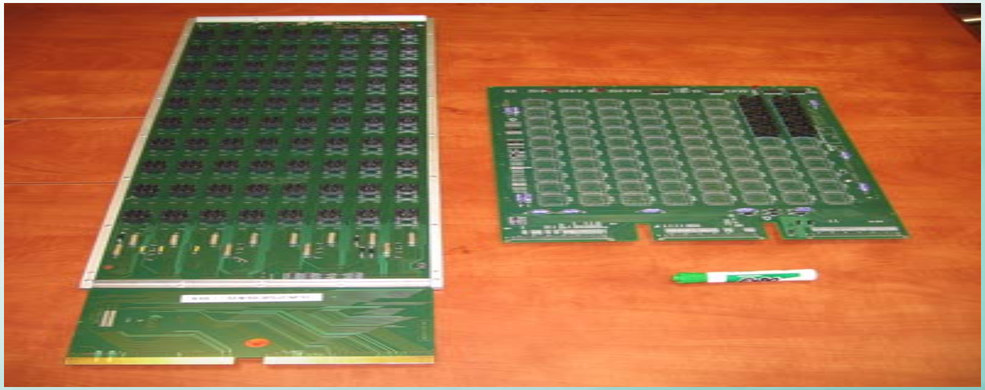
Embedded Passives, Go for it !



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

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…we had to design a board:

Size: 30.7”x 11.4” = 350sq”

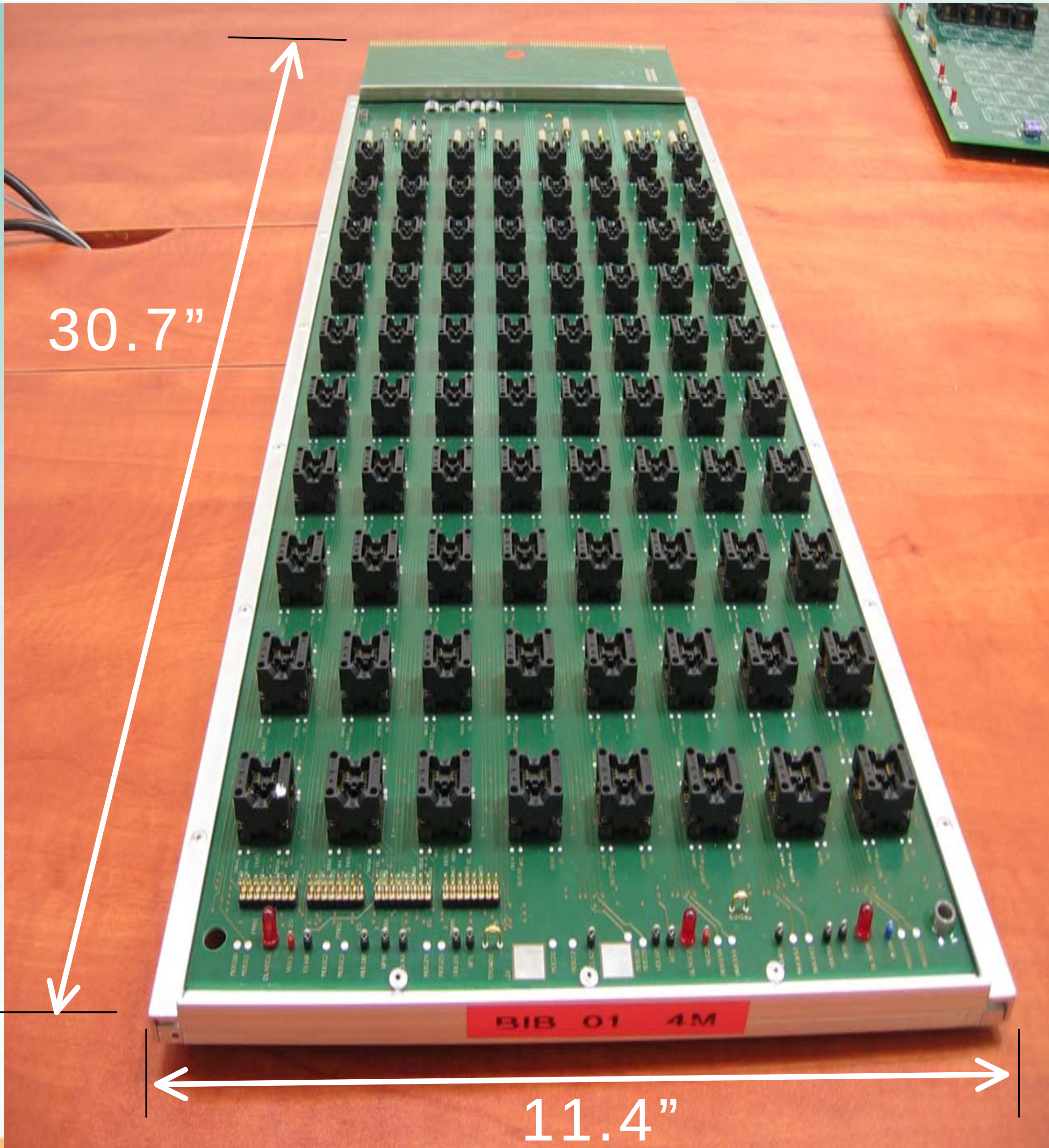
100 pins gold edge Connector

Material: FR4, Hi-TG

Industrial components

Termination and P/U Resistors 2300

Controlled Impedance signals 50/100ohm



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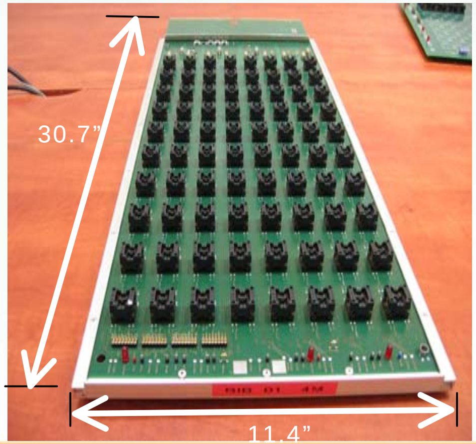
Board size is 30.7”x 11.4”

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.

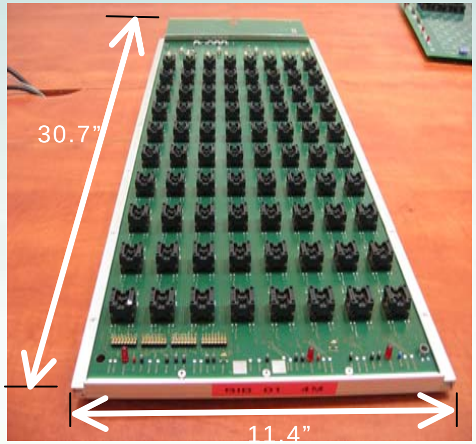


Review of options and selection of solution

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

Availability of:

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



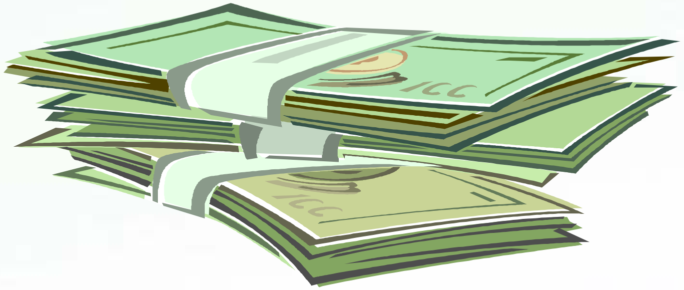
❖ An open question remains: How do we construct the **Cost** model ?

Cost & Technology

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:

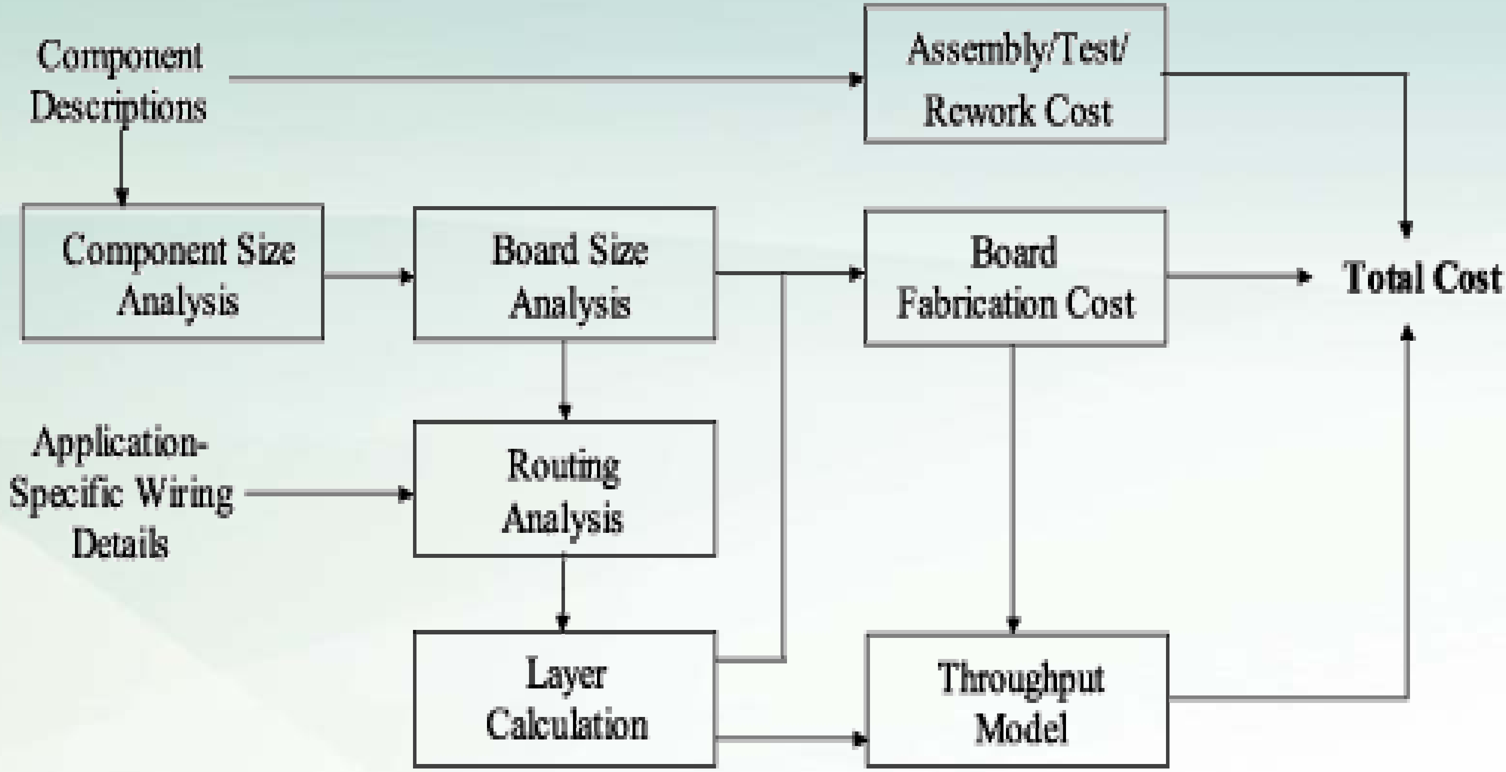
Source 1: CALCE Cost modeling: University of Maryland. This model is based on Assembly, Materials, Yield, Trimming, Parts procurement Parts handling, Rework



Cost & Technology

Source 2. A model for application-specific analysis of discrete passive components

P. A. Sandborn, B. Etienne, and G. Subramanian, "Application-Specific Economic Analysis of Integral Passives in Printed Circuit Boards."
IEEE Trans. on Electronics Packaging Manufacturing, Vol. 24, No. 3, pp. 203-213, July 2001.



Our case study: the board, designed with Embedded resistor technology

Size: 12.9” x 14.4” =185sq”

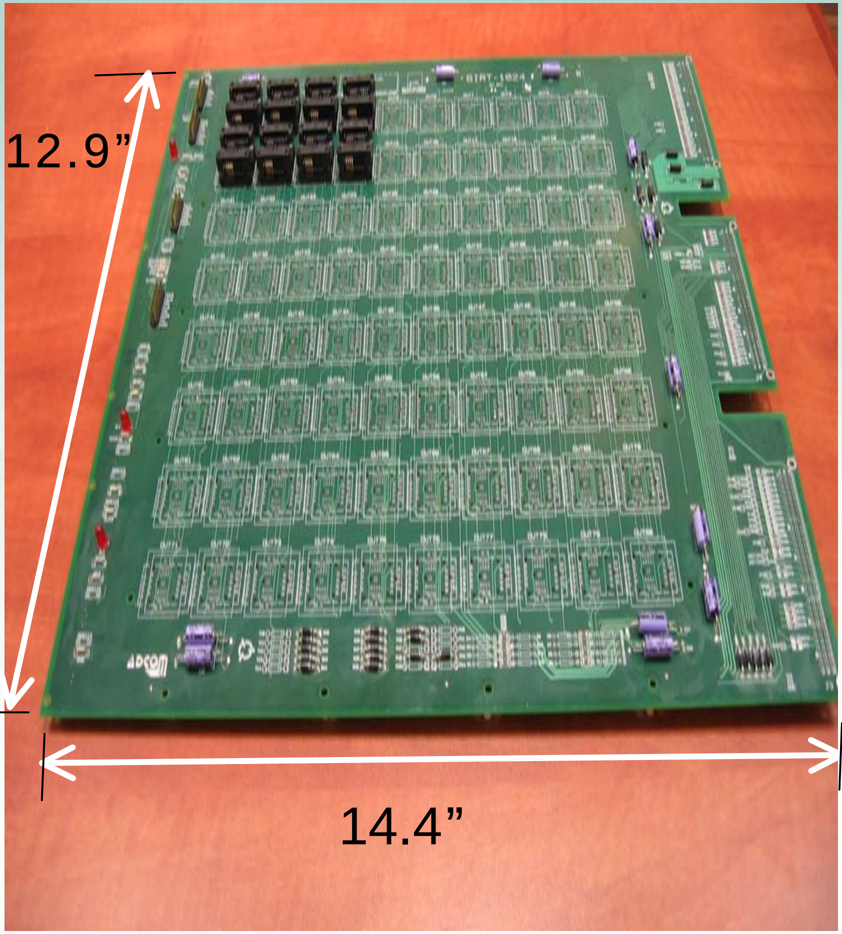
PCB Thickness 1.6mm

Material FR4 Hi-TG

Industrial components

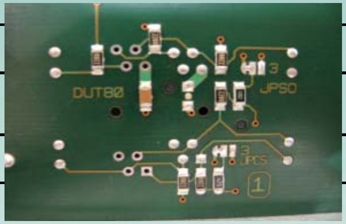
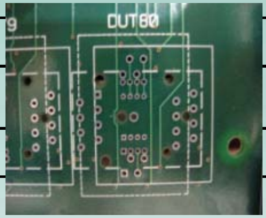
Embedded Resistors 2300

Controlled Impedance signals 50/100ohm



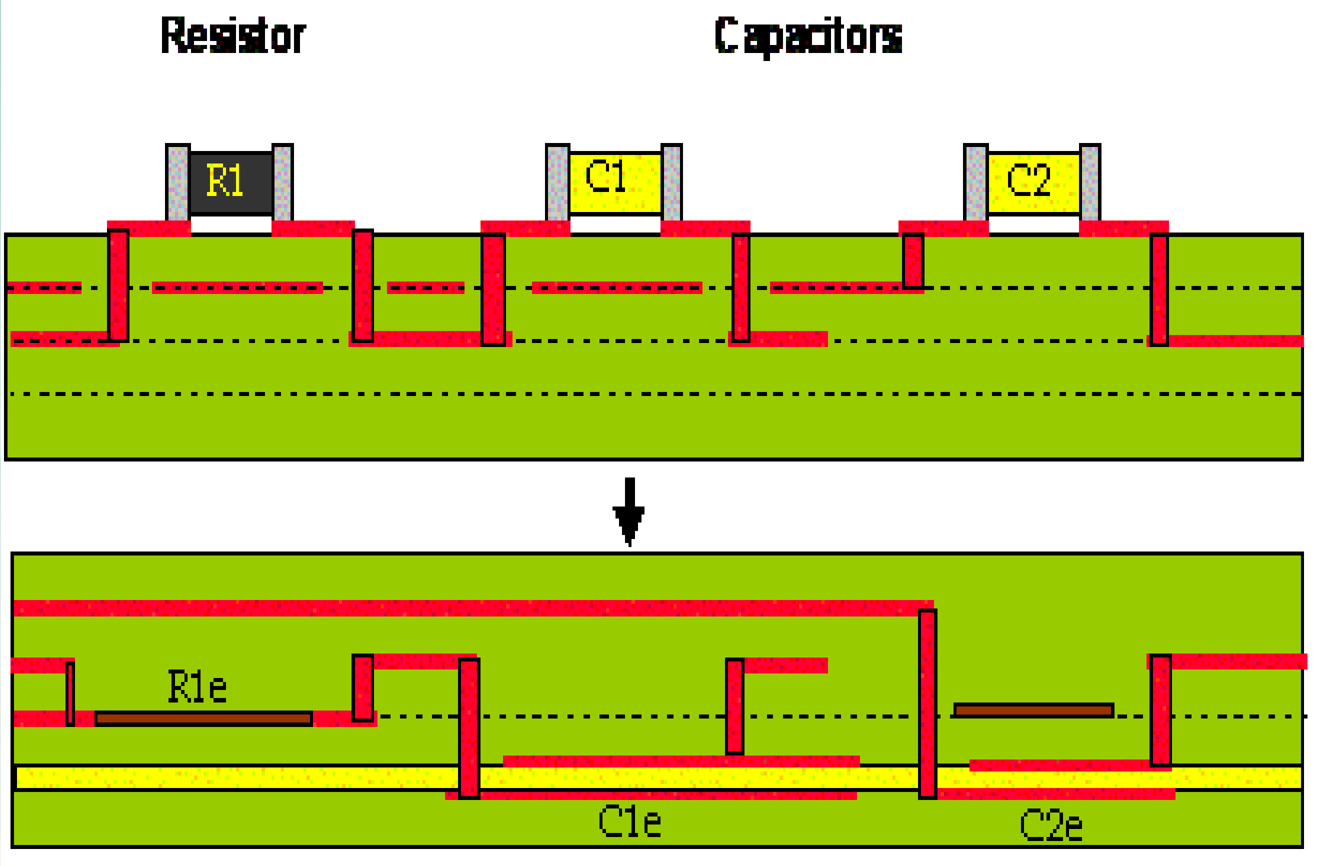
Comparison of boards

Comparison Chart

		Standard Technology	Embedded Technology
	dimension	30.7"x 11.4" = 350sq"	12.9" x 14.4" = 185sq
unit size	layout		
	area	100%	52%
	substrate	41%	16%
unit cost	BOM	17%	22%
	assembly	42%	10%
		100%	48%

This is our case study….

