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ELECTRONIC CONTRACT MANUFACTURER
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TECHNICAL PAPER



SMT VS. THROUGH-HOLE: CHOOSING THE RIGHT ASSEMBLY PROCESS

Where mixed technology makes sense, and how the choice affects yield and cost.

A practical guide for engineers and sourcing teams evaluating an outsourced assembly partner.

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ABSTRACT

Surface mount technology (SMT) dominates modern electronics assembly, enabling high component density, fine-pitch devices, automated placement, and cost-effective production at volume. Through-hole technology (THT), however, remains important where solder joints must withstand greater mechanical loads, carry higher current, or support connectors subjected to repeated insertion and removal. For many PCB assemblies, the right solution is not one technology or the other, but a deliberate combination of both.

That choice has consequences beyond component attachment. Mixing technologies can add soldering processes, handling, tooling, inspection, and labor, all of which can affect first-pass yield, cycle time, and assembly cost. The way SMT and THT components are divided across the board therefore becomes an important design-for-manufacturability (DFM) and cost decision.

This paper compares SMT and THT, explains what separates the two processes, identifies the applications best suited to each, and examines when mixed-technology assembly is justified. It also explores opportunities to replace through-hole components, particularly connectors, with surface mount alternatives when mechanical and electrical requirements permit, potentially eliminating an entire solder process and taking real cost out of a build.

Written for design engineers and sourcing teams evaluating an outsourced assembly partner, the paper provides a practical framework for selecting the right process before it becomes embedded in the design and quote.

PROCESS DECISIONS ARE COST AND RELIABILITY DECISIONS

Every component and footprint choice influences how a board will be assembled, and those decisions can determine much of the manufacturing process flow. When engineering specifies a through-hole connector without considering how it will be soldered, the assembler inherits the decision, often in the form of an additional soldering operation, more board handling, and recurring labor cost.

Choosing the assembly process deliberately, component by component, is therefore a high-leverage design for manufacturability (DFM) decision. The mix of SMT and THT components affects process flow, handling, tooling, inspection, yield, and ultimately assembly cost. Those choices should be driven by the product's electrical and mechanical requirements, reliability expectations, operating environment, and applicable IPC requirements, not simply by the contents of a reused component library.

WHAT SURFACE MOUNT BUYS, AND WHAT IT DEMANDS

In surface mount technology (SMT), the components are mounted and soldered to lands on the board surface rather than inserting leads through plated holes. This approach helped enable the miniaturization and automation that define modern electronics. SMT accommodates fine-pitch QFPs, BGAs, bottom-terminated packages, and passives down to 0201 and smaller, on one side or both sides of the board. In a typical SMT process, solder paste is stencil printed, components are placed by automated pick-and-place machines, and the assembly is soldered in a reflow process. The payoff is high component density, high placement speed, reduced lead parasitics for RF and high-speed designs, and low assembly cost at production volume.

SMT also imposes tighter process requirements. Stencil design and paste deposition must be carefully controlled, with IPC-7525 providing guidance for stencil and aperture design. Land patterns should follow established design standards such as IPC-7351 and component manufacturer recommendations to promote reliable solder joints and support component self-alignment during reflow. Copper distribution and thermal mass must also be properly balanced to reduce defects such as tombstoning.

Mechanical loading requires particular attention. Unlike a conventional through-hole termination, an SMT connection does not gain mechanical support from a lead extending through the board. Instead, the component is mechanically attached primarily through its solder joints and the copper lands to which they are bonded. For components subjected to significant vibration, shock, or repeated mechanical loading, those joints and lands may carry substantial mechanical stress. Connectors, switches, large components, and other mechanically loaded parts may therefore require additional mechanical support or a through-hole alternative. The decision should be based on the component, loading conditions, board design, and reliability requirements rather than mounting technology alone.

WHAT THROUGH-HOLE STILL DOES BETTER, AND WHAT IT COSTS

In through-hole technology (THT), component leads pass through plated holes and are soldered to the board, creating connections mechanically anchored through the PCB rather than attached only to surface lands. That mechanical strength remains one of THT's primary advantages. Connectors, transformers, large electrolytic capacitors, relays, and other mechanically loaded components may be subjected to insertion forces, cable loads, shock, or vibration that place significant stress on solder joints. Through-hole mounting transfers more of those loads through the lead and plated hole.

THT can also provide advantages for certain high-current and high-power components, where larger leads and plated-through-hole connection can provide substantial conductor cross-section to support demanding electrical and thermal loads. Through-hole joints are also generally easier to visually inspect and manually rework; benefits can be important for field-serviceable hardware.

