Embedded Passives, Go for it!

Ruth Kastner
Eli Moshe
Outline

- Description of a case study: Problem definition
- New technology to the rescue: Embedded passive components
- Benefits from new technology
- Design flow
- Summary and conclusions
Outline

- Description of a case study:
  Problem definition
- New technology to the rescue:
  Embedded passive components
- Benefits from new technology
- Design flow
- Summary and conclusions.
…we had to design a board:

Size: 30.7” x 11.4” = 350sq”

100 pins gold edge Connector

Material: FR4, Hi-TG

Industrial components

Termination and P/U Resistors 2300

Controlled Impedance signals 50/100ohm
Outline

- Description of a case study: Problem definition
- New technology to the rescue: Embedded passive components
- Benefits from new technology
- Design flow
- Summary and conclusions.
Very few PCB manufacturing houses would be able to handle this **size**. If they can, the **cost** would be high.

Most would lack the right tooling and capabilities for manufacturing of the PCB.

Even fewer assembly houses would be able to place a board of this **size** within the stencil, on the pick & place machines, and then through the re-flow oven.

Again, **cost** would be an issue.
Review of options and selection of solution

The following criteria led to the selection of Embedded resistor technology:

Availability of:

✓ Design tools
✓ PCB layout tools
✓ PCB manufacturers
✓ Reliability data
✓ Assembly houses

❖ An open question remains: How do we construct the Cost model?
Resistor embedded design rules were studied in a very short time with the help of design guidelines by Ohmega-Ply.

Found two sources on cost models:

**Source 1:** CALCE Cost modeling: University of Maryland. This model is based on Assembly, Materials, Yield, Trimming, Parts procurement, Parts handling, Rework
Source 2. A model for application-specific analysis of discrete passive components
Our case study: the board, designed with Embedded resistor technology

Size: 12.9” x 14.4” =185sq”

PCB Thickness 1.6mm

Material  FR4 Hi-TG

Industrial components

Embedded Resistors 2300

Controlled Impedance signals
50/100ohm
Comparison of boards
<table>
<thead>
<tr>
<th>Unit Size</th>
<th>Standard Technology</th>
<th>Embedded Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>dimension</td>
<td>30.7” x 11.4” = 350sq”</td>
<td>12.9” x 14.4” = 185sq</td>
</tr>
<tr>
<td>unit size</td>
<td>layout</td>
<td></td>
</tr>
<tr>
<td>area</td>
<td>100%</td>
<td>52%</td>
</tr>
<tr>
<td>substrate</td>
<td>41%</td>
<td>16%</td>
</tr>
<tr>
<td>unit cost</td>
<td>BOM</td>
<td></td>
</tr>
<tr>
<td>assembly</td>
<td>42%</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>48%</td>
</tr>
</tbody>
</table>
This is our case study....

We considered Embedded Resistor technology

Reasons being....
The trend towards miniaturization has been with us for quite a while.

A question that arises frequently in this context is as follows:

Can we offer miniaturization in **three dimensions** rather than the conventional **two**?

A positive answer to this question is now provided through the embedded passive technology.
Passive components are known to dominate in many categories.

- Passives on circuit boards
  - occupy 40%+ of available substrate area,
  - contain about 30% of all solder joints,
  - take about 90% of the total assembly cost.
  - Each IC employs additional 15 – 40 passive components in a typical design.

⇒ Passive components have an adverse effect on the size, weight, performance and overall cost of PCBs.
Outline

- Description of a case study: Problem definition
- New technology to the rescue: Embedded passive components
- Benefits from new technology
- Design flow
- Summary and conclusions.
Benefit: Electronic Performance

- Improved line impedance matching
- Elimination of inductive reactance of SMT devices
- Reduced series inductance
- Shorter signal paths
- Reduced cross-talk, noise and EMI
Benefit: Lower resistor parasitic inductance

Better functionality $\Rightarrow$ lower inductance

- from: 0.9 nHy for a1206 SMT resistor
- to: 0.4 nHy for an embedded resistor
Benefit: Easier PCB Layout Design

- Increased active component density & reduced form factors
- Improved wire-ability due to elimination of via and smt pads
- Reduced board size/reduced layer count
Benefit: Lower Cost

- Elimination of discrete components
- Improved assembly yield
- Assembly on top side rather than on both sides
- Board reduced size/layer
- Reduced purchase cost, management, shipments
- Reduced storage floor area
Benefit: Better Quality & Reliability

- Fewer defects per unit (DPU) when BP is used
- Two fewer solder joints per discrete component
- Two fewer vias per discrete component
- Longer MTBF of an assembled board
- Actual values can be derived from DoD-MIL-HDBK-217 or Bellcore FR-NWT-000978
Outline

- Description of a case study: Problem definition
- New technology to the rescue: Embedded passive components
- Benefits from new technology
- Design flow
- Summary and conclusions.
Design flow

- Consider BP at the Circuit Design phase, preferably earlier
- Define material, component technology, select design Kit(s)
- Analyze your design. You can determine if BP is a viable option and which components should be Embedded.
- Decide together with your PCB Manufacturer on the choice of the resistive sheet to be used in the design.
In the process of schematic design, define naming convention for the BP and run simulation phase.
## Design flow

