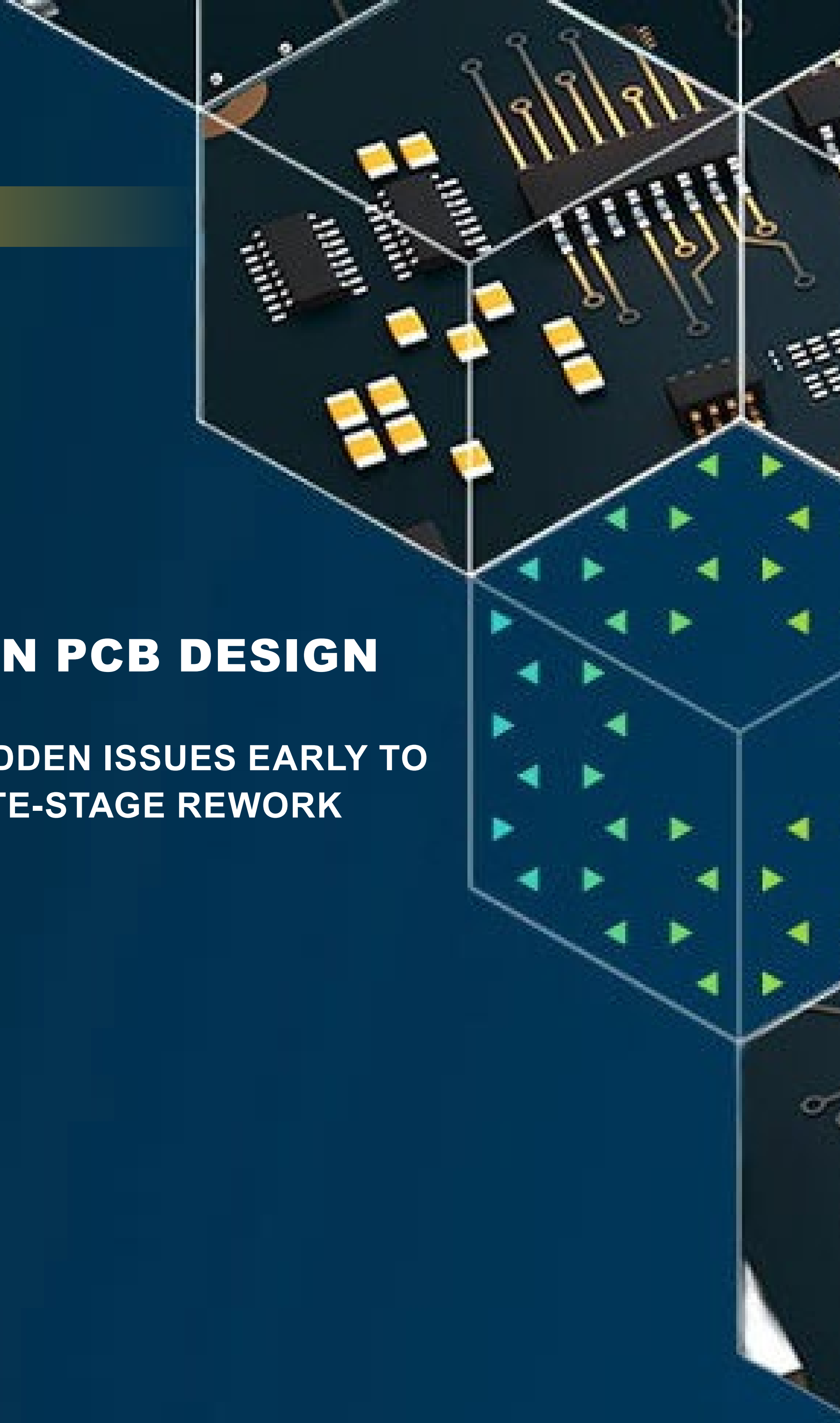
eBook



SHIFT LEFT IN PCB DESIGN

HOW TO CATCH HIDDEN ISSUES EARLY TO AVOID COSTLY LATE-STAGE REWORK

cādence®

SHIFT LEFT IN PCB DESIGN

HOW TO CATCH HIDDEN ISSUES EARLY TO AVOID COSTLY LATE-STAGE REWORK

Design issues in PCBs rarely appear out of nowhere. More often, they're introduced early in the design process but aren't discovered until layout, prototyping, or even manufacturing. That's where delays, redesigns, and added costs pile up.

This ebook explores the concept of **Shifting Left** in PCB design or moving issue detection and decision-making earlier in the design lifecycle. In this eBook, you'll learn why traditional workflows allow problems to surface too late, how those issues impact schedules and budgets, and what modern PCB teams are doing to identify risks sooner.

Using real-world PCB challenges as examples, this eBook walks through the most common problem areas including:

- Component selection
- Electrical functionality
- Reliability
- Mechanical fit
- Electrical performance
- Manufacturability
- Release to manufacturing

This eBook is a practical guide showing how to find, fix, and optimize early to improve your design process and outcomes. It explains how catching these issues earlier leads to faster design cycles, fewer respins, and more predictable outcomes and investigates the future of shift-left PCB design including transitioning from issue prevention to design optimization and incorporating AI.