These advantages come with a cost. Every through-hole lead requires a drilled hole and consumes routing area on inner layers through the board stackup. THT components may also require a soldering process separate from SMT reflow, such as wave, selective, or hand soldering, although pin-in-paste (PiP) can sometimes bring compatible through-hole components into the SMT reflow process. Taken together, these added process requirements can mean more handling, tooling, inspection, and labor, increasing cycle time and per-unit assembly cost, particularly as production volume rises.

WHEN MIXED TECHNOLOGY MAKES SENSE

Many PCB assemblies combine SMT and THT because different components impose different electrical, mechanical, and reliability requirements. The manufacturing question is therefore not simply which technology to use, but how to combine them with the fewest additional process steps.

A typical mixed-technology assembly is stencil printed, populated, and reflow soldered for SMT components, with a second reflow cycle added when SMT components are mounted on both sides of the board. Remaining through-hole components are then soldered using the process best suited to their number, location, and design. For boards with relatively few THT connections, selective soldering provides a programmable, localized process that limits solder exposure to specific joints. Hand soldering offers maximum flexibility for low volumes, prototypes, or difficult-to-access components, but is more operator-dependent and carries a high labor cost per joint.

Pin-in-paste, also called paste-in-hole or intrusive reflow, can eliminate a separate THT soldering operation for compatible through-hole parts by printing solder paste into or over plated holes, inserting the leads, and soldering them during SMT reflow. When through-hole content is high, wave soldering may provide greater throughput, but it introduces additional design and process considerations addressed in the next section.

The manufacturing implication is straightforward; every additional soldering operation adds handling, process time, and another thermal excursion. Minimizing those operations where design and reliability requirements permit can reduce manufacturing complexity, defect opportunities, and recurring assembly cost.

WAVE SOLDERING: EFFICIENT AT VOLUME, BUT DESIGN DEPENDENT

Wave soldering passes the underside of the PCB across a controlled wave of molten solder, soldering many exposed joints in a single pass. This makes it particularly efficient for assemblies with a large population of through-hole leads. Although primarily associated with through-hole assembly, wave soldering can also solder certain surface mount components placed on the bottom side of a mixed-technology board.

Those bottom-side SMT components must first be secured to the PCB with adhesive so that they remain in place as the inverted board passes over the solder wave. The adhesive is typically dispensed or printed beneath each component and cured before wave soldering. This introduces additional process steps for adhesive application, curing, and inspection, as well as potential defects such as insufficient adhesive, poor component retention, or adhesive contamination of solderable surface.

Wave soldering also imposes significant component and layout constraints. J-STD-001 establishes requirements applicable to soldered electronic assemblies, while IPC-7530 provide guidance for thermal profiling of soldering processes, including wave soldering. Many small, fine-pitch, area-array, and bottom-terminated packages are unsuitable for direct exposure to the solder wave. Very small chip components can also become increasingly difficult to process reliability as package size decreases. BGAs, QFNs, and similar packages therefore remain topside on the reflow-soldered side of the assembly. Even wave-compatible SMT packages must have accessible terminations and sufficient spacing to achieve reliable solder flow without excessive bridging or shadowing.

The process is best suited to through-hole components, and where appropriate, robust bottom-side SMT packages such as chip resistors and capacitors, MELF and SOT devices, and wider-pitch SOICs. Component orientation is critical because the direction of travel through the wave affects solder drainage, shadowing, and bridging. For leaded packages such as SOICs, solder thieves can be added beyond the trailing leads to draw away excess solder and reduce bridging.

Wave soldering is therefore most economical when the assembly is designed around the process and contains enough through-hole content to justify it. When only a few connectors or other through-hole components remain, selective soldering, pin-in-paste, or another localized soldering process may eliminate the tooling and process constraints associated with running the entire assembly through a solder wave.

HOW THE MIX DRIVES YIELD

Every soldering and board-handling step introduces another opportunity for defects. A single-sided assembly completed in one reflow pass generally presents fewer process risks than a double-sided board requiring multiple reflow cycles, wave soldering, and manual rework.

Each process introduces its own defect mechanisms. Reflow can tombstone small passives or bridge fine-pitch leads. Wave soldering can cause bridging, insufficient solder, and incomplete barrel fill, particularly when component orientation or board geometry creates shadowing or large copper areas draw heat away from through-hole joints. Additional thermal cycles can also stress components and solder joints that have already undergone reflow.

Reducing the number of process steps can therefore improve first-pass yield while lowering manufacturing complexity. Placing components on one side or converting suitable through-hole parts to pin-in-paste, for example, can eliminate an entire soldering operation, and the defect opportunities associated with it.

HOW PROCESS MIX DRIVES COST

SMT and THT create different cost structures as production volume increases. SMT concentrates cost upfront in stencil fabrication, machine programming, setup, and first-article verification, then uses high-speed automation to drive down the cost per placement at higher volumes. Through-hole assembly concentrates more cost in recurring labor and handling, so its cost per assembly typically declines less with increasing volume.

At prototype and low volumes, a few manually inserted and soldered through-hole components may be more economical than the tooling and programming needed for an automated selective-soldering process. At higher volumes, however, eliminating unnecessary through-hole components or converting suitable parts to pin-in-paste can reduce recurring labor and processing time.

The number of manufacturing steps matters as well. A second reflow cycle, wave-soldering operation, or selective-soldering process adds setup costs, handling, inspection, and cycle time. When the design permits, keeping SMT components on one side can therefore reduce cost compared with a double-sided assembly. The same principle extends to connectors, wiring, and box-build integration: every additional manual operation adds recurring labor that becomes increasingly significant as production volume grows.

CONNECTOR SELECTION CAN SIMPLIFY THE PROCESS

Connector selection can significantly influence the manufacturing process. Many board-to-board, wire-to-board, USB, RF, pin-header, and other I/O connectors are available in both through-hole and surface mount configurations. When an SMT version meets the electrical and mechanical requirements, it can often be placed and reflowed with the rest of the board, potentially eliminating a separate soldering operation.

Mechanical requirements remain an important consideration. Connectors exposed to repeated mating cycles, cable strain, or high mechanical loads may benefit from through-hole mounting or additional mechanical retention. Some SMT connectors incorporate hold-downs, board locks, or other mechanical features that transfer these loads into the PCB while allowing the signal terminals to be reflow soldered. Press-fit connectors provide another option for applications requiring robust mechanical retention without a soldering operation.

The objective is not to eliminate through-hole technology where it provides a functional advantage, but to select the termination method that meets the product requirements with the simplest practical manufacturing process. Evaluating connector options before footprints are finalized allows mechanical requirements and manufacturing efficiency to be considered together while design changes are still relatively easy to make.

DEFINE THE PROCESS WITH YOUR MANUFACTURING PARTNER

Engaging with your electronics manufacturing services (EMS) provider before design freeze allows the component mix, board layout, and production requirements to be reviewed together rather than after the manufacturing process has already been constrained by the design.

Once the applicable IPC requirements and other product-specific criteria have been defined, the EMS provider can map the assembly to an appropriate process flow, identify components that require special handling or soldering, and determine where practical design changes could simplify production.

The goal is not simply to minimize the number of process steps, but to establish the most efficient process that meets the product's performance, reliability, volume, and cost requirements. Making those decisions collaboratively before design freeze gives both engineering and manufacturing greater flexibility to achieve that balance.

KEY TAKEAWAYS

- **Component selection and layout shape the manufacturing process.** Decisions about package type, board side, component placement, and termination method determine which assembly and soldering processes are required. Evaluating those choices before design freeze preserves opportunities to simplify manufacturing.
- **SMT combines automation with high component density.** Stencil fabrication, programming, setup, and first-article verification create upfront costs, but automated placement and reflow improve manufacturing efficiency as volume increases. SMT also supports fine-pitch packages, high densities, and short interconnections required by many modern designs.
- **THT remains valuable where its advantages matter.** Connectors, transformers, large electrolytic capacitors, and other mechanically demanding or high-power components may benefit from through-hole mounting. The tradeoff is typically greater handling and recurring labor than highly automated SMT assembly.
- **Mixed technology assemblies require the right process mix.** Reflow, wave soldering, selective soldering, hand soldering, and pin-in-paste each have applications where they make technical and economic sense. The objective is to select the combination that meets product requirements without adding unnecessary manufacturing complexity.
- **Additional process steps create additional cost and yield considerations.** Multiple reflow cycles, wave or selective soldering, manual operations, and repeated board handling add setup, cycle time, inspection, and opportunities for defects. Where practical, process consolidation can improve manufacturing efficiency and first-pass yield.
- **Engage the EMS provider before design freeze.** Early DFM collaboration allows component choices, layout, production volume, and process options to be evaluated together. The goal is not simply the fewest process steps, but the most efficient manufacturing process that meets the product's performance, reliability, volume, and cost requirements.



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