### Component selection: type, value, tolerance, power rating

| 25 | 97 | R1, R2, R5, R6, R9, R10, R13, 10K | br10k_005w_100 |
| 26 | 8  | R3, R4, R7, R8, R11, R12, R15, 1K | rD0805 |
| 27 | 13 | R93, R94, R95, R15, R24, 330 | br330_025w_100 |
| 28 | 1  | R96, 2.2K | rD0805 |
| 29 | 4  | R141, R143, R145, R147, 1K | br1k_010w_100 |
| 30 | 1  | R178, 50K | rD0805 |
| 31 | 1  | R179, 680 | rD0805 |
| 32 | 1  | R180, 200K | rD0805 |
| 33 | 1  | R181, 500 | rD0805 |
| 34 | 1  | R182, 130K | rD0805 |

### Embedded BOM

1. R1, R2, R5, R6, R9, R10, R13, 10K
2. R14, R17, R18, R19, R20, R21
3. R22, R23, R24, R25, R27, R28
4. R29, R30, R31, R32, R33, R34
5. R35, R36, R37, R38, R45, R46
6. R47, R48, R49, R50, R51, R52
7. R53, R54, R55, R56, R57, R58
8. R59, R60, R77, R78, R79, R80
9. R81, R82, R83, R84, R85, R86
10. R87, R88, R89, R90, R91, R92
11. R112, R114, R115, R116, R117
12. R118, R119, R120, R122
13. R123, R124, R125, R126
14. R128, R142, R144, R146, R148
15. R161, R162, R163, R164, R165
16. R166, R167, R168, R169
17. R171, R172, R173, R174
18. R176

### Conventional BOM

1. R1, R2, R5, R6, R9, R10, R13, 10K
2. R14, R17, R18, R19, R20, R21
3. R22, R23, R24, R25, R27, R28
4. R29, R30, R31, R32, R33, R34
5. R35, R36, R37, R38, R45, R46
6. R47, R48, R49, R50, R51, R52
7. R53, R54, R55, R56, R57, R58
8. R59, R60, R77, R78, R79, R80
9. R81, R82, R83, R84, R85, R86
10. R87, R88, R89, R90, R91, R92
11. R112, R114, R115, R116, R117
12. R118, R119, R120, R122
13. R123, R124, R125, R126
14. R128, R142, R144, R146, R148
15. R161, R162, R163, R164, R165
16. R166, R167, R168, R169
17. R171, R172, R173, R174
18. R176
Design flow

- Optimize component design:
  - p/u & p/d values
  - termination values

- Create component library

- Generate components
  minimize component area and material use

Figure 1: 47 ohms resistor footprint

Resistor Width = 22 mils
Resistor Length = 10.3 mils
No. of square = 10.3 mils/22 mils = 0.4
Resistance value = 0.47 square x 100 ohms/square = 47 ohms

Figure 2: 220 ohms resistor footprint

Resistor Width = 10 mils
Resistor Length = 22 mils
No. of square = 22 mils/10 mils = 2.2
Resistance value = 2.2 square x 100 ohms/square = 220 ohms
Design flow

- Design your stack-up
- Verify with your PCB manufacturer: feasibility, material, cost
- Update Stack-up
- BOM preparation for PCB manufacture indicating:
  - resistor value
  - in what layer
  - what tolerance is required
Design flow

Start Layout placement:

- Place main IC and components
- Place embedded passives in relevant layers
Design flow

Start Routing:

- Connect embedded resistors
- Leave open plane channels
- Power layer route
GND plane: Direct connection of the embedded resistors to the plane layer
Design flow

Gerber preparations: Superposition of GND and embedded resistor layers
Outline

- Description of a case study: Problem definition
- New technology to the rescue: Embedded passive components
- Benefits from new technology
- Design flow
- Summary and conclusions.
What have we gained?

✓ Smaller PCB size in production
✓ Cheaper Assembly
✓ Faster Assembly
✓ Higher Reliability
✓ Shorter Signal Traces
✓ Gained Component storage area
✓ Reduced purchase costs
What are the tradeoffs?

✓ Flexibility to change resistor values
Eliminating passives in assembly:
Can resolve critical bottle necks in assembly!

• 200 fewer components in 5M pcs @50k parts/hour: 800+ days less in the assembly line!

• 2000 fewer components in 100,000 pcs @50k parts/hour: 166+ days less in the assembly line!

.......@ 24h operation!
Emerging Standards

| IPC–D37A   | Embedded Passive Devices Design Task group |
| IPC–D37B   | Embedded Passive Materials Task group       |
| IPC–D37C   | Embedded Passive Devices Performance Task group |
| IPC–D37D   | Embedded Passive Devices Test Methods Task group |
| IPC-2316   | Design Guide for Embedded Passive Devices   |
| IPC-4821   | Specification for Embedded Passive Capacitor |
| IPC-4902   | Specification for Materials for Embedded Passive |
Embedded passives are seen as a key enabling technology in the National Electronics Manufacturing Initiative (NEMI) Roadmap.

The technology developed in this program will translate to a variety of other applications because of the expanded performance, potential for lower system cost, reduced area requirements, and improved reliability.
Yet another board:
I. Conventional resistors
II. With 2000 embedded resistors
THANK YOU

Questions and queries are welcome

Ruth Kastner
+972- 9-7417411 – ext. 106
+972- 54-6681414
Ruthk@adcom.co.il