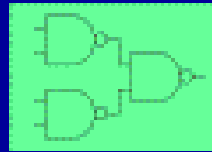
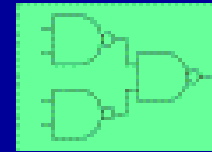


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# Electronics in High Energy Physics

*Winter Term: Introduction to Electronics in HEP*

Printed Circuit Boards (PCB) and Hybrids: Part 1  
Design and Assembly

Betty Magnin / TS-DEM

3 February 2005

# From schematic to assembly

A 3-step process



# Design of PCB layout

1. Design steps
2. Tools
3. Good practice

# Design of PCB layout

## 1. Design steps

- Select and create components
- Capture schematics
- Define mechanical layout
- Place components
- Define PCB stackup
- Routing
- Autorouting
- Post routing issues
- Create manufacturing and assembly documents

# Design of PCB layout

## Select and create components

- Search into libraries
- Select according to electrical requirements
- Select component package (PTH/SMD, QFP/BGA, ...)
- Create new components (standardize)

# Design of PCB layout

## Capture schematics

- Use hierarchical structure (pages, blocks)
- Insert all components (decoupling caps, safety components,..)
- Trace bus and interconnections
- Arrange the presentation
- Verify (NC, all 0V, grounds and power supplies, ... )

# Design of PCB layout

## Define mechanical layout

- Specific or standard formats (3U, 6U, 9U...)
- Mechanical requirements (fixing holes, cooling, ...)
- Position of components on the front panel

# Design of PCB layout

## Place components

- Electrical constraints ( Impedance, EMC, RF, ...)
- Mechanical constraints ( limited height, cooling...)
- Assembly process (PTH/SMD, top, bottom, clearance for machines,...)



# Design of PCB layout

## Determine the PCB layer stackup

- Even number of copper layers
- Symmetrical stackup
- Voltage planes next to ground planes to form embedded capacitors
- Impedance requirements

# Design of PCB layout

## PCB Routing

- Electrical requirements (line spacing and width, impedance, ...)
- Iterative process between placing and routing
- Consider manufacturing capabilities
- Add test pads (for automatic test fixture)

# Design of PCB layout

## Autorouting

- Saves time for simple designs or simple parts of complex designs
- Routes according to specified parameters
- Not always optimum in terms of PCB manufacturing cost and efficiency (increases number of vias and density of lines)
- Suited for small quantities

# Design of PCB layout

## Post routing issues

- Add identification (part name, number, revision, ...)
- Analyze the layout for potential signal integrity problems
- Add copper surfaces to equalize copper density
- Use CAD control tools to verify ( minimum line spacing, shorts or not connected, ...)

# Design of PCB layout

## Create specification for manufacturing and assembly

- Generate Gerber files for layers, use Extended Gerber (embedded apertures) format
- Generate drilling files
- Specify stackup and impedance controlled layers, laminate, marking, solder mask, finish required, hole plating requirements
- Create BOM and placing files for assembly
- Create a panel drawing (several PCB's on one panel)

