and assembly + board price

- 12 x 18 in
- 242 applicable (replaceable) capacitors
- 610 applicable resistors

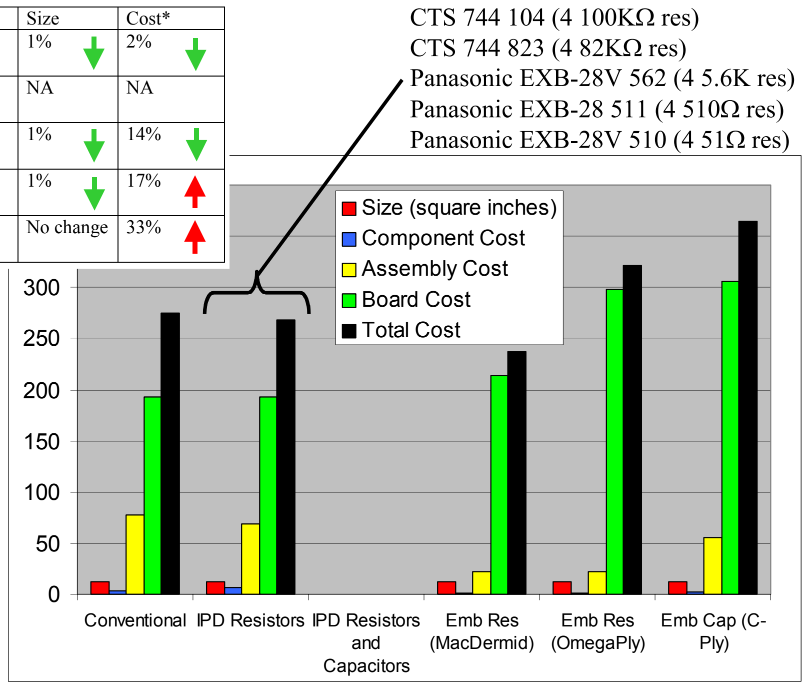

Figure 5 – Fiber channel card, note, costs only include the price of passives, the assembly of passives and the board price, all other costs are assumed to be equivalent between the cases and not included.

Discussion

IPD resistors are available in a wide enough variety of values and tolerances to be a useful design consideration. The general availability of IPD capacitors is poor and finding applicable capacitor networks is difficult. Using IPD resistors was reasonably space efficient for the replacement of 0603 or larger discrete resistors, however, for 0402 or smaller discrete resistor replacement a size penalty may occur. IPDs are more expensive (on a per passive procurement basis) than discrete passives, however, for resistors, the procurement penalty was more than made up by the decrease in assembly costs. In the cases considered, we saw 2-7% decreases in the cost of passive procurement, passive assembly, and the board. Plated (MacDermid) embedded resistors appear to always be the most economical solution, however, for all but the highest density case, using IPDs was more economical than Ohmega-Ply.

[1] P. Sandborn, "The Economics of Embedded Passives," in *Integrated Passive Component Technology*, R. Ulrich and L. Schaper editors, IEEE Press, Fall 2002.