



Design, Diagnosis, and Digitization for Efficient System Test and Analytics to Accelerate Time to Quality across the End to End Value Chain

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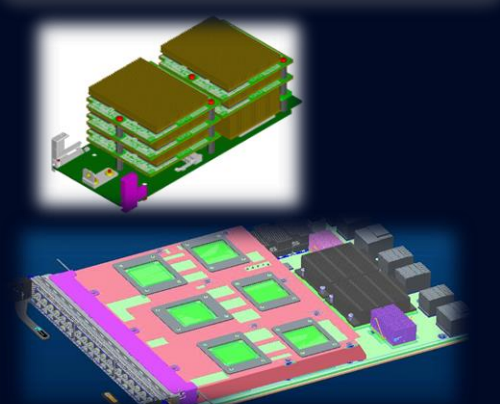
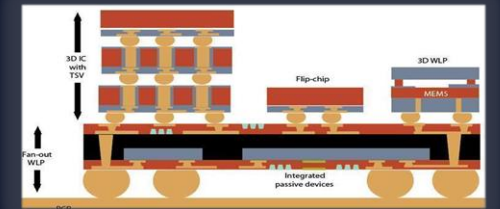
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Areas of Discussion

- KGD life over End-To End (ETE) Value Chain
- Where can KGD become Known Bad Die (KBD)
- Why KGD become KBD
- How to alleviate the problem
 - Orchestrating across multiple domains
 - Facilitating co-optimization with other components
 - Extending characterization
 - Expected results
 - ETE Analytics

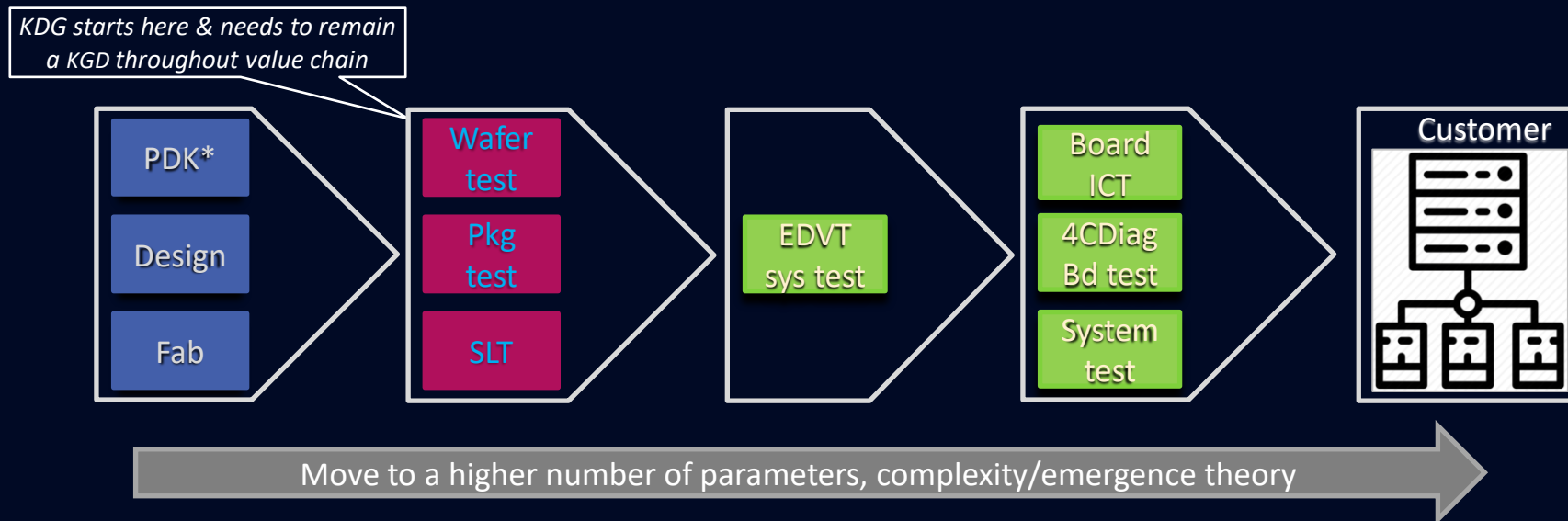
Known Good becomes Known Bad

- You test for a KG 'something' at any point in the ETE test flow.
 - You start with KGD, KGStack,
 - KGD in package/module,
 - KG part on board, KG part in system,
 - KG at customer in the ETE value chain.
- What is KG at one point, may not be good at the next step:
 - Can you detect it isn't?
 - If you can detect it, can you diagnose it?
 - Why does this happen?
 - From the diagnosis are you able to drive detection earlier to previous step or steps?
 - How can you avoid this in future?