# Design of PCB layout

## 2. Tools

- Design
- Documentation for assembly
- Archiving

# Design of PCB layout

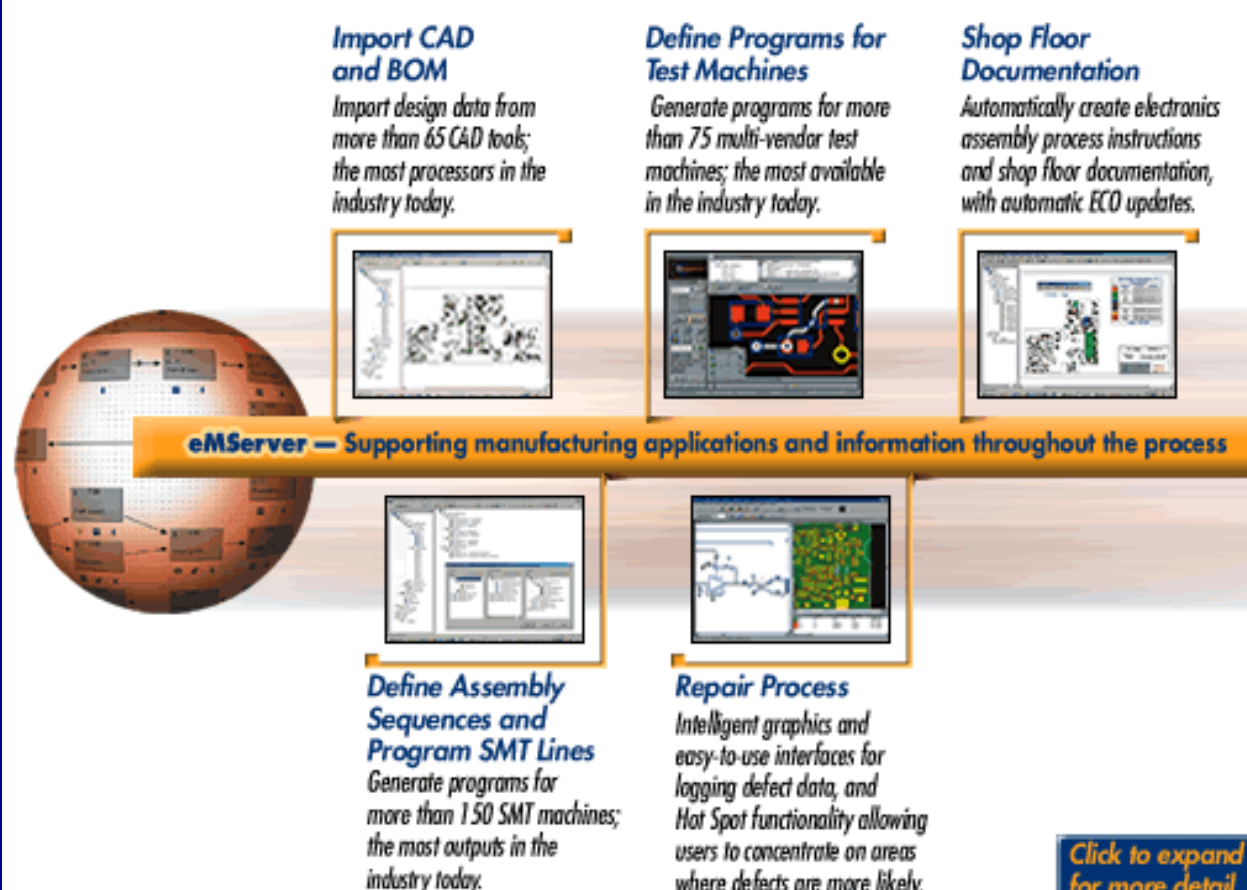
## Design

- PCAD, CADENCE : maintained at CERN (training, support by IT and design office, centralized CERN library, ...)
- MENTOR, PROTEL, Express PCB, Eagle, WinqCAD, Target 3AD, PCB123, CAD Design,...

# Design of PCB layout

## Documentation for assembly

### Fabmaster



**Import CAD and BOM**  
*Import design data from more than 65 CAD tools; the most processors in the industry today.*

**Define Programs for Test Machines**  
*Generate programs for more than 75 multi-vendor test machines; the most available in the industry today.*

**Shop Floor Documentation**  
*Automatically create electronics assembly process instructions and shop floor documentation, with automatic ECO updates.*

**eMServer — Supporting manufacturing applications and information throughout the process**

**Define Assembly Sequences and Program SMT Lines**  
*Generate programs for more than 150 SMT machines; the most outputs in the industry today.*

**Repair Process**  
*Intelligent graphics and easy-to-use interfaces for logging defect data, and Hot Spot functionality allowing users to concentrate on areas where defects are more likely.*

[Click to expand for more detail](#)



# Design of PCB layout

## Archiving EDMS

The screenshot displays the EDMS Item Page for BTV/MTV 1003. The page header includes the EDMS logo, navigation links (Home, Navigator, Search, Help, EDMS Site, News, Login), and the user name GUEST. The main content area shows the item details: Item Id: EDA-00879, Eq. code: -, ver. 0, and a status of In Work. Below this, there are tabs for Summary, B.O.M., As Built, Documents, Used in, and Versions & other info. The Documents tab is active, showing a list of documents with their IDs, descriptions, and status. The documents listed are:

| Document ID | Description  | Status   |
|-------------|--|----------|
| 523508 v.1  | BTV/MTV 1003 schematics<br>EDA-00879-V1_sch sch (3 Mb) pdf (1 Mb)  | In Work  |
| 523509 v.1  | BTV/MTV 1003 specification   | In Work  |
| 523510 v.1  | BTV/MTV 1003 PCB-layout<br>EDA-00879-V1_pcb pcb (2 Mb) pdf (571 Kb)  | In Work  |
| 523511 v.1  | BTV/MTV 1003 Board manufacturing data<br>EDA-00879-V1_specif xls (52 Kb) pdf (79 Kb)<br>EDA-00879-V1_mfg zip (419 Kb) pdf (1 Mb)   | Released |
| 523512 v.1  | BTV/MTV 1003 Assembly data<br>EDA-00879-V1_pcb-mat xls (475 Kb) pdf (84 Kb)<br>EDA-00879-V1_top pdf (6 Mb)<br>EDA-00879-V1_bot pdf (1 Mb)<br>EDA-00879-V1_assy zip (7 Mb)<br>EDA-00879-V1_PCB FAZ (9 Mb) | In Work  |
| 523513 v.1a | BTV/MTV 1003 Mechanical parts<br>EDA-00879-V1_a_fp dwg (724 Kb) gbr (88 Kb) pdf (162 Kb)   | In Work  |

# Design of PCB layout

## 3. Good practice

- Clearly specify all requirements before starting a layout: do it right the first time, rather than adding continuous changes will save time and problems (use check-lists and design reviews)
- Comply with manufacturing and assembly design rules when designing libraries and layout: fiducials, locating holes, minimum panel size, pads for wave soldering, distance around a component for inspection and repair, ...

# Design of PCB layout

## 3. Good practice

- Keep in touch with progress in technologies: Pb-free will have an influence on a layout !
- Comply with known standards: IPC working groups have already done the job
- Use all possible tools to verify each step (Cadence : Checkplus, ..)
- Provide a clear and complete job to manufacturing and assembly: they cannot guess what you expect if you do not tell them (write instead of say)

# From schematic to assembly

A 3-step process



# Assembly

- Components
- Variants of layouts
- Assembly steps
- Assembly process: automatic or manual
- Conditions for quality

# Assembly

## Components

- Through hole (PTH, Trad, ...)
- Surface mount (SMD, CMS, ...)
- Packaging : row, tape and reels, sticks, trays



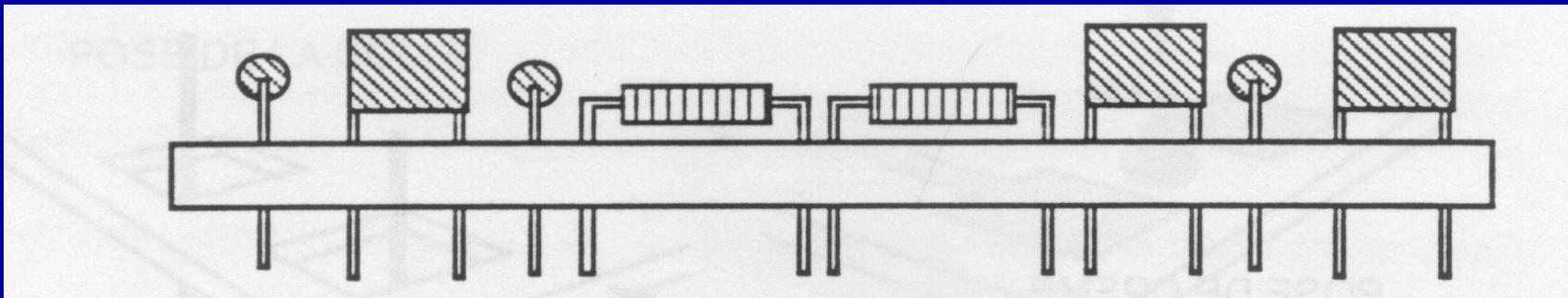
# Assembly

## Layout

- Components may be placed on several manners
- Each will have an influence on the process to be used