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THE HIDDEN COST OF LATE-STAGE PCB ISSUES

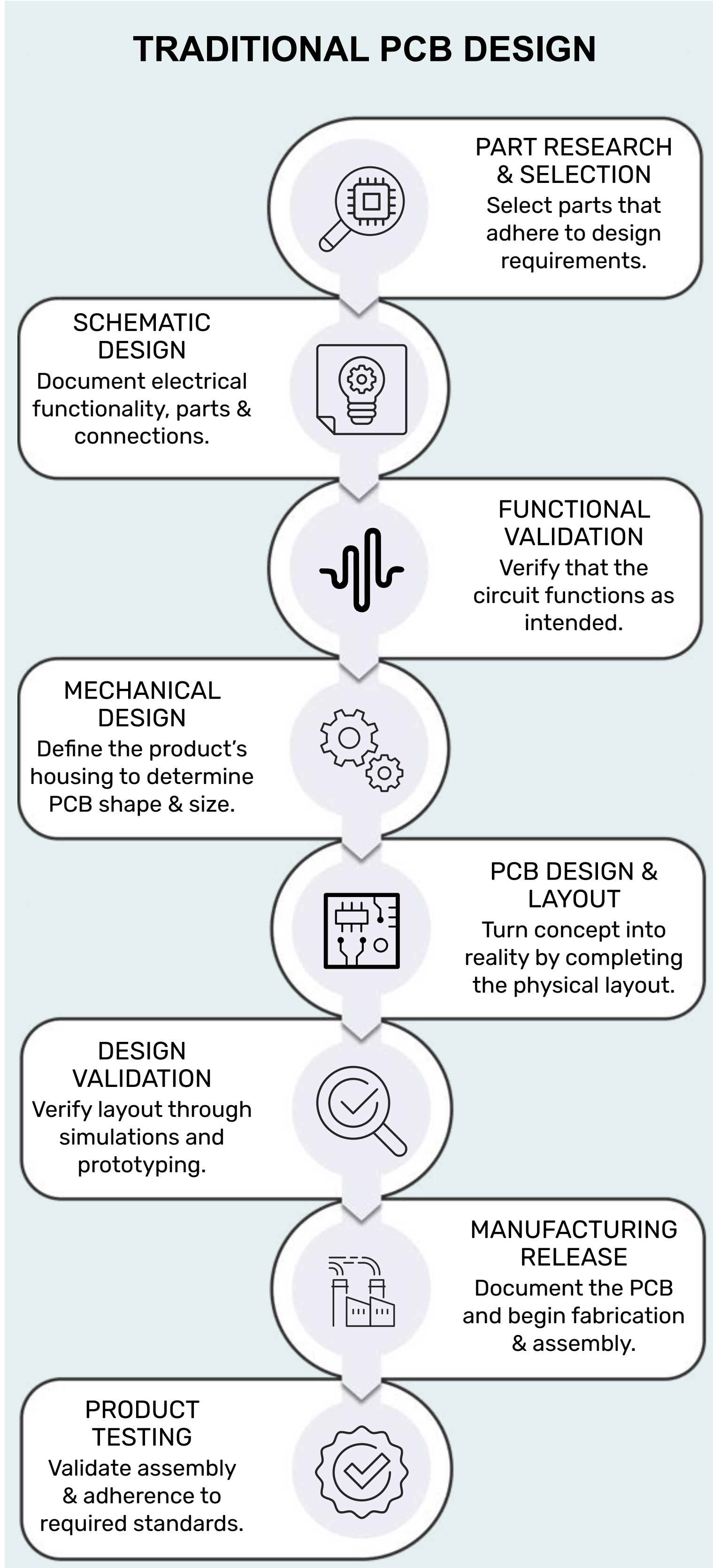
Modern PCB design has evolved into a highly complex, multidisciplinary challenge. It's no longer just about connecting signals or fitting components onto a board. Today's engineers must simultaneously balance electrical performance, manufacturability, supply chain constraints, mechanical integration, and increasingly aggressive development timelines.

With a traditional PCB workflow, achieving that balance is extremely difficult. Historically, PCB development has been fragmented with each discipline operating in its own silo. Electrical engineers, mechanical designers, component procurement teams, and SI/PI specialists often work independently, with limited real-time collaboration.

While each group optimizes for its own objectives, the overall system can suffer from misalignment. This disjointed approach introduces a critical problem: Design issues are often discovered far too late.

With a traditional, disjointed PCB development process, if issues occur, they typically are not discovered until layout, prototyping, or even manufacturing when the cost of change is high. Early-stage choices (component selection, board outline, stackup, etc.) become the foundation for everything that follows. As the design matures, these decisions become increasingly difficult and expensive to change. The result is a well-known but often underestimated reality: The cost of change grows exponentially as the design progresses.

What might be a quick adjustment during schematic design can turn into days of rework during layout, weeks of delay during prototyping or significant financial loss during production.