We considered Embedded Resistor technology



Reasons being….

PCB Evolution

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.

PCB Evolution

Passive components are known to dominate in many categories.

- World market share: $700B+ (2004).
- 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 additonal 15 – 40 passive components in a typical design.

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

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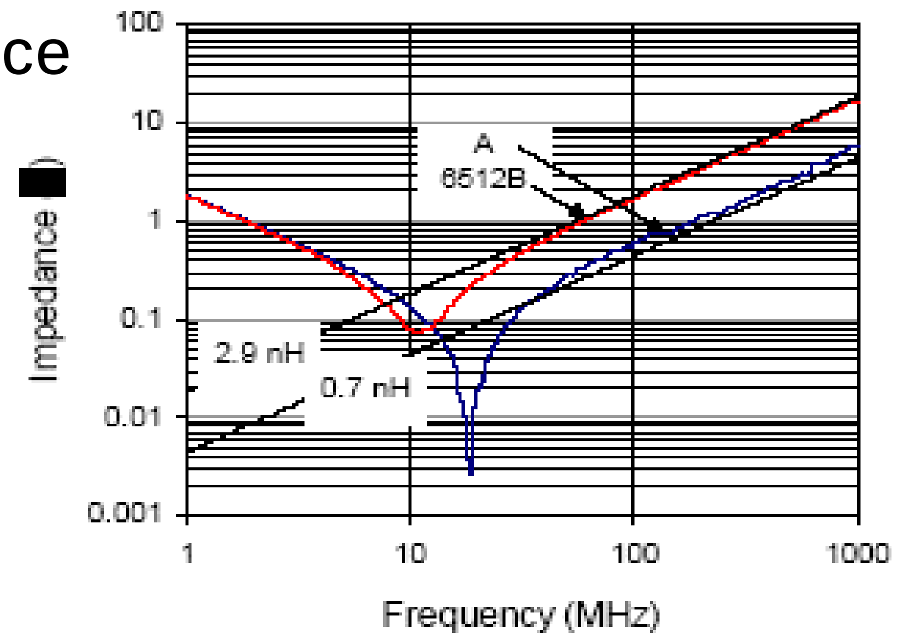
Benefit: Electronic Performance

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



Impedance of a SMT capacitor (6512B) and a BC test board (A)
Figure 12

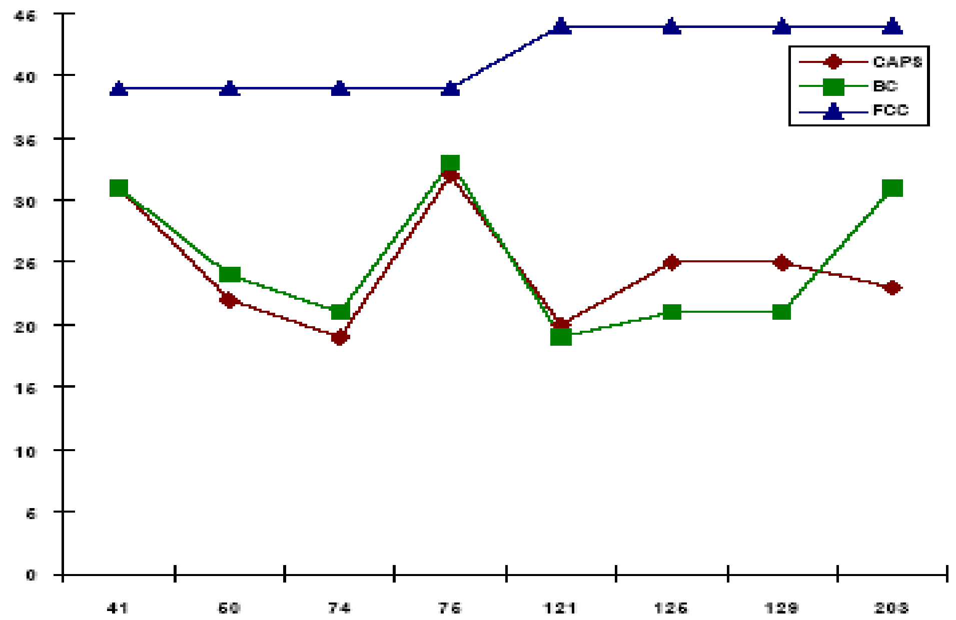
Benefit: Lower resistor parasitic inductance

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



Example Board Assembly Radiated EMI Plots With and Without BC
Figure 10

A Sanmina-SCI Corporation

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

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Design flow

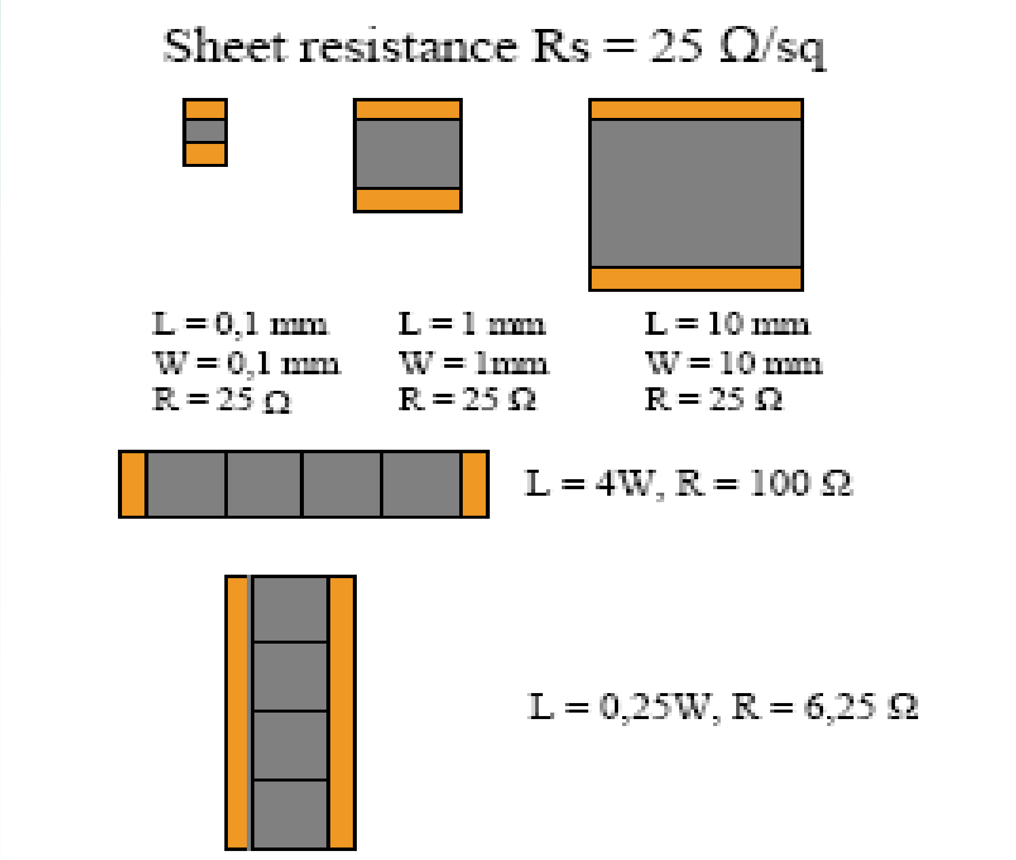
- Consider BP at the Circuit Design phase, preferably earlier

- Define material, component technology, select design Kit(s)