# Assembly

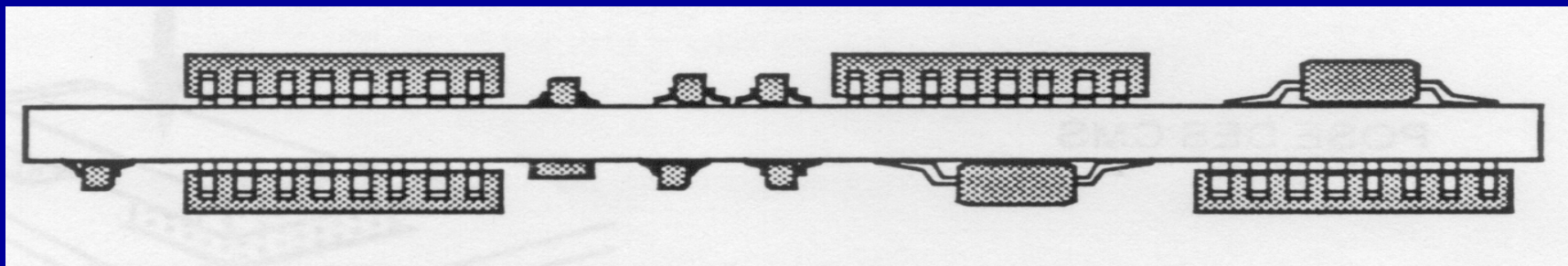
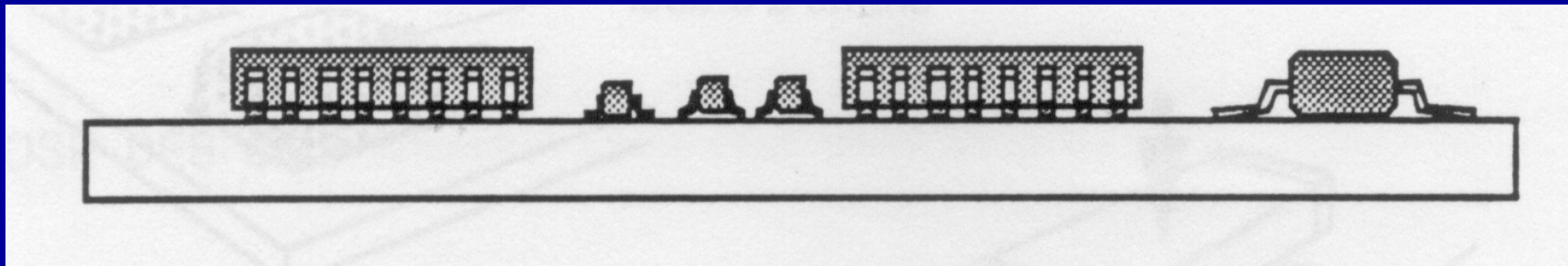
## Through hole