ETE Value Chain Mapping - Technically

- We are operating in the multidimensional Value Chain.
- It is not just about our small space and what we do.
- Influence is from design to end product at customer
- It is about execution up and down the ETE value chain.



‘Complex’ system transpires where KGD behavior outcomes are affected by multiple dependencies. Emergence is coalescence of data into something meaningful.

Examples of What can go Wrong

Fab process

- Design vs wafer process interaction

WaferTest

- Design vs package process interaction
- No coverage of package, chip to chip interfaces, different thermal/voltage map

Package/
Heterogeneous/
Stack Test

- Test + temperature/power/voltage map does not fully represent system
- Limited functional coverage, PS/cooling ATE/system mismatch

SLT

- Margin assessment possible, lacks full system interoperability.
- Supplier bases development on limited set of specs from foundry that may not fully extend to manufacturing flow and environment in customer application + degradation requirements

System
Testing

- Functional test - first observation of interactions spawn more fails.
- Degradation effects observable

Each step widens interaction of die in environment, new parameters/settings can affect die performance.
Complexity Theory/Emergence: properties/behaviors emerge only when parts interact in a wider whole.

ETE Value Chain Mapping - Relationally



Moving to a higher number of technical parameters is one dimension

Another dimension complementing technical is relational

- Goal clarity: Plan upfront with ETE in mind.
 - Plan across domains. Build a common language. Be credible, sell proposal that is a win-win.
- Building a Guiding Coalition.
 - Build relationships for active Collaboration across all product functions (IP, design, test, yield, product dev, Q&R) to co optimize for performance, TTM, cost.
- Orchestrate Cross-Functionally and Outside-In.
 - Define Shared metrics with the end product in mind.
 - Enable data flow from the product (test, field) to supply chain to co-optimize process control and future design
- Embrace New Technologies. Test and Learn.
 - The greatest value in end-to-end supply chain projects are fueled by decision support technologies, cognitive learning and visualization analytics.
 - These are the infrastructures needed to sense, adapt and respond. They drive agility

Diagnosis Through Parameters & Data

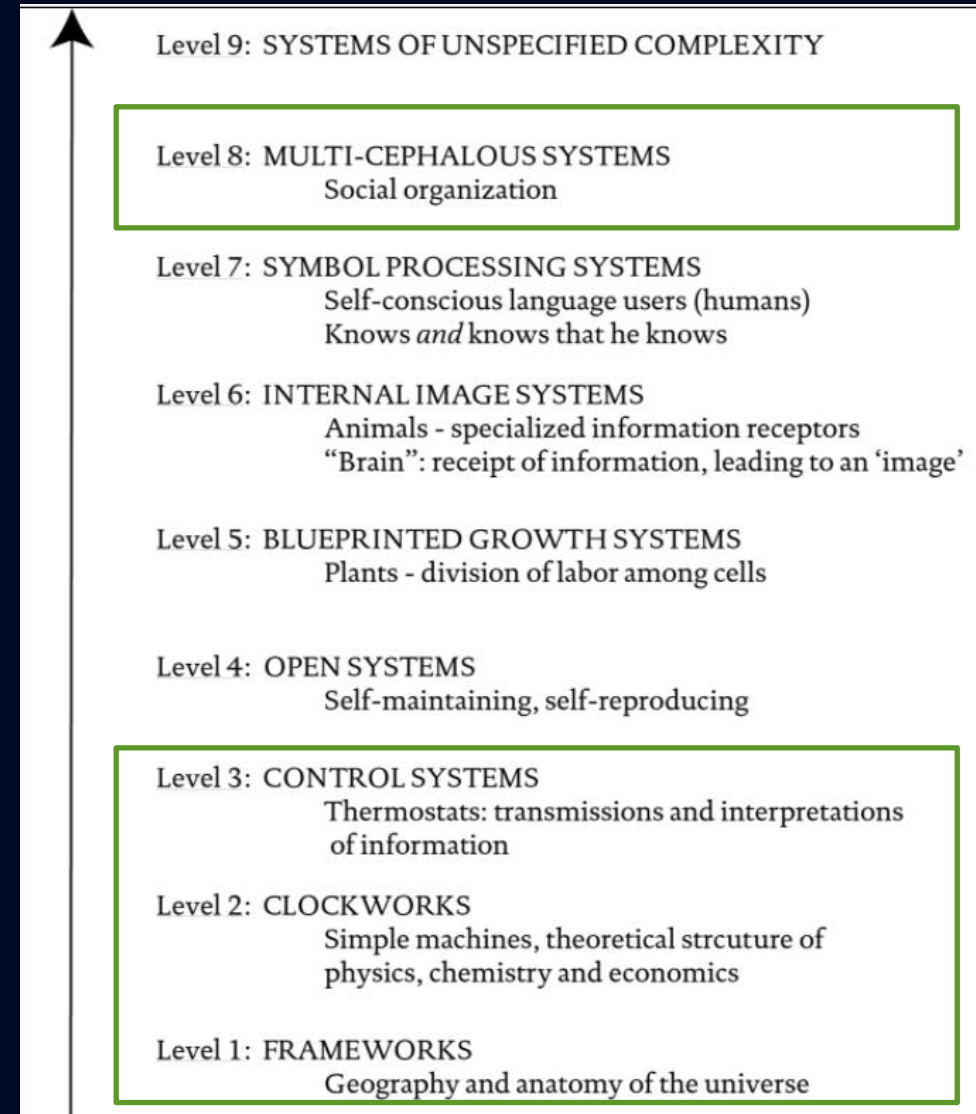
- **Parameters - if not 'spot-on' or 'addressed' effect yield, quality, and performance:**
 - Power / Power Integrity, thermal map
 - On die voltage map, noise margin, voltage bin
 - Signal Integrity (die/package), resistance, timing (margin)
- **This drives the need for:**
 - Fault isolation to sub-die
 - Margin matching across test steps and chip to chip, board to board
 - **Thermal/noise measurements** at all test steps
 - Reliability compliance
 - **WS data* as feedback** to foundry for improved process target and yield
 - Data to create best matching (**voltage bin, power, etc**) with other dies
 - **Voltage/Noise marginality** to comply with system PS requirements
 - **Thermal map/resistance** data to identify compliance with thermal map of other dies and system thermal solution

Complex Systems and Emergence

- *Complex Systems are systems in which large collections of components interact in nonlinear ways.*
- *Nonlinear interactions cause the whole to be “more than the sum of its parts”*
- *New system properties may result in Emergence*
 - forward motion emerges when a bicycle and its rider interoperate, but neither part can produce the behavior on their own.
 - ant colonies, cells, brains, immune systems, social groups, or economic markets exhibit emergent property: self-organization.

Cat vs Washing Machine*

- Simple: You push a button, say, a light switch, and get an exact response, with no possible ambiguity in the consequences
- But with complex systems, interdependencies are severe.
- Is “component” complicated or complex?
- “System with components” is one step further from a “washing machine” to a “cat”



*Nassim Taleb, “Antifragile”

Boulding, K. (1968). “General systems theory: The skeleton of science,” in Walter Buckley (ed.), *Modern systems research for the behavioral scientist*, Chicago, IL: Aldine, ISBN 0202300110, pp. 3-10.

Note on Formal Modeling and Simulation

- Because a complex system is usually composed of many components and their interactions, it can be represented by a network in which nodes represent the components and links represent their interactions.
- Complex networks can largely simplify real systems and preserve the essential information of the interaction structure that leads to emergent complex phenomena.

Revealing Interactions Across Domain Boundaries

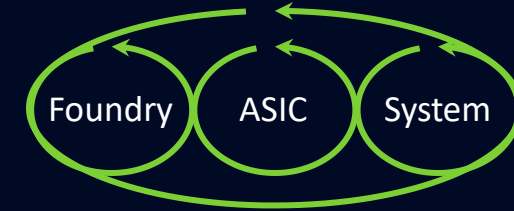
- **Improve coverage and real time Fault Isolation (FI)**
 - FI at MBIST, Scan, Functional test
 - Test insertions (e.g SLT) for earlier problem detection
- **Map circuit performance to environment**
 - Monitor environment (e.g. V/T/noise sensors)
 - Monitor process parameters: PMRO, in situ delay,
 - System cooling characterization (Simulations ,HS, TIM2,)
 - System Power Supply characterization
- **Map circuit performance over time**
 - In situ degradation: stressing PMRO/delay agents along with functional performance in HTOL and ORT
 - Validate degradation model → “just enough margin”



Design and Characterization to Discover Interactions

- **Top down (system → design → foundry):**
 - Map system and SLT results down to circuit margins and process performance.
 - Example: map transistor performance at WC customer system setup to WAT and design corner simulations
- **Bottom up (circuit → to system):**
 - Quantify high risk issues detected in component characterization into SLT/system.
 - Example: Quantify circuit parametric sensitivity (e.g. V_{min}) to V/T in customer system setup.

Expected Results



- **More realistic modeling**
 - S2S: certain IR-drop and thermal gradient has non zero probability to cause memory failure undetectable by BIST.
 - Yield model: will include system level yield loss dependencies
 - Q&R risk model: will add degrade of transistor across Lifetime to assess failure rate in the field
- **Application for ETE:**
 - S2S mechanism & FI model to be shared with foundry,
 - Cooling design (thermal gradient), system PS design (V noise),
 - SW- Functional test (extend similar tests),
- **Recap:**
 - Propagate margin from customer environment back in the form of specs: System -> Component -> Foundry -> Suppliers
- **Resource Allocation Philosophy:**
 - use model above to identify pareto, allocate resources towards bottle necks and major system constraints provides the best ROI

Extend Current Analytics to Cover for ETE and “across domain concept”

- **Goal:**
 - Capture all data in DB to create effective communication, provide data interface for every supplier to cover their design space
- **Data Features:**
 - Cloud hosting across all test insertions + supplier data + subset sharing with supplier
- **Enrich data by stage:**
 - Characterization/NPI, Pilot/HVM, Field

Mapping Back to “Extended KGD Philosophy”:

- **Addressing Complexity: Mapping from customer application to ‘known good’**
 - System/Module+Package/Die/Process/Incoming materials
- **ETE based approach:**
 - Extend design space (co-design/co-optimization) to stake holders/supply chain partners to preserve autonomy, maximize collaboration, align roadmap
- **Make the data tell the story:**
 - Improves collaboration across industry domains (e.g. materials, equipment, component, PCB, cooling, system, software)

Current Gaps and Solutions that may help

- ETE supply chain- enhance component/system design model abstraction to enable direct inputs from and co optimization with suppliers
- Map circuit performance to circuit environment – more advanced in die/in system sensing IP and data processing methodology
- Circuit performance over time- accumulate across industry degradation data for more relevant degradation model

References and Acknowledgement

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Carrier Solutions for Known Good

Vacuum Release Carriers

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KGD Handling



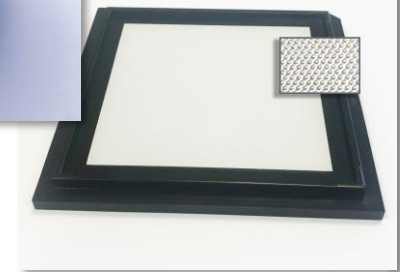
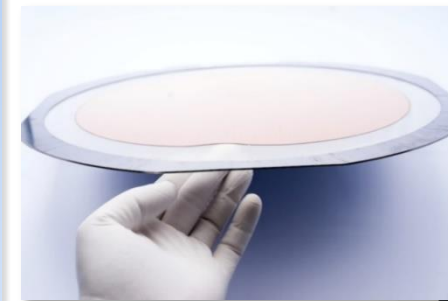
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