- Analyze your design

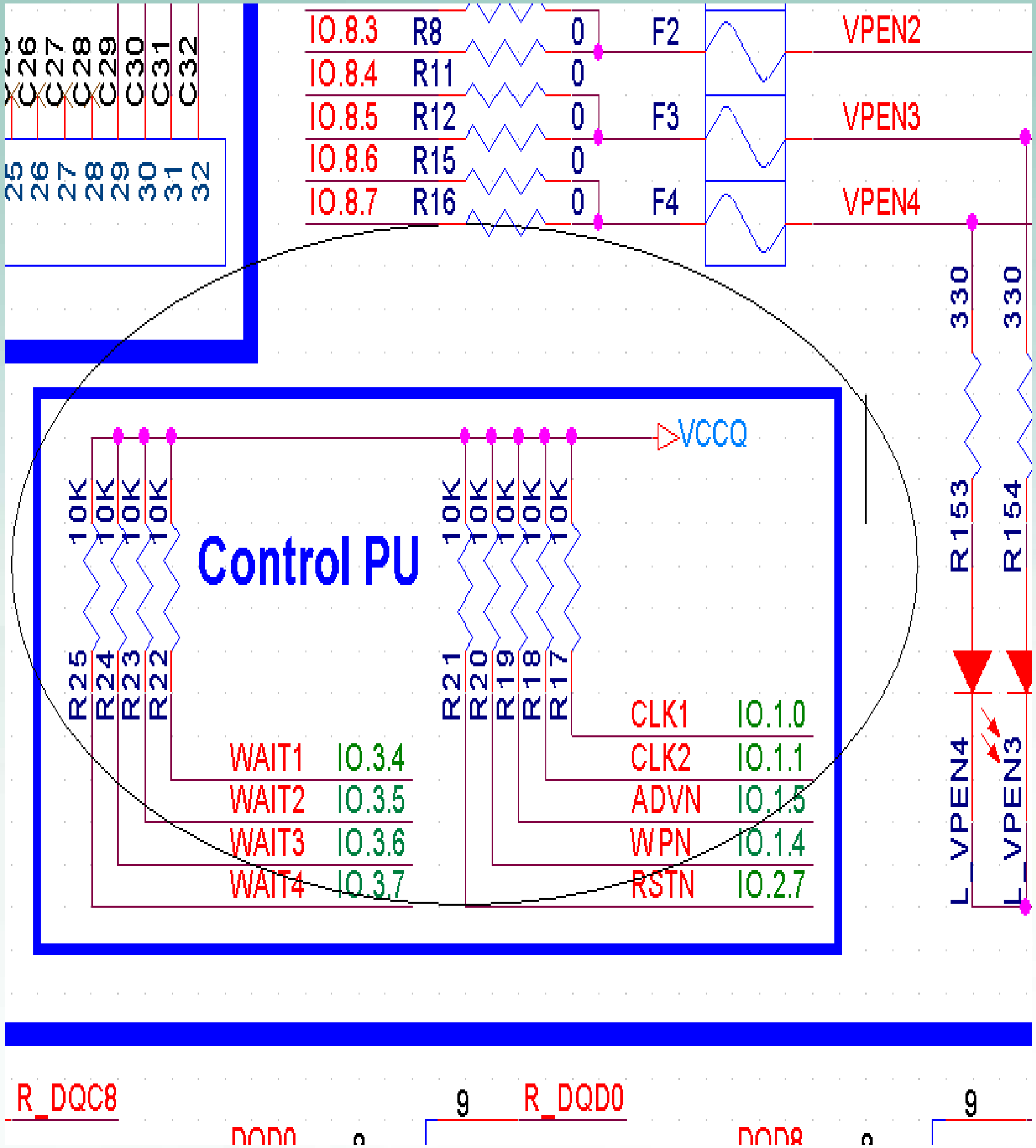
You can determine if BP is a viable option and which components should be Embedded

- Decide together with your PCB Manufacturer on the choice of the resistive sheet to be used in the design



Design flow

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, R14,R17,R18,R19,R20,R21, R22,R23,R24,R25,R27,R28, R29,R30,R31,R32,R33,R34, R35,R36,R37,R38,R45,R46, R47,R48,R49,R50,R51,R52, R53,R54,R55,R56,R57,R58, R59,R60,R77,R78,R79,R80, R81,R82,R83,R84,R85,R86, R87,R88,R89,R90,R91,R92, R113,R114,R115,R116,R117, R118,R119,R120,R121,R122, R123,R124,R125,R126,R127, R128,R142,R144,R146,R148, R161,R162,R163,R164,R165, R166,R167,R168,R169,R170, R171,R172,R173,R174,R175, R176	10K	br10k_005w_100
26	8	R3,R4,R7,R8,R11,R12,R15, R16	0	r0805
27	15	R93,R94,R95,R153,R154, R155,R156,R204,R205,R207, R208,R209,R210,R212,R213	330	br330_025w_100
28	1	R96	2.2K	r0805
29	4	R141,R143,R145,R147	1K	br1k_010w_100
30	1	R178	50K	r0805
31	1	R179	680	r0805
32	1	R180	200K	r0805
33	1	R181	500	r0805
34	1	R182	150K	r0805

97	R1,R2,R5,R6,R9,R10,R13, R14,R17,R18,R19,R20,R21, R22,R23,R24,R25,R27,R28, R29,R30,R31,R32,R33,R34, R35,R36,R37,R38,R45,R46, R47,R48,R49,R50,R51,R52, R53,R54,R55,R56,R57,R58, R59,R60,R77,R78,R79,R80, R81,R82,R83,R84,R85,R86, R87,R88,R89,R90,R91,R92, R113,R114,R115,R116,R117, R118,R119,R120,R121,R122, R123,R124,R125,R126,R127, R128,R142,R144,R146,R148, R161,R162,R163,R164,R165, R166,R167,R168,R169,R170, R171,R172,R173,R174,R175, R176	10K	r0805
8	R3,R4,R7,R8,R11,R12,R15, R16	0	r0805
15	R93,R94,R95,R153,R154, R155,R156,R204,R205,R207, R208,R209,R210,R212,R213	330	r0805
1	R96	2.2K	r0805
4	R141,R143,R145,R147	1K	r0805
1	R178	50K	r0805
1	R179	680	r0805
1	R180	200K	r0805
1	R181	500	r0805
1	R182	150K	r0805

Embedded BOM

Conventional BOM

Design flow

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

➢ Create component library

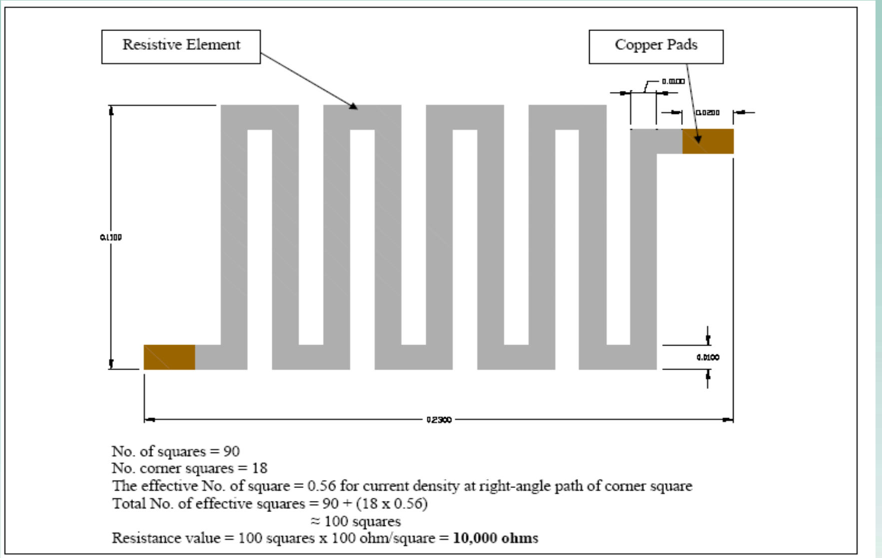


Figure 3: 10,000 ohms resistor footprints

➢ Generate components
minimize component area and material use

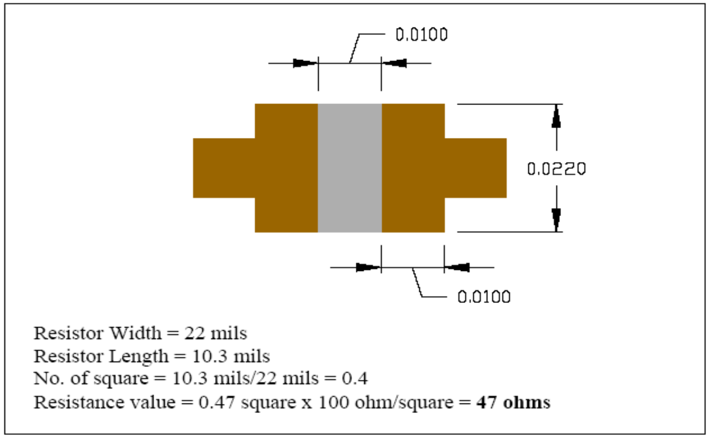


Figure 1: 47 ohms resistor footprint

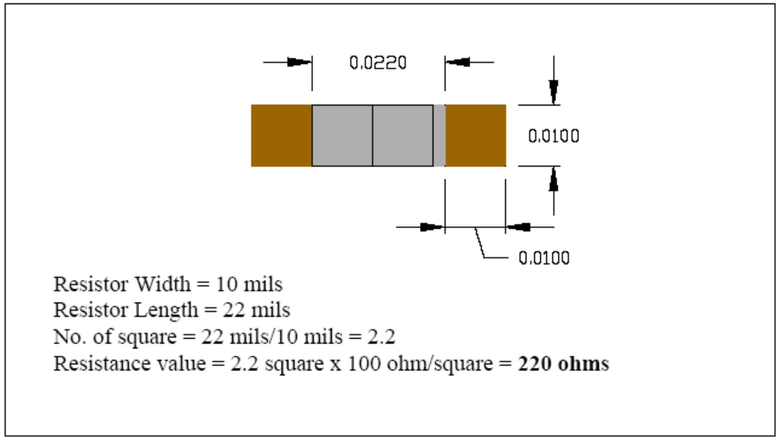
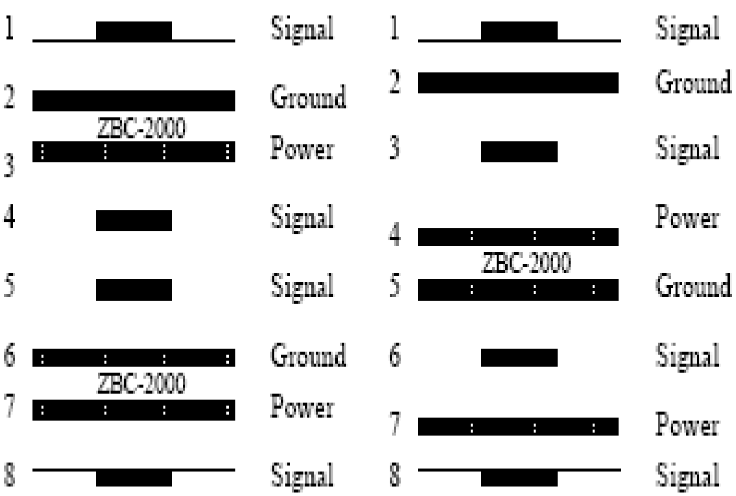