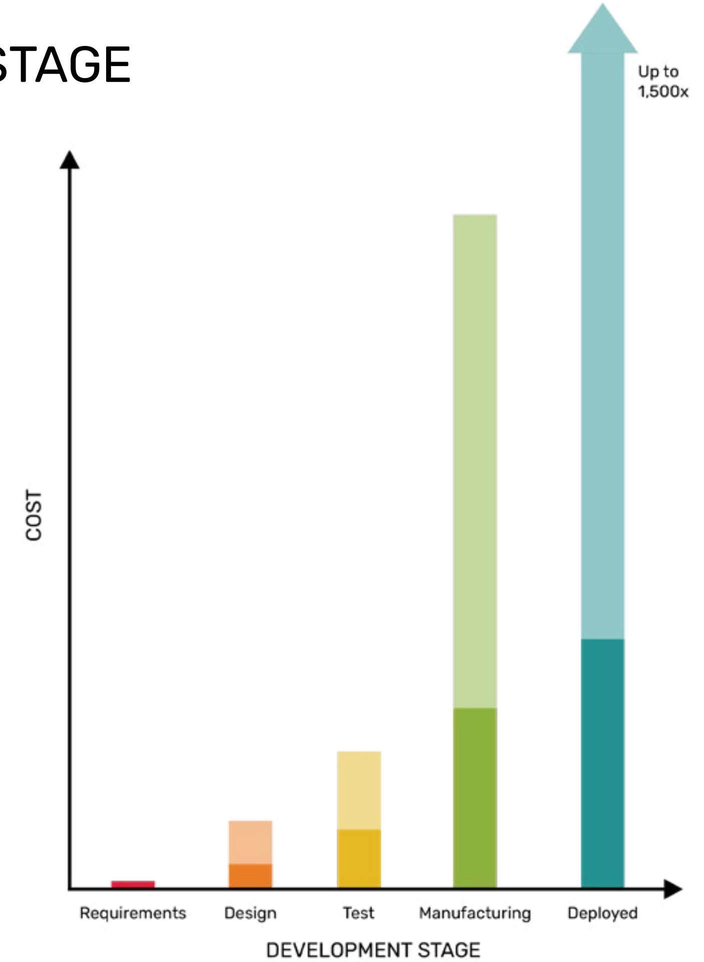


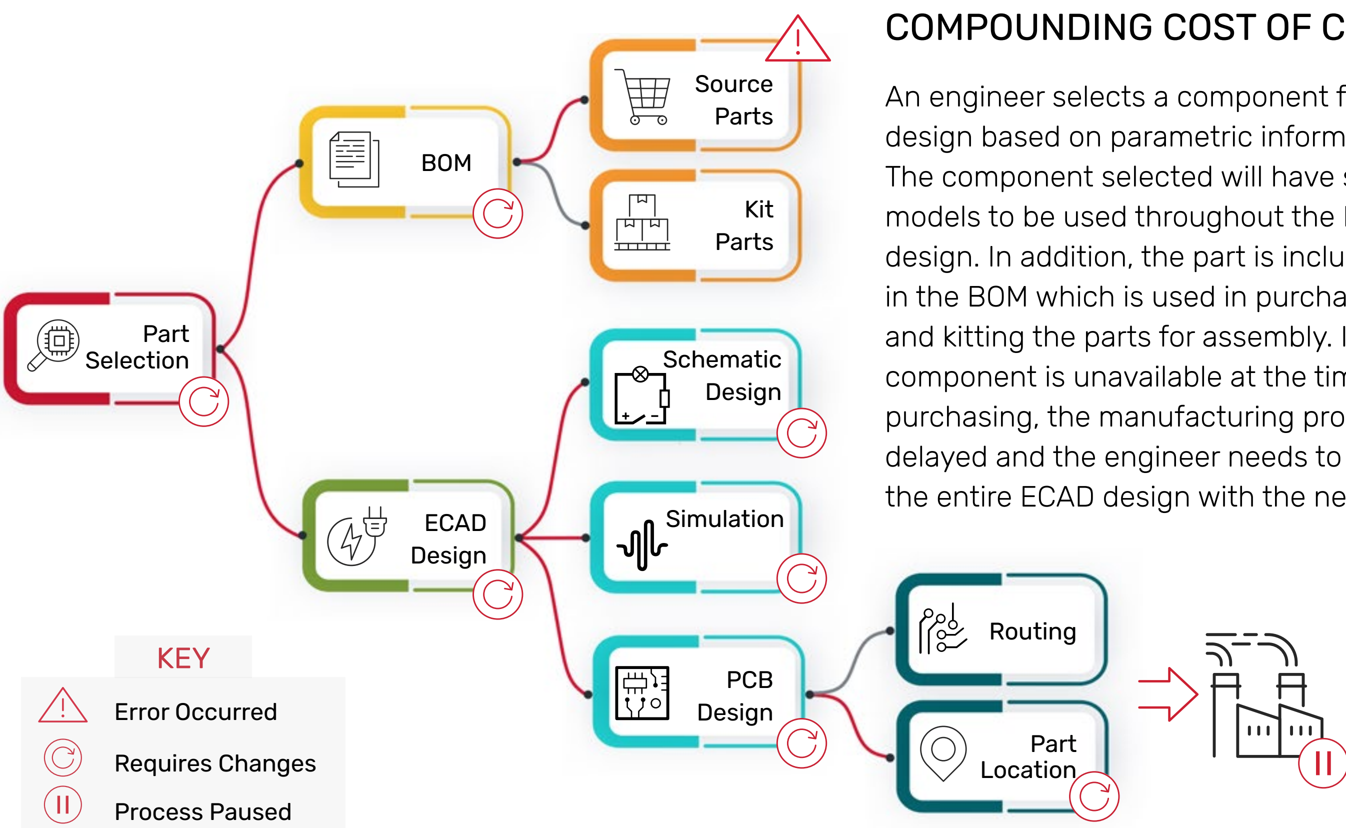
THE HIDDEN COST OF LATE-STAGE PCB ISSUES

According to a NASA study for hardware and embedded design, fixing a design issue too late can increase costs by orders of magnitude. Their findings showed that a defect costs:

- 3x to 8x more to fix if found in design instead of requirements
- 7x to 16x more if found during manufacturing
- 21x to 78x more during integration and test
- 29x to more than 1,500x more once the product is in operation or in the field

For PCB programs, late discovery often means full board respins, wasted assemblies, delayed launches, and customer-facing risk. Let's take a look at a simplified example of a common issue and the repercussions if not caught early in the PCB design cycle:





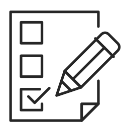
COMPOUNDING COST OF CHANGE

An engineer selects a component for the design based on parametric information. The component selected will have specific models to be used throughout the ECAD design. In addition, the part is included in the BOM which is used in purchasing and kitting the parts for assembly. If the component is unavailable at the time of purchasing, the manufacturing process is delayed and the engineer needs to redesign the entire ECAD design with the new part.

