

# A Coming Disruption: The Convergence of the Occam Process and Printed Electronics

For more than half a century, the electronics industry has advanced largely through incremental refinement of printed circuit board fabrication and circuit board assembly materials and processes. Line widths shrank, layer counts increased, signal integrity concerns rose in importance, surface-mount technology replaced through-hole components, and automated assembly became ubiquitous. Yet the fundamental paradigm has remained unchanged: i.e. rigid or flexible copper-clad laminates are fabricated through subtractive processes, components are manufactured separately, and their joining in assembly relies on solder-based interconnection.

Today, that paradigm is facing a potentially profound disruption. The convergence of **The Occam Process for electronic component assembly** with **printed electronics** introduces a new, minimalist manufacturing philosophy—one that reduces complexity, cost, material waste, and design constraints while enabling levels of integration not practical with conventional approaches to PCB manufacture and assembly.

This shift, we believe, is not evolutionary; it is architectural.

## The Limits of Conventional PCB and PCBA

Traditional PCB manufacturing is inherently inefficient and wasteful. Subtractive copper etching wastes significant material, multilayer stackups add cost and yield risk, this includes even semiadditive processing (SAP) and variations. Moreover, assembly requires dozens to hundreds of discrete components to be sourced, placed, soldered, inspected, and too often reworked to correct manufacturing defects. As systems grow more complex, designers compensate by increasing layer counts to accommodate redistribution wiring to complete wiring routes, adding rigid-flex transitions, or embedding components—each step raising cost and reducing manufacturability.

Moreover, traditional electronics manufacturing remains dominated by **serial process steps**: fabricate the board, fabricate components, assemble, solder, test, and package. Even advanced system-in-package (SiP) or module approaches still rely on the same fundamental flow.

In contrast, modern product requirements—ultra-thin form factors, conformal electronics, massive IoT scale, and cost pressure—are pushing against the physical and economic limits of this model.

## The Occam Process: A First-Principles Re-Think

The Occam Process is based on a simple but powerful principle: *eliminate unnecessary structure and process steps while preserving or enhancing function*. Applied to electronics, this means a complete rethinking by collapsing fabrication and assembly into a unified process where

**conductors, passives, interconnects, and even structural elements are created additively and selectively**, only where needed.

Rather than manufacturing a generic PCB and populating it with hundreds of discrete parts, the Occam Process enables:

- **Additive formation of interconnects** without copper-clad laminates
- **Selective integration of passive elements** directly into printed or deposited structures
- **Direct attachment or embedding of active devices** without conventional solder joints
- **Function-driven layouts** unconstrained by panelization, drill rules, or etch limitations

The result is not merely a different board—it is a different *system architecture*.

## Printed Electronics as the Enabling Platform

Printed electronics provide the foundational tools complimenting Occam's many features. Advances in inkjet, aerosol jet, screen, gravure, and hybrid additive techniques allow conductors, dielectrics, and semiconducting materials to be sequentially deposited on flexible, stretchable, rigid, or even three-dimensional substrates.

When combined with Occam principles, printed electronics enable:

- **Component reduction**, by printing resistors, capacitors, antennas, sensors, and interconnects directly
- **Geometric freedom**, including curved, conformal, and non-planar electronics with three dimensional routing
- **Material efficiency**, using only the conductive material required for electrical performance
- **Localized customization**, supporting mass customization without tooling changes
- **Potential for a customer run, lights out factory, driven by AI integration**

This convergence collapses the boundary between PCB fabrication and assembly, turning electronics manufacturing into a **single, digitally driven intelligent additive workflow**.

## Disrupting the PCB Supply Chain

The implications for incumbent PCB and PCBA industries are significant.

First, **layer count becomes irrelevant**. Functionality is achieved through spatial placement rather than stacked copper planes. Second, **assembly labor and equipment intensity drops sharply**, as fewer discrete components need placement and no wave or reflow soldering is required for many designs. Third, **inventory complexity shrinks**, since many passives are no longer sourced as components at all.

For OEMs, this means shorter supply chains, faster design iterations, and lower non-recurring engineering (NRE) costs. For contract manufacturers, it represents both a threat and an opportunity: traditional board shops risk disintermediation, while those that adopt additive, Occam-aligned processes can move up the value chain.

# Design Freedom and Functional Integration

Perhaps the most profound disruption lies in **design freedom**. Conventional PCB design is constrained by manufacturability rules rooted in subtractive processes—minimum trace widths, drill sizes, annular rings, and solder mask clearances. The Occam Process, combined with printed electronics, replaces these with **physics-based constraints**: current density, thermal dissipation, and signal integrity.

This enables:

- Electronics integrated into structural parts
- Load-bearing substrates with embedded circuitry
- Ultra-thin electronics for medical, wearable, and aerospace applications
- Distributed electronics architectures optimized for function rather than assembly convenience

In effect, electronics become a *material property* rather than a discrete subsystem.

## Progress in Conductive Inks vs. Plated Copper

A key question often raised is whether printed conductive inks can truly compete with plated copper. Historically, the answer was no—ink conductivity lagged copper by an order of magnitude or more. However, that gap is narrowing.

Modern silver nanoparticle inks routinely achieve **40–70% of bulk copper conductivity**, with some formulations exceeding this when properly sintered. Copper inks, once limited by oxidation, are now commercially viable through oxide-reduction chemistries, photonic sintering, and encapsulation strategies. Graphene-based and hybrid metal-carbon inks further expand the design space, offering flexibility, durability, and acceptable conductivity for many applications.

While printed inks may not replace plated copper in high-current or ultra-high-frequency backplanes, today, they are already *more than sufficient* for the majority of signal, sensor, antenna, and power-distribution needs in IoT, medical, automotive interiors, and consumer electronics. Importantly, Occam-based architectures often **require less conductivity overall**, because interconnect lengths are shorter and parasitics are reduced. In such systems, “good enough conductivity” paired with superior integration often outperforms traditional copper solutions.

# Economic and Environmental Impacts

Beyond performance, the Occam Process offers compelling economic and sustainability benefits:

- **Material waste reduction**, eliminating copper etch scrap and excess laminate
- **Lower energy consumption**, avoiding high-temperature solder reflow and multiple wet processes
- **Reduced capital intensity**, replacing large fabrication lines with digital, additive equipment
- **Improved recyclability**, through simplified material stacks

As regulatory and ESG pressures increase, these advantages will become increasingly decisive.

## Conclusion: From Boards to Built-In Electronics

The convergence of the Occam Process and printed electronics signals a transition from **boards as platforms** to **electronics as an intrinsic feature of products**. This is a very important shift that challenges decades of PCB and PCBA assumptions, but it also unlocks unprecedented opportunities for innovation, efficiency, and integration.

Just as surface-mount technology once redefined electronics assembly in the 1980s, Occam-driven additive manufacturing stands poised to redefine electronics *architecture*. Companies that recognize this early—and adapt their design, manufacturing, and business models accordingly—will help shape the next era of electronic systems.

The disruption is not hypothetical. It is already underway. You are invited and encouraged to join and help drive the shift.

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