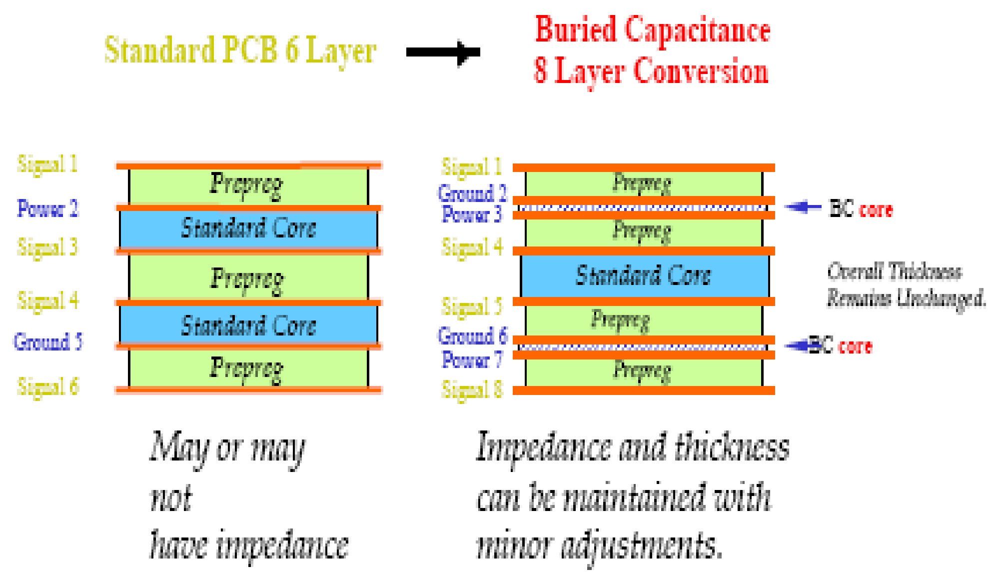
Figure 2: 220 ohms resistor footprint

Design flow

- Design your stack-up
- Verify with your PCB manufacturer: feasibility, material, cost



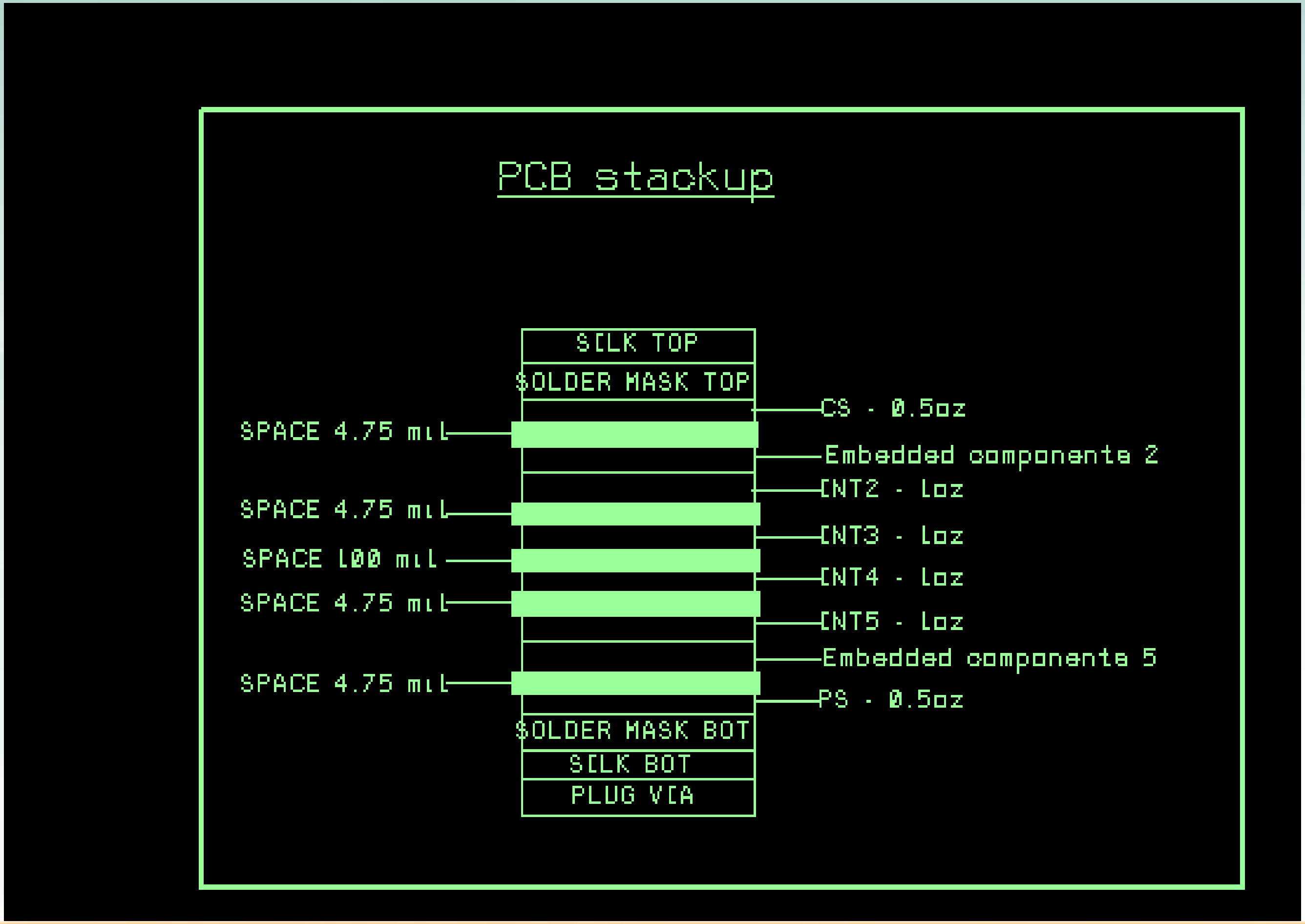
Eight Layer BC Layup
Figure 16



Design flow

- Update Stack-up
- BOM preparation for PCB manufacture indicating:
  - resistor value
  - in what layer
  - what tolerance

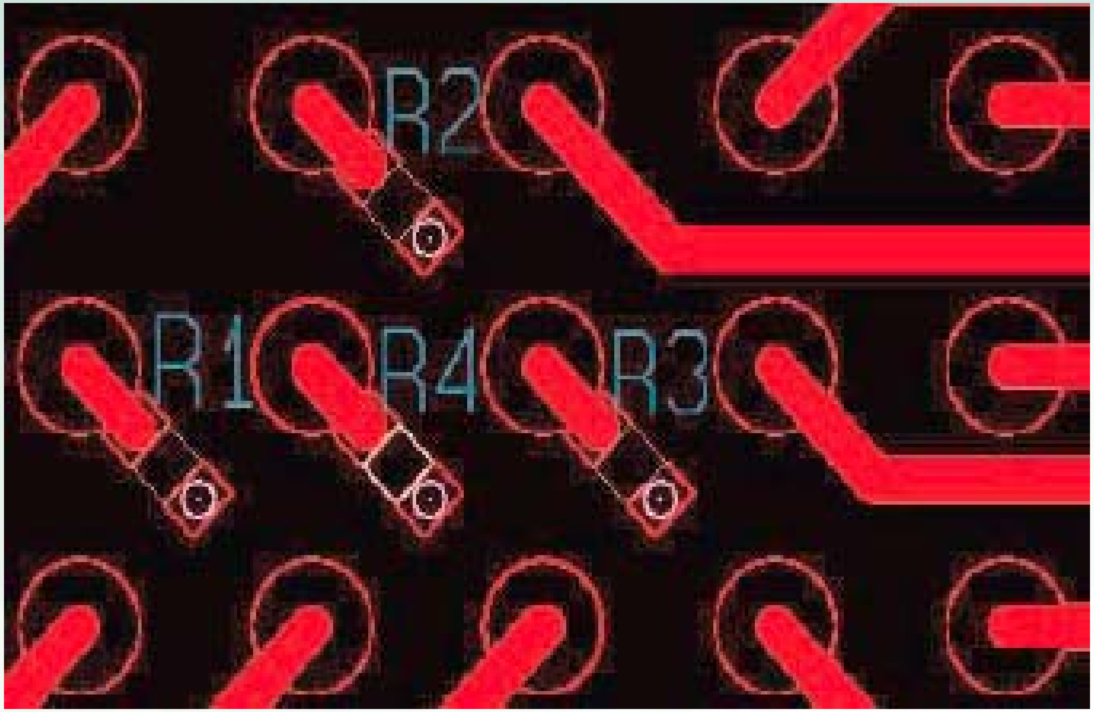
  is required



Design flow

Start Layout placement:

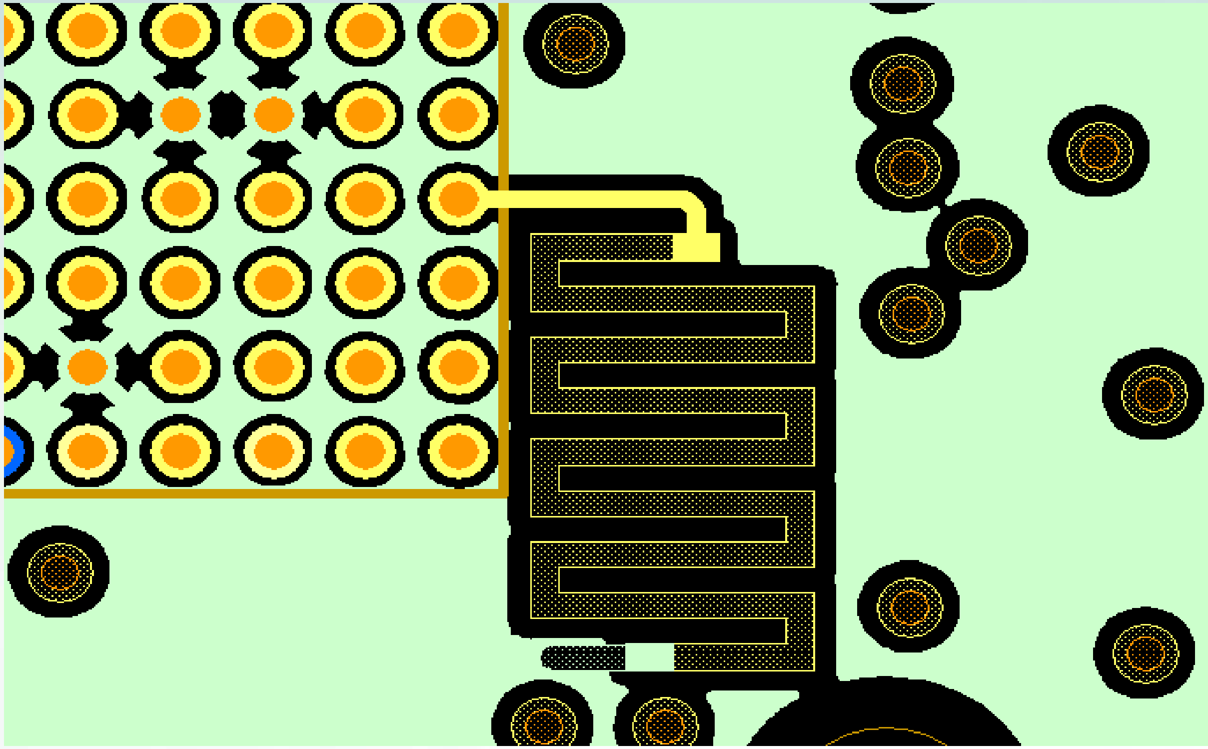
- Place main IC and components
- Place embedded passives in relevant layers



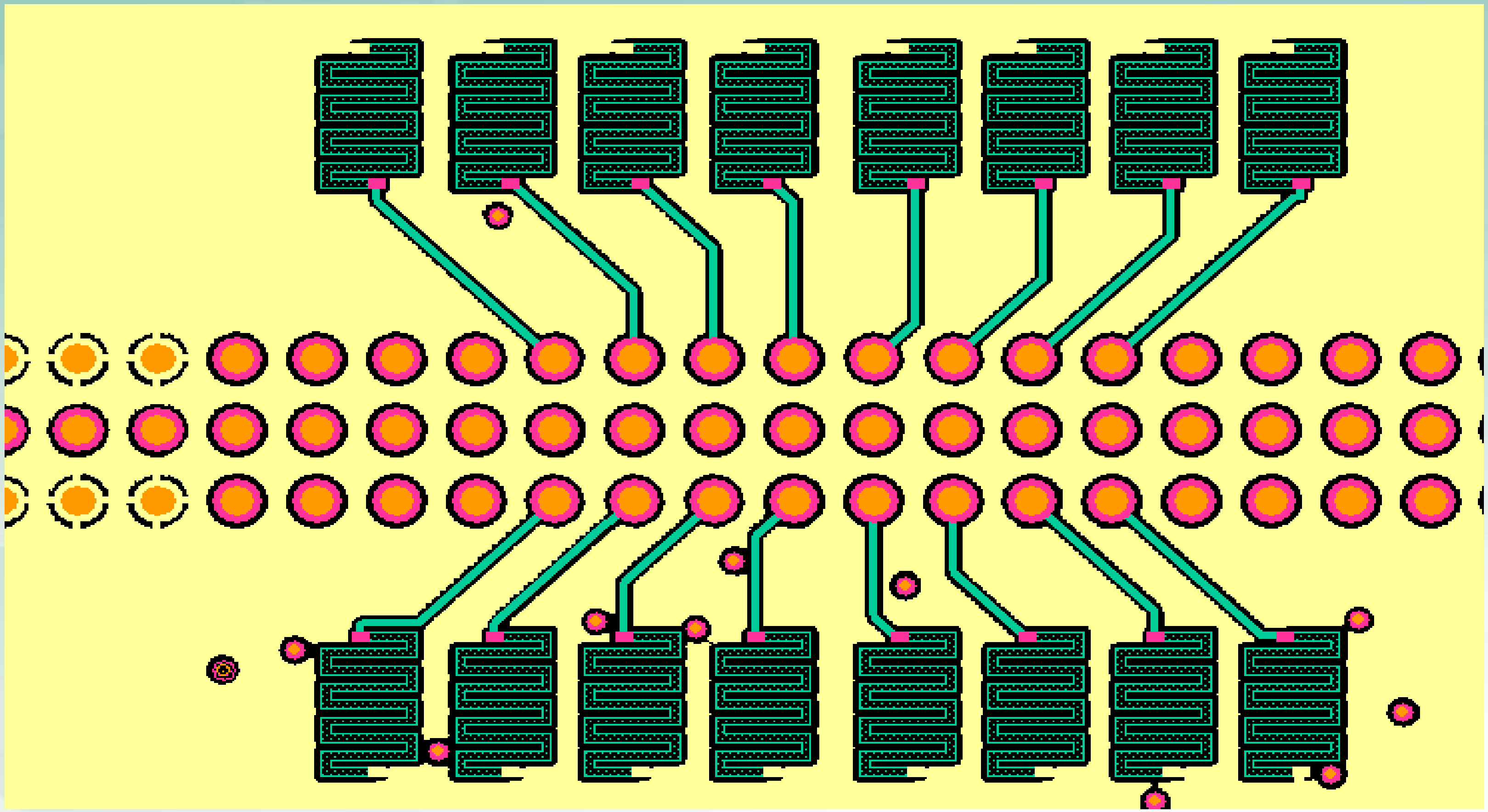
Design flow

Start Routing:

- Connect embedded resistors
- Leave open plane channels
- Power layer route

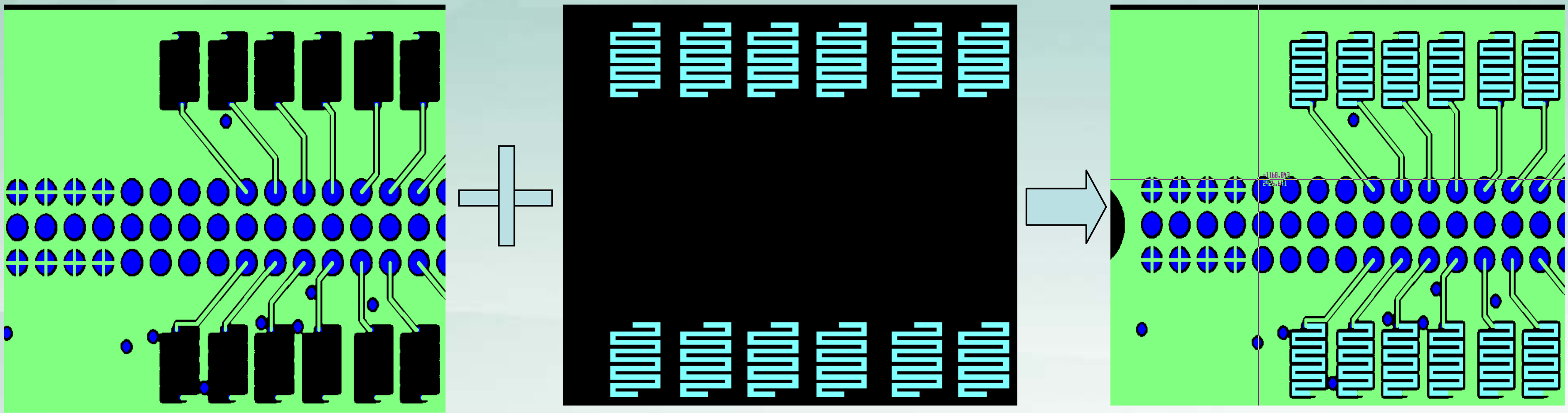


Design flow

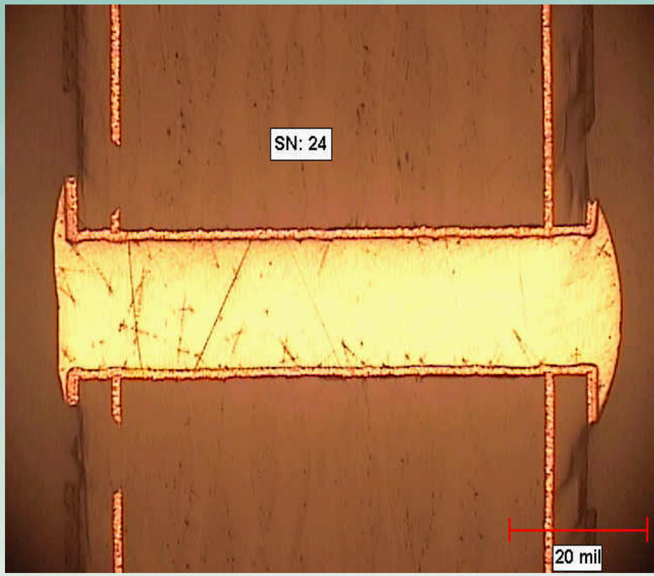


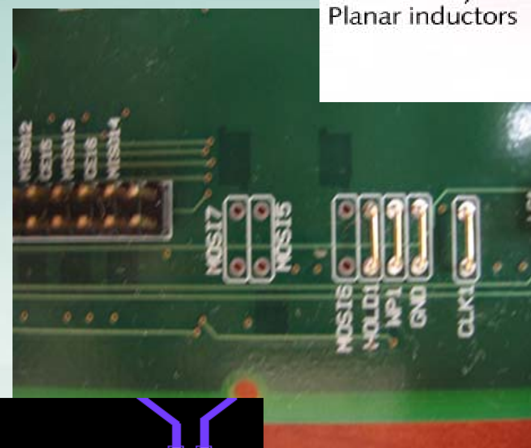
GND plane: Direct connection of the embedded resistors to the plane layer

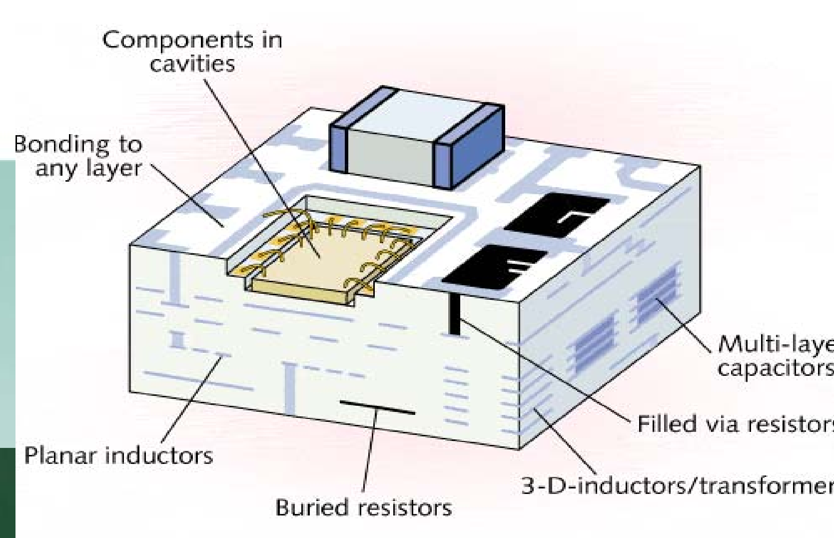
Design flow

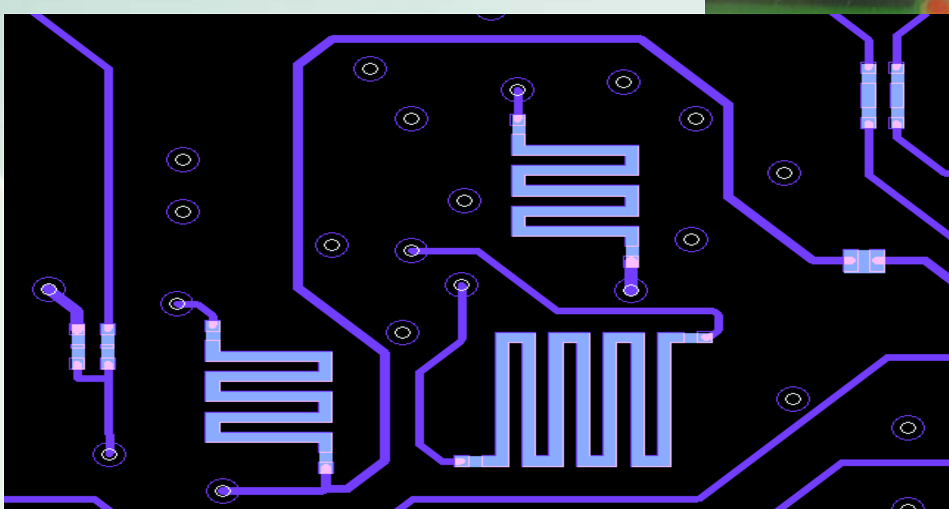


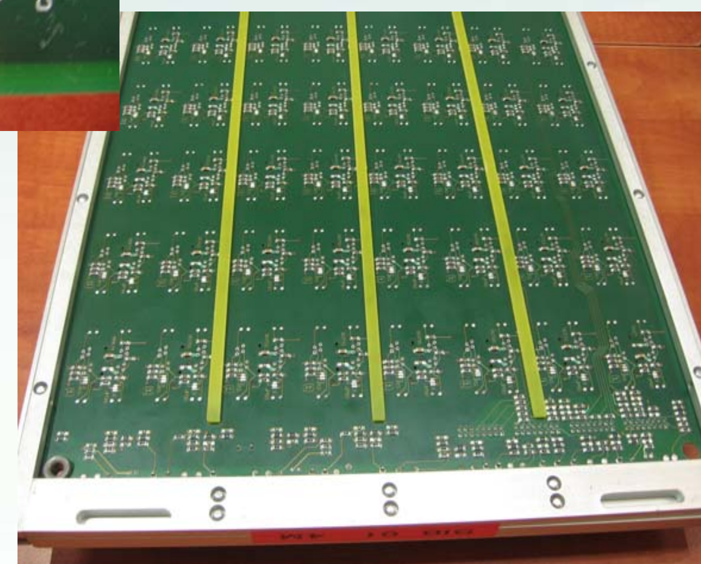
Gerber preparations: Superposition of GND and embedded resistor layers


SN: 24
20 mil




Components in cavities
Bonding to any layer
Multi-layer capacitors
Filled via resistors
Planar inductors
3-D-inductors/transformers
Buried resistors





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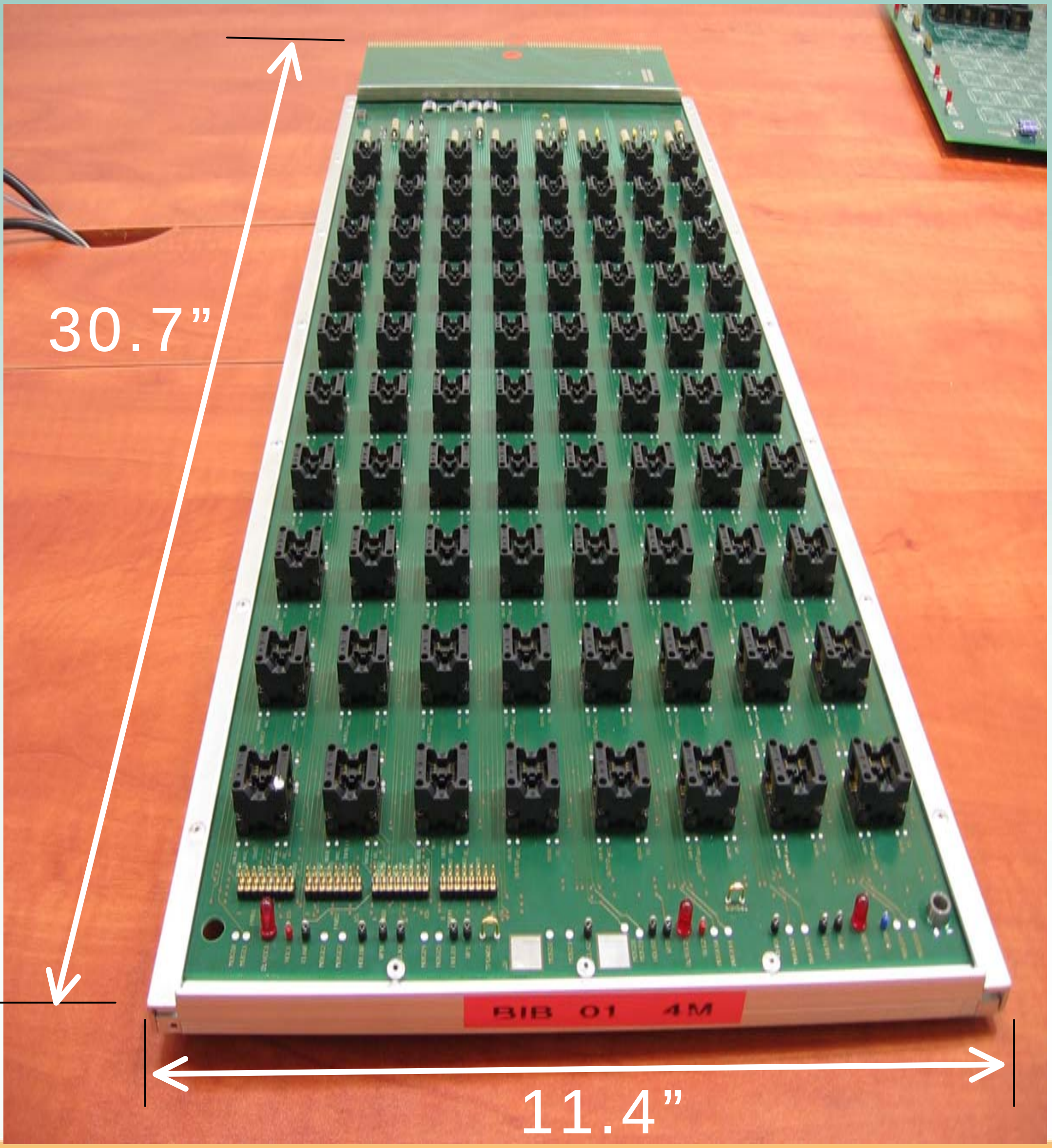
What have we gained?

- 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



Example (Mentor Graphics)

<u>Eliminating passives in assembly:</u>
Can resolve critical bottle necks in assembly!

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

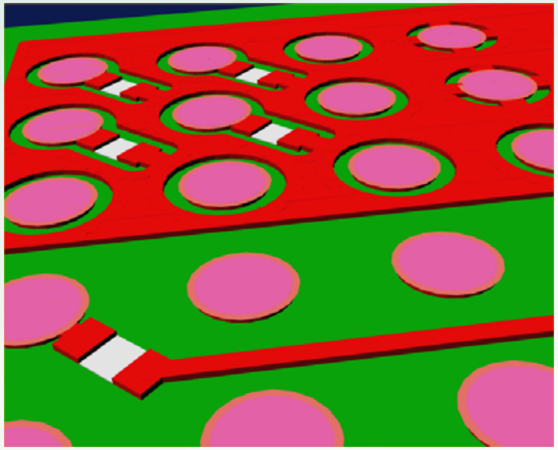
- **2000 fewer components in 100.000pcs @50k parts/hour: 166+ days less in the assembly line!**

.......@ 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-4811 Specification for Embedded Passive Resistor Materials.
IPC-4821 Specification for Embedded Passive Capacitor Materials.
IPC-4902 Specification for Materials for Embedded Passive

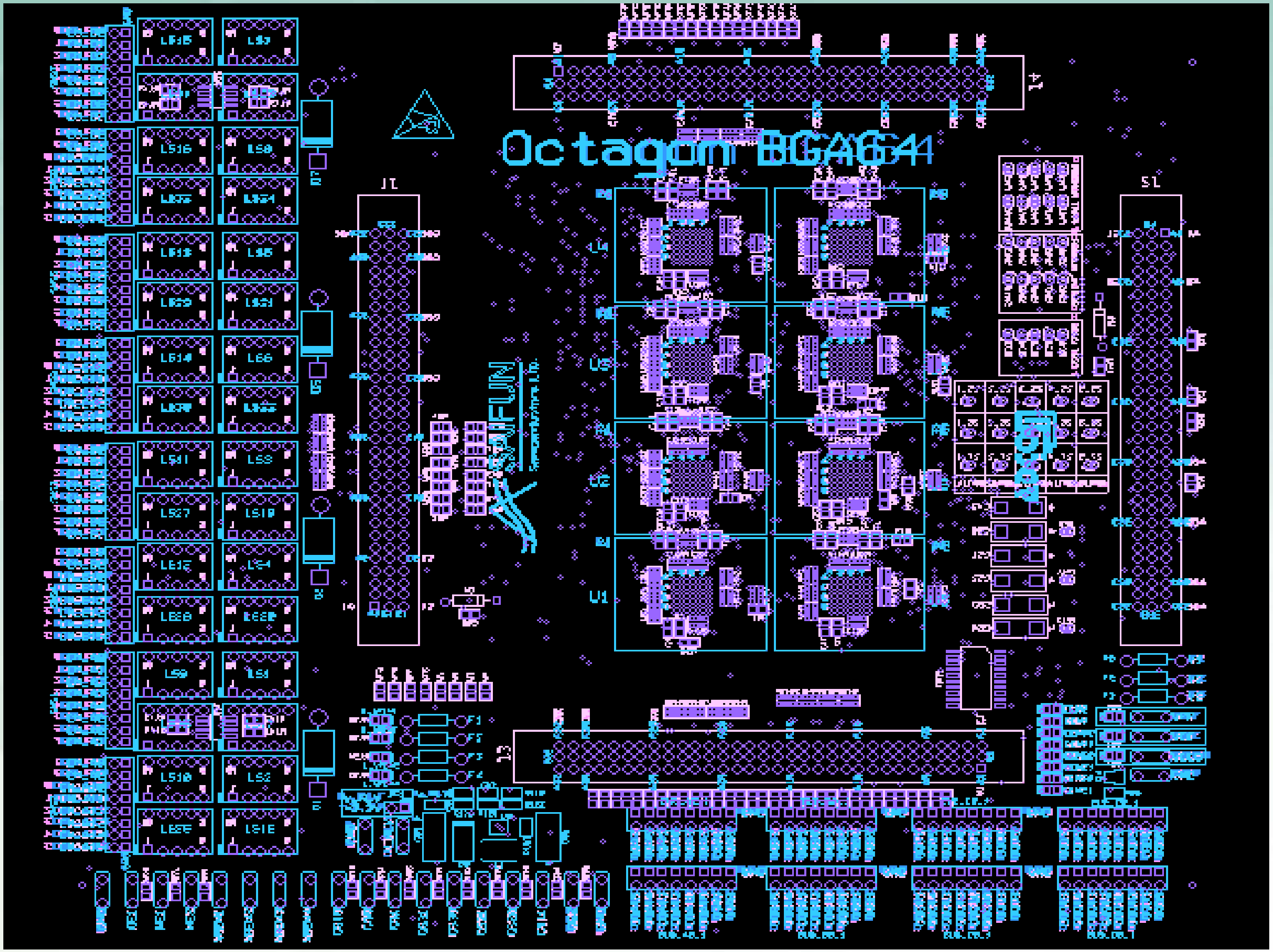


From the National Institute of Standards and Technology (NIST):

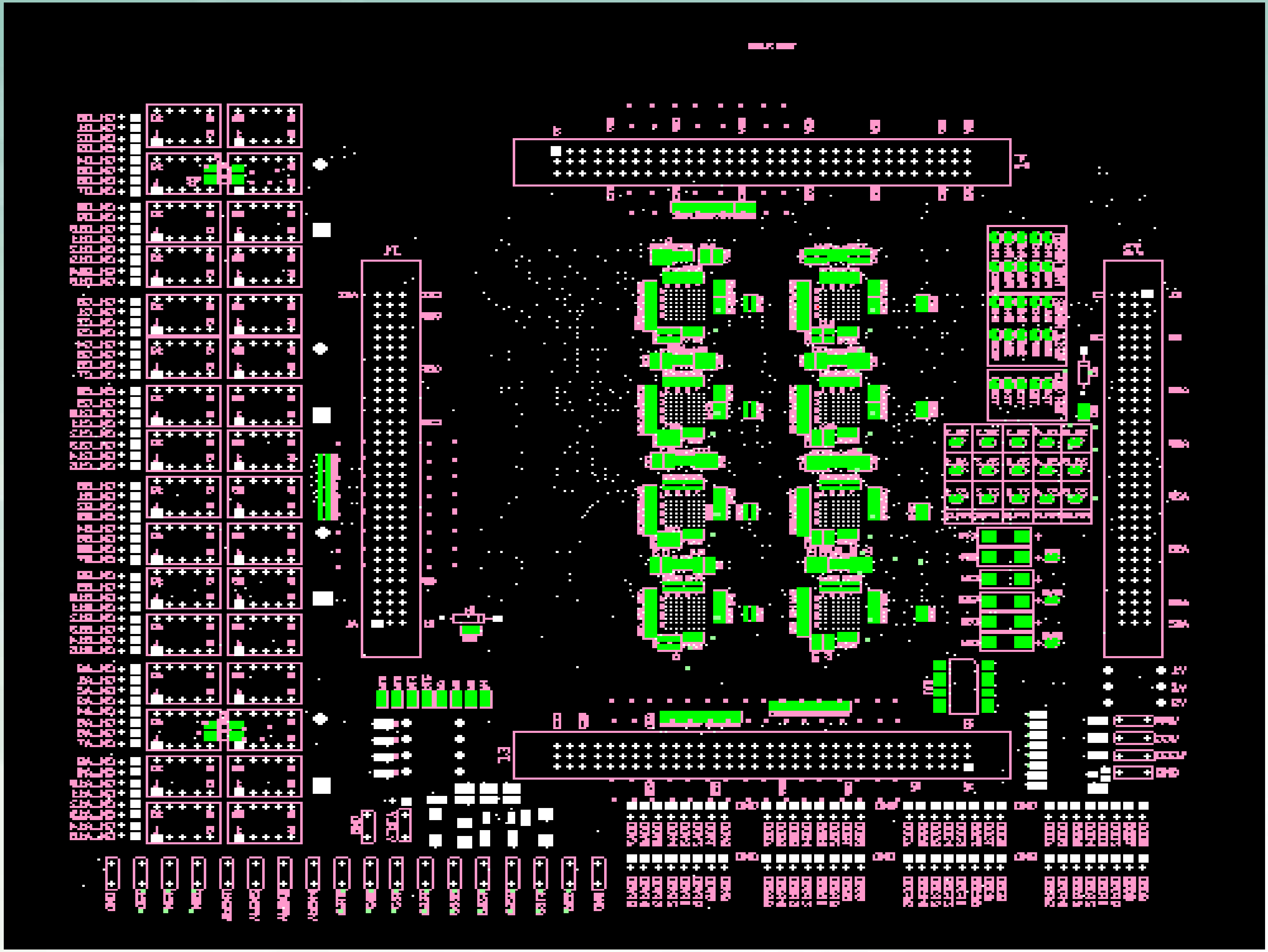
Embedded passives are seen as a key enabling technology in the National Electronics Manufacturing Initiative (NEMI) Roadmap.

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