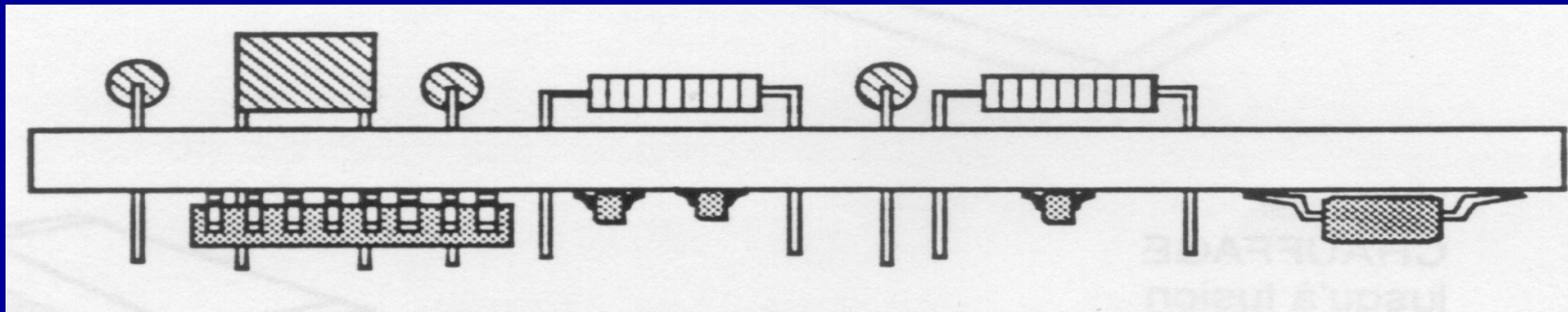
# Assembly

SMD, single side or both sides



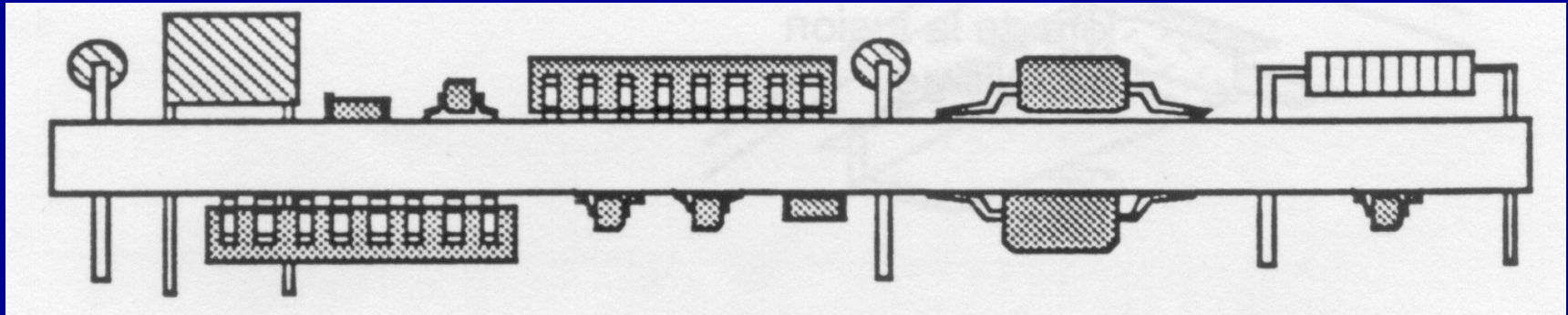
# Assembly

Trad + SMD-bottom



# Assembly

Trad + SMD-top + SMD-bottom



# Assembly

## Assembly steps

- Prepare components
- Mount
- Solder
- Clean
- Inspect
- Repair

# Assembly

## Assembly processes

- 100% machine
- 100% manual
- Mixed (used at CERN)