THE HIDDEN COST OF LATE-STAGE PCB ISSUES

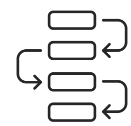
If changes are made late in the design process or communicated inefficiently, costs can amass quickly depending on where the PCB is in the development process. At a minimum, extra costs are accumulated for the additional engineering man-hours required to adjust the PCB design; but if the PCB is already in production when these issues are realized the cost of a redesign is staggering.

In a recent study, the Software Engineering Institute (SEI) (CMU), working with DoD and aerospace programs, found ~70% of defects are introduced during requirements and architecture stages. This is critically important for PCB and electronics teams:



REQUIREMENTS

Early decisions based on requirements dominate downstream failure modes.

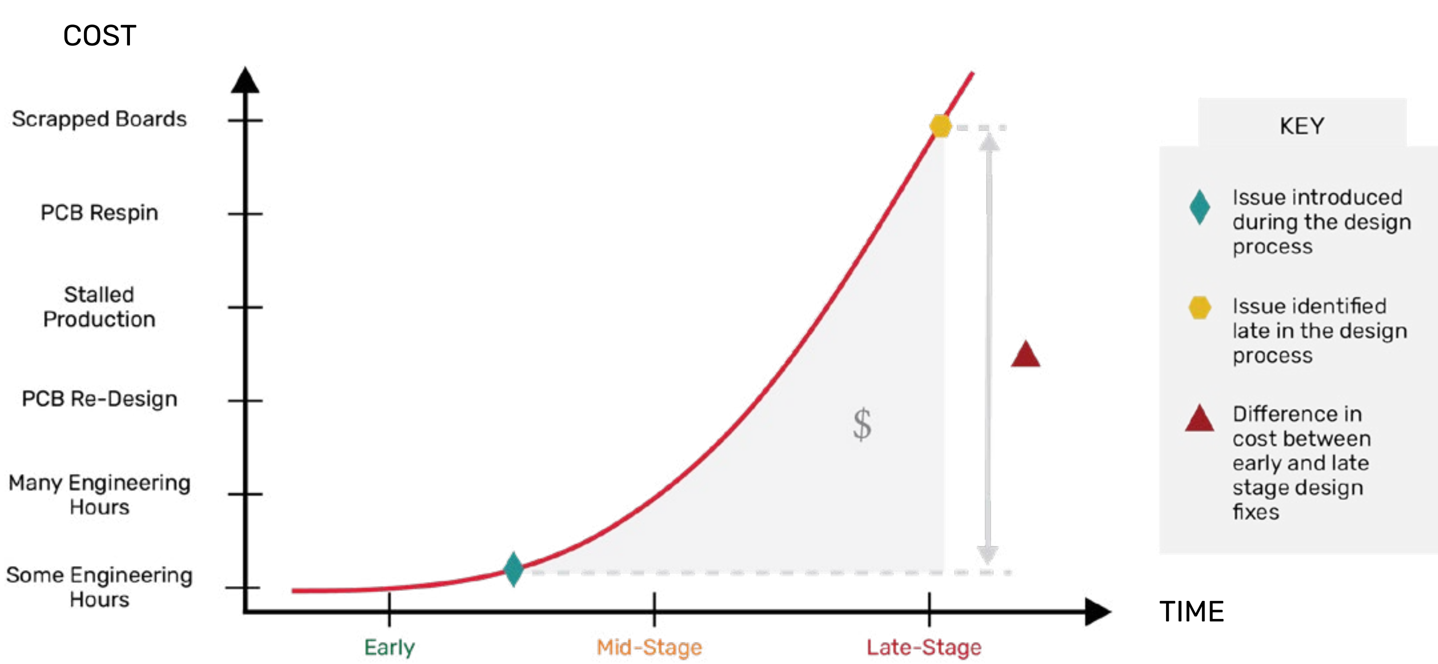


ARCHITECTURE

Influences stackup, interfaces, voltage domains, and topologies.

Moreover, 80% of those defects are not discovered until system integration, test, or later in the development cycle. Modern PCB design teams are rethinking when and where issues are detected to minimize costs, reduce respins, and keep the design on schedule. This is when a “Shift-Left” approach can be implemented.

COMPOUNDING COST OF CHANGE



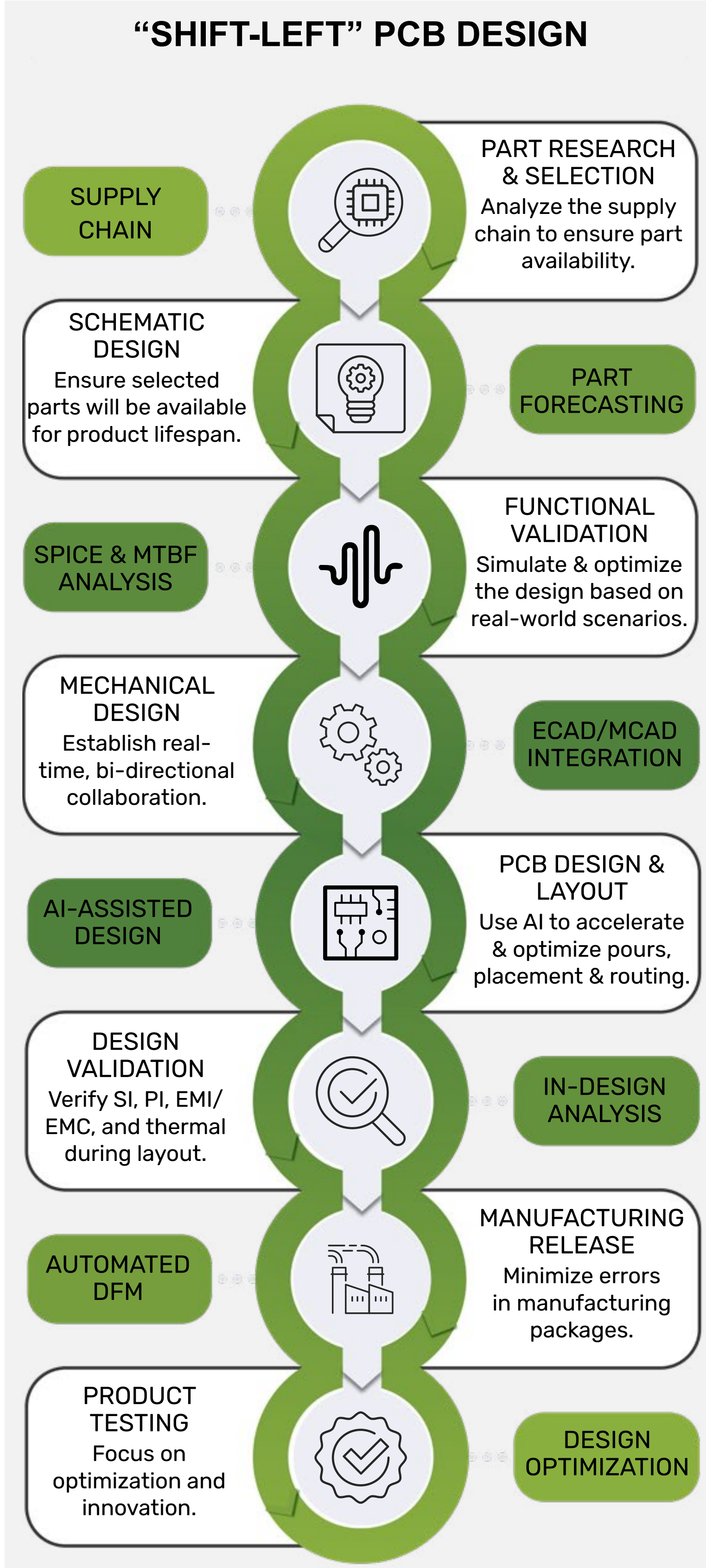
WHAT DOES "SHIFT-LEFT" MEAN IN PCB DESIGN?

In the context of PCB development, "Shift-Left" refers to driving traditional end stage verification and validation processes early in the design, giving engineers broader context to make decisions based on a fuller dataset. A shift-left approach not only moves tasks forward but allows for early stage tasks to have the needed context to make decisions that will support the ultimate end product state.

At its core, shift-left is about making better decisions sooner. A shift-left approach enables design teams to identify hard to find issues early in the design process and reduce errors with the ability to:

- Identify obsolete or unavailable components during schematic creation
- Verify and optimizing electrical performance with realistic simulation
- Validate mechanical fit and enclosure integration
- Enhance SI, PI, and thermal performance during PCB layout
- Design with manufacturing & assembly considerations in mind
- Ensure a complete and accurate manufacturing package for release

Since these issues compound as projects move downstream, early identification minimizes the hidden costs associated with late-stage PCB issues. A shift-left methodology changes the traditional workflow dynamics by creating a more connected and context-aware design environment, where electrical, mechanical, and manufacturing considerations are evaluated in parallel not sequentially. This enables teams to move from a reactive problem-solving approach to proactive design optimization.



WHAT DOES "SHIFT-LEFT" MEAN IN PCB DESIGN?

By adopting a shift-left approach, PCB design teams can:

- Reduce costly respins and redesign cycles
- Shorten development timelines
- Improve first-pass success rates
- Enhance collaboration across disciplines
- Deliver more robust, manufacturable designs

Ultimately, **shift-left is not just a process improvement, it is a strategic shift in how design decisions are made**, enabling teams to manage complexity with greater confidence and control.

This ebook will provide concrete and actionable examples showing how shift-left processes can be implemented to identify risks earlier, reduce costly redesigns, improve cross-functional collaboration, and accelerate time to market while ensuring designs are optimized for performance, manufacturability, and long-term reliability from the very start.

TOP 5 TIPS FOR ACHIEVING "SHIFT-LEFT" PCB DESIGN

1 ESTABLISH EARLY COMMUNICATION
Establish relationships and communication with stakeholders or cross-discipline teams early.

2 SIMULATE EARLY AND OFTEN
Simulate to ensure circuit functionality and performance early and often to correct issues when change is easiest.

3 COLLABORATE CONTINUOUSLY
Collaborate continuously with other teams, not sequentially, as all aspects of the design are developed simultaneously,

4 DESIGN FOR EXCELLENCE
Consider design cost, performance, reliability, longevity, and other DFx objectives from the start.

5 CORRECT BY CONSTRUCTION DESIGN
Establish a constraint-driven design methodology to ensure the PCB is built correctly from the start.

"Ultimately, **shift-left is not just a process improvement, it is a strategic shift in how design decisions are made**, enabling teams to manage complexity with greater confidence and control."

SHIFTING LEFT STARTS WITH SMARTER COMPONENT DECISIONS

Selecting the right part for your designs is not only vital for electrical performance and functional compatibility but also keeping your project on schedule. When designers are selecting components, part procurement should be considered including supply chain and sourcing. To choose the right part upfront designers should ask themselves several questions to ensure part purchasing that is on time and on budget:

1. Is the part active and recommended for new designs?
2. Is the part available in the required quantities?
3. Is the part going to be available for the lifecycle of the product?
4. Does the part meet the compliance requirements of the design?
5. Is there a reliable second source to purchase the component from?
6. Is there a lead time for the part & does it align with the time frame of the project?
7. Does the part have a replacement that is equivalent in fit, form, and function?
8. Does the price of the part align with the budgetary restrictions?

Typically, many of these questions would be reviewed by the component purchasing team but this is often too late in the design process. By the time component purchasing occurs, the schematic and PCB layout are usually completed, and the design is sent to manufacturing. Finding an issue with the components selected at this point can be detrimental to product launch. Best case scenario, a replacement part can be purchased with the exact form, fit, and function and easily swapped out in the design. Worst case scenario, the product launch is delayed waiting for components with long lead time to assembly the PCB or a complete redesign is required to accommodate new parts. By reviewing the right information upfront, ideally directly in the ECAD design environment, designers are likely to make intelligent decisions that align with the project requirements. This information includes:

- Lead time
- Price
- Quantity on Hand
- Part Status
- Secondary Sourcing
- Alternate Components
- Component Risk
- Compliance and Regulatory Data
- Part History
- Forecasting Trends

Let’s take a look at an example of how a shift-left approach to component selection can be implemented to minimize issues later in the development process.

SHIFTING LEFT STARTS WITH SMARTER COMPONENT DECISIONS

During schematic creation, four capacitors are being compared for implementation. The designer reviews the typical information including parametric data, functionality, and unit price. By only reviewing these criteria, a designer would likely choose the least expensive component that meets the electrical and performance requirements: the Murata capacitor that costs $0.01. **But what if additional supply chain information, typically reviewed during part procurement, was considered upfront?**

MPN	Supplier	Description	Avg. Price	Min. Lead Time [Week(s)]	Max. Lead Time [Week(s)]
C0402C102J5GACTU	KEMET CORPORATION	Cap Ceramic 0.001uF 50V C0G 5% Pad SMD 0402 125°C T/R	$0.02	54	54
CL05C102JB5NNND	SAMSUNG ELECTRO-MECHANICS	Cap Ceramic 0.001uF 50V C0G 5% Pad SMD 0402 125°C T/R	$0.02	24	24
GRM1555C1H102JA01B	MURATA MANUFACTURING	Cap Ceramic 0.001uF 50V C0G 5% Pad SMD 0402 125°C Bulk	$0.01	Obsolete	Obsolete
C0402C102J5GACAUTO	KEMET CORPORATION	Cap Ceramic 0.001uF 50V C0G 5% Pad SMD 0402 125°C Automotive T/R	$0.05	33	33

With supply chain information considered upfront, the component selected for the design would be different. The designer would select a component that is active and can be procured within the time frame of the project, likely the Samsung capacitor with 24-week lead time.

	TYPICAL PART SELECTION	SUPPLY CHAIN AWARE	SUPPLY CHAIN RESILIENT
Manufacturer and PN	✓	✓	✓
Supplier	✓	✓	✓
Parametric Information	✓	✓	✓
Price	✓	✓	✓
Quantity & Lead Time	X	✓	✓
Compliance Data	X	✓	✓
Availability & Lifecycle	X	✓	✓
Alternate Parts	X	X	✓
Secondary Sourcing	X	X	✓
Component Risk	X	X	✓

A shift-left approach to component selection should be implemented in the PCB design process at either the design or library level to ensure a compliant and orderable BOM. With the integration of real-time supply chain information during part selection and schematic creation, designers can optimize part selection, reduce costs, keep production on track, and create a supply chain resilient design.

PREDICTING FAILURE BEFORE IT HAPPENS

INTEGRATED, ADVANCED SPICE ANALYSIS

With the schematic complete, engineers must validate functionality. At a minimum, this includes manual calculations to verify proper voltage and current levels; however, a prototype is often created to test and debug the circuit before final production. Prototyping can be a time-consuming process and many project schedules don't allow for thorough analysis. Electrical validation can be shifted left by creating a virtual prototype and simulating realistic circuit behavior with SPICE simulation.

INTEGRATED SPICE ANALYSIS

Ideally, SPICE simulations should be directly integrated into your ECAD design environment to prevent design translations, minimize errors, and streamline the design process. Simulations include:

BIAS POINT

Shows the steady-state voltage, current, and power for quick verifications of basic functionality.

TRANSIENT

Shows the behavior of voltage, current, or power in the time-domain as if it was plotted on an oscilloscope.

DC SWEEP

Analyze circuit behavior when specific parameters are varied during the simulation.

AC SWEEP

Analyze circuit behavior in the frequency domain and verify functionality.

ADVANCED SPICE ANALYSIS

SPICE analysis can be enhanced by considering how the PCB will behave in real-world conditions. This allows users to incorporate environmental conditions to predict field failures and analyze reliability with:

COMPONENT STRESS

Detect and modify components that are over-stressed, reducing field failures and increasing reliability.

MONTE CARLO

Analyze statistical behavior when multiple components are varied within their tolerance range to improve yield.

NOISE ANALYSIS

Analyze noise from power supplies or components that lead to incorrect operation.

TEMPERATURE SWEEP

Vary environmental conditions to ensuring proper operation in the field.

SPICE simulation allows the validation of electrical functionality by incorporating realistic models of components, tolerances, and environmental conditions such as temperature variations; however, for critical devices in the medical and aerospace, reliability analysis should be evaluated further as these products must adhere to industry standard reliability and safety requirements.

PREDICT FAILURE BEFORE IT HAPPENS

MEAN TIME BETWEEN FAILURE (MTBF) ANALYSIS

For critical devices or products that must work consistently with minimal interruptions to operation, industry standards may provide requirements to monitor and improve electronic reliability, especially in harsh environmental conditions. Typically, these critical devices must be put through rigorous testing including thermal cycling, vibration testing, shock testing, and more to validate adherence to industry standards such as ISO13485 for medical devices and AS9100 for aerospace. If devices fail these reliability tests, or failures are discovered during burn-in, field testing, or worse after deployment, the cost to redesign is crippling. To reduce the likelihood of redesign and minimize testing iterations, a shift-left approach to predicting failure can be implemented by performing Mean Time Before Failure (MTBF) analysis. MTBF is an attribute of durability that estimates the performance and safety of electrical, mechanical, and electro-mechanical parts and simulates the electrical stress on a circuit by incorporating.

PCB ENVIRONMENT

Configure a list or range of ambient temperatures in which the PCB will operate to analyze MTBF in realistic conditions. Additionally, indicate the environment in which the PCB will be used such as ground, airborne, naval, etc. & if the product will be fixed or in motion.

PCB LIFESPAN

Define and include the reliability standard to determine the PCB life estimation. Additionally, define the target PCB life in years. Mean Time Between Failure analysis failure or success is computed based on the actual life compared to the target life.

QUALITY STANDARDS

Industries such as military, automotive, data processing, and more, must adhere to additional standards. For real-time design analysis, define multiple time-based scenarios such as Helicopter Onboard Navigation to estimate life expectancy.

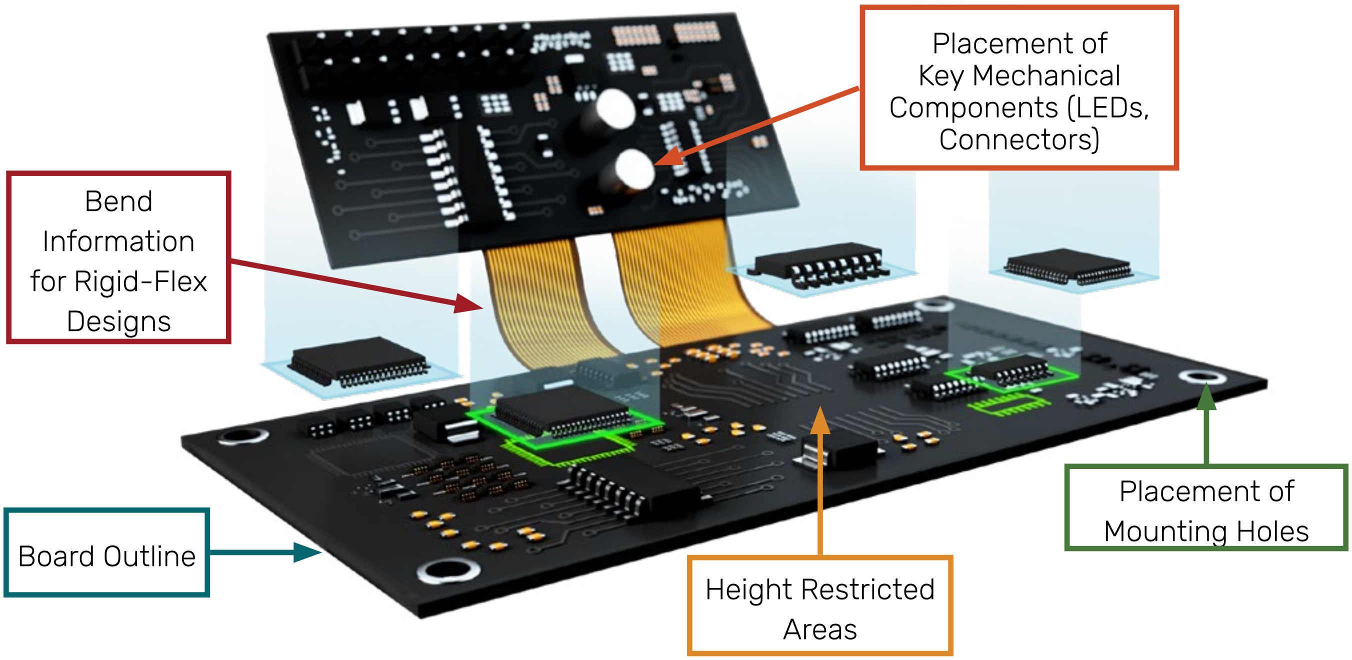
COMPONENT STRESS

Use electrical stress simulation results to produce accurate MTBF calculations. Electrical stress considers power dissipation, voltage and current to compare component stress against maximum or derated ratings at varying temperatures.

Performing MTBF analysis will evaluate failure in time and the estimated PCB life to identify overstressed components, improving design reliability and longevity. MTBF analysis can pinpoint errors in the schematic and efficiently identify components with low life expectancies. This will ensure the components selected for the design will be reliable for the duration of the PCB life expectancy. Instead of identifying critical reliability issues in testing, shifting reliability analysis left with MTBF simulations will ensure adherence to industry standards during component selection and circuit creation when the cost and effort of change is easiest.

CLOSING THE GAP BETWEEN ELECTRICAL AND MECHANICAL DESIGN

With the components selected and schematic completed, the next step in the design process is the PCB layout. In many of today's products, the PCB must fit in a small mechanical housing; therefore, it is common for the mechanical engineering team to determine the form and fit of the board including:



Concurrent design, where the MCAD and ECAD teams are working on their respective designs simultaneously, is crucial to meet industry time-to-market demands; however, it greatly increases the likelihood of discrepancies:

- MCAD and ECAD requirements not aligning
- Mutual design elements are not synchronized
- Uncommunicated changes
- Fitment issues (connectors not aligning with cutouts)
- Thermal issues and heat flow challenges
- Misunderstanding between nomenclature
- Inconsistent 3D models between tools

Every change made by either mechanical or electrical teams, impacts the other. At a minimum, teams need to know what the other is doing; however, MCAD and ECAD design teams are often siloed, as the software used for development is different for electrical versus mechanical design. This disjointed design environment not only prohibits the effective communication of requirements but makes it difficult to visualize electrical and mechanical elements holistically to review the assembly as a whole. With a traditional design process, any errors made between ECAD and MCAD integration, won't be realized until the PCB is produced and the product is assembled, having serious ramifications on both the project budget and schedule. To close the gap between electrical and mechanical design, a shift-left approach can be implemented.

CLOSING THE GAP BETWEEN ELECTRICAL AND MECHANICAL DESIGN

A shift-left approach to ECAD/MCAD co-design integrates the electrical and mechanical design environments to create a single source of truth to create a full digital prototype which can be accessed, analyzed, and modified by either the electrical or mechanical design teams. To achieve this, a shift-left solution needs to incorporate the following key aspects:

TRANSFER OF INTELLIGENT DATA

Low-resolution boxes indicating component locations on a PCB is no longer enough to guarantee proper interaction in the final assembly. Instead, detailed, intelligent data is required to obtain a realistic representation and accurate digital prototype.

BI-DIRECTIONAL COLLABORATION

With a concurrent design process, changes can come from either the mechanical or electrical team. A shift-left approach needs to be able to support bi-directional updates and the ability to accept or reject changes to create a collaborative environment.

ECAD AND MCAD AWARE

Differences between disciplines, such as naming conventions, can be resolved with a shift-left approach that is MCAD and ECAD aware. This will associate mechanical elements, including parts, drawings, and assemblies, with the electrical design.

NATIVE DESIGN

Collaboration between ECAD and MCAD teams needs to happen natively within the respective CAD tools. With a native approach to collaboration, models are converted into their native format, the file sizes are reduced, and the speed at which information is communicated and adopted into the design is accelerated.

INCREMENTAL CHANGES

Along with importing or exporting a baseline design, both the ECAD and MCAD environments should accept incremental updates to eliminate lengthy file transfers. This provides each team the ability to review potential changes in real-time, ensure ECAD and MCAD requirements align, and reject or accept the modifications.

TRACEABILITY

A shift-left approach to ECAD MCAD design should incorporate a detailed history to understand when and why design elements changed (and by which team). Real-time traceability will help document the product's development and keep track of approvals to design changes while minimizing miscommunication.

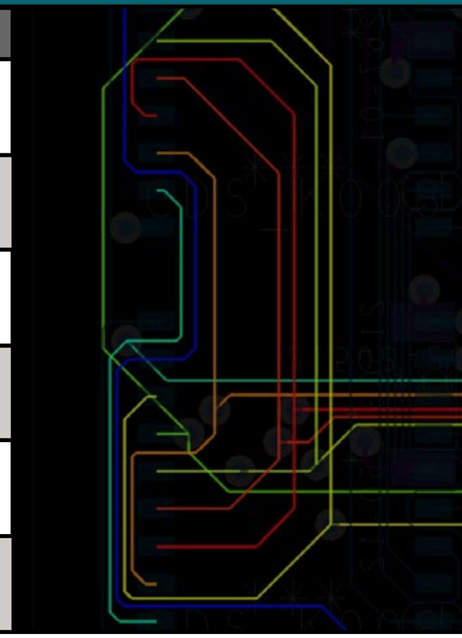
By incorporating a shift-left mentality, product development teams can achieve seamless ECAD/MCAD co-design, improve collaboration, minimize the likelihood of errors, and validate form, fit, and function of the final assembly before production.

CATCHING ELECTRICAL ISSUES DURING DESIGN, NOT AFTER

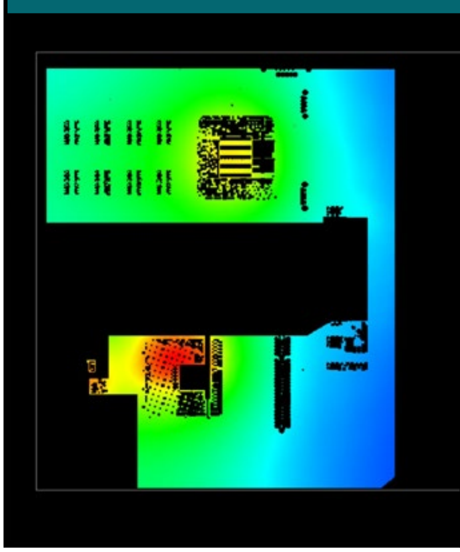
Once the components are selected, schematic is complete, circuit operation and reliability are verified, and the board outline is defined the PCB layout can begin. This section of the design process includes creating the physical implementation of electrical functionality. With designs becoming more complex, signal and power quality issues are more difficult to detect visually.

SIGNAL INTEGRITY

ISSUE	DESCRIPTION
Impedance Discontinuities	Cause signal reflections & distortions, which can degrade signal integrity & lead to errors or data loss.
Signal Coupling	Electromagnetic interference (EMI) is generated and induces unwanted noise onto adjacent traces.
Crosstalk	Signals in close proximity to each other can transfer energy, causing noise or crosstalk.
Reflections & Ringing	Part of the signal is reflected back towards the source, causing noise and reducing signal quality.
Unreliable Data Transmission	Degraded signal quality can result in bit errors or communication failures in high-speed systems.
Overshoot or Undershoot	The signal to exceeds or drops below its normal levels of operation.



POWER INTEGRITY



ISSUE	DESCRIPTION
Hot Spots	Localized areas on the PCB that are significantly warmer than surrounding regions during operation.
Intermittent Failures	Issues within the power delivery network are often inconsistent and difficult to identify/troubleshoot.
Malfunctioning Components	Insufficient power delivery may result in incorrect operation if voltage dips below the minimum threshold.
Ground Bounce	Voltage fluctuations on a ground plane caused by rapid switching currents leading to data errors.
Poor Decap Performance	Reduced effectiveness at suppressing high-frequency noise and delivering instantaneous power as required.

Circuit performance becomes even more difficult to troubleshoot when signal quality and power quality issues intertwine; this scenario is only more prevalent as PCB designs increase in complexity.

CATCHING ELECTRICAL ISSUES DURING DESIGN, NOT