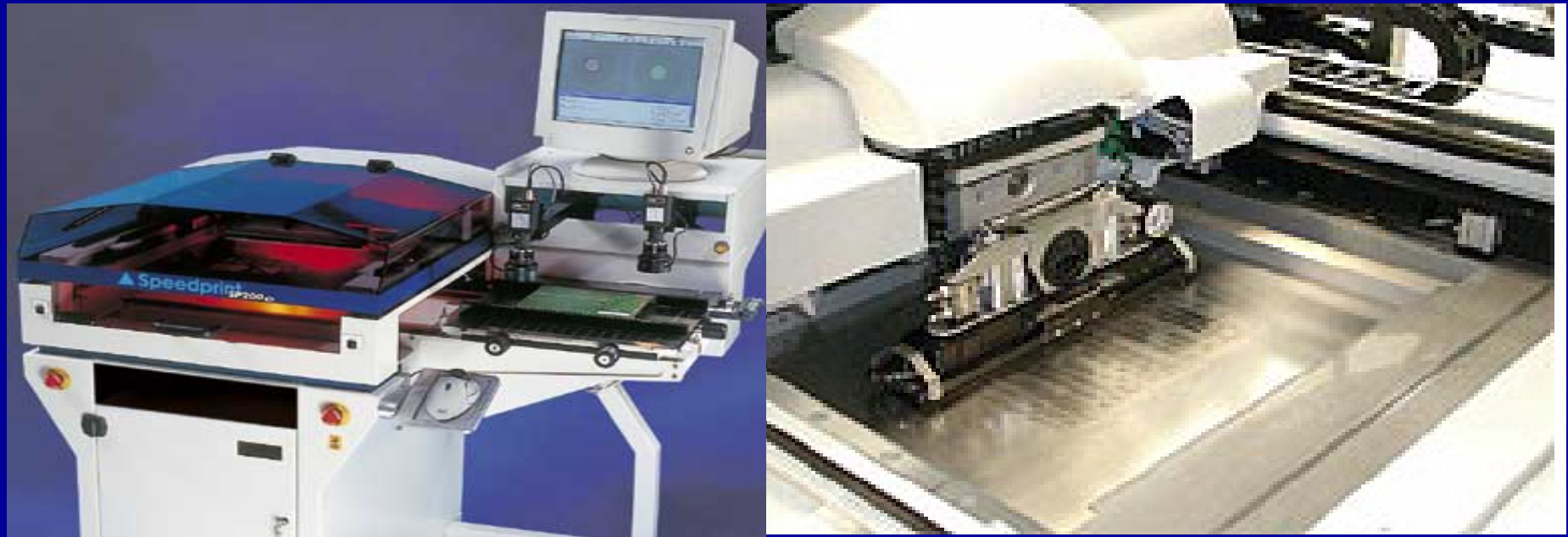
# Assembly

## 100% machine

- Process for series (>30 pieces)
- Manufacturing price is important for large quantities
- Components on tapes and reels or trays
- Board design must respect design rules (solder pads, fiducials, board sizes, spacing around components, ...)

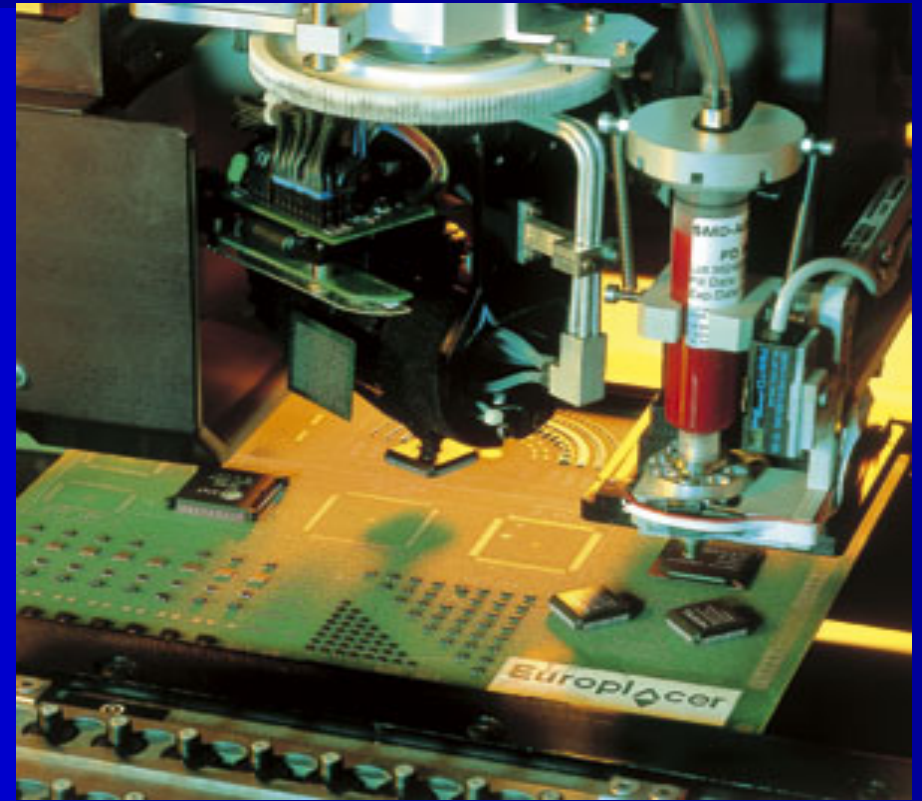
# Assembly

## Screen printing of solder paste



# Assembly

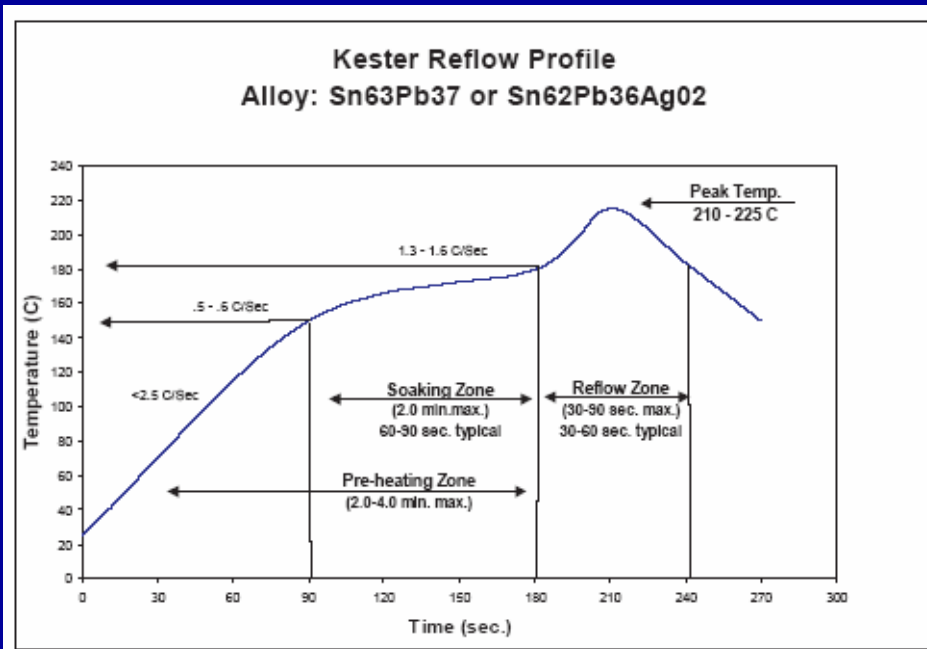
## Placement of SMD components





# Assembly

Reflow soldering: convection, IR, vapor phase



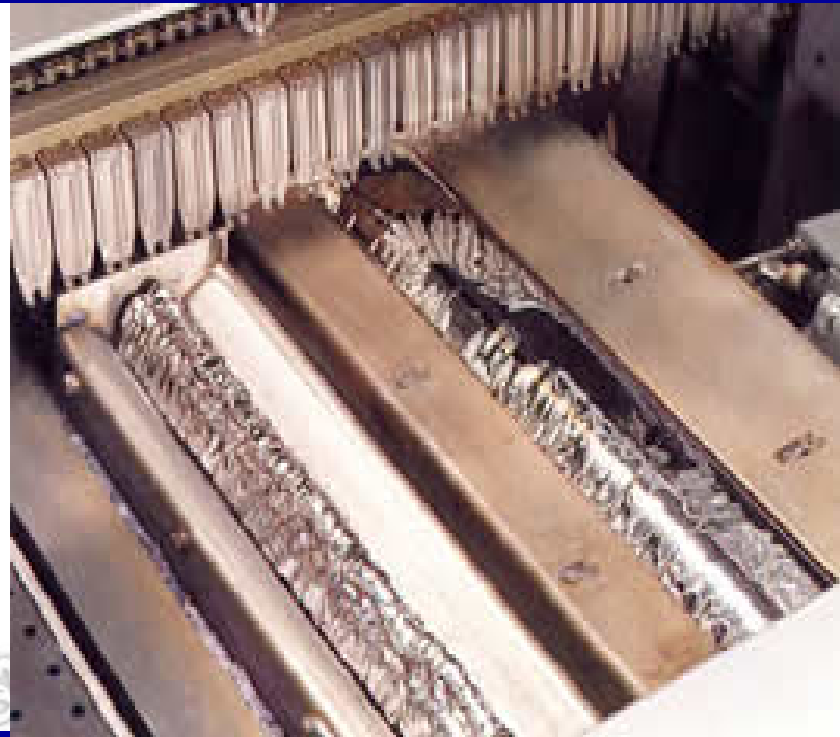
# Assembly

Insertion of through hole components, automatic or manual



# Assembly

## Wave soldering



# Assembly

Inspection  
AOI



# Assembly

Test: In-Circuit, flying probe, dedicated functional



# Assembly

## Manual or semi-manual process

- Process for prototypes or small series
- Handling of bulk components or parts of tapes is possible, but not preferable (risk in handling and placement of polarized components, ...)
- May use parts of automatic process (i.e.: placement of 100 coupling caps on 3 boards, reflow soldering, ...)
- Board design must respect design rules (SMD pads, free space around components, fiducial for solder paste dispensing or machine placement, ...)
- Expensive process

# Assembly

## Solder paste dispensing



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# Assembly

Placement



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# Assembly

## Hand soldering



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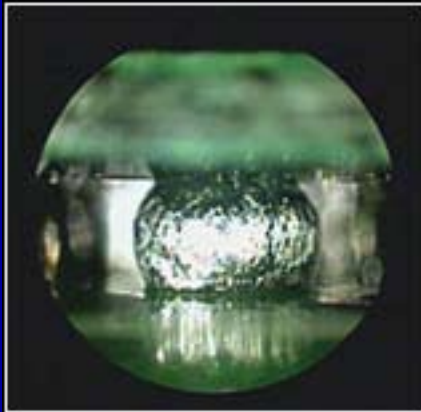
# Assembly

Visual  
inspection



# Assembly

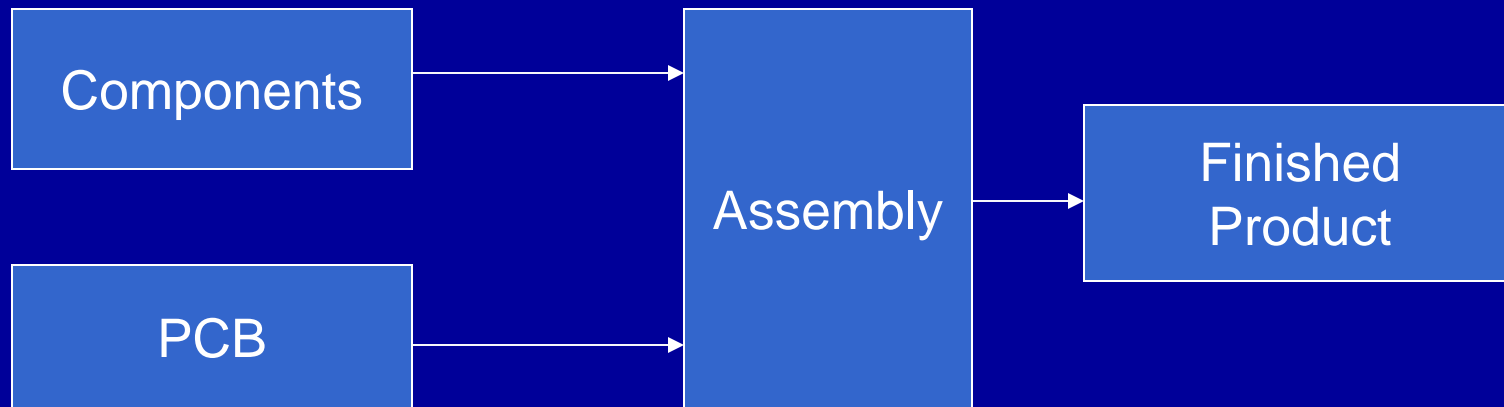
Repair



# Assembly

## Conditions for quality

- Quality of assembly process
- Quality of components
- Quality of design



# Assembly

## Quality of assembly process

- Machines and processes understood and under control
- Trained operators
- Repetitive results
- Cleanliness is mandatory for reliability

# Assembly

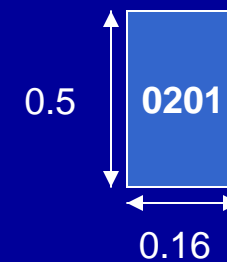
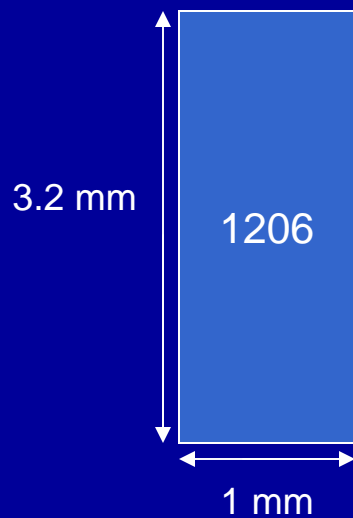
## Quality of components

- Protect from
  - Humidity
  - Static discharge
  - Mechanical damage (bent pins)
  - Oxidation
- Allow automatic handling
  - Even for manual process

# Assembly

## Quality of components

- PCB is the most important component
- Adapted to controlled process



- 1206 :  $12 * 0.001'' \times 6 * 0.001''$

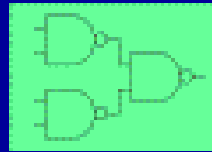
# Assembly

## Quality of design

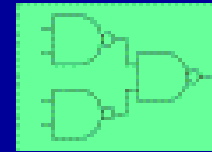
- Designer's functional requirements
- Manufacturing requirements
- Assembly requirements
- Compliance with tested standards (IPC)
- In phase with current technologies (lead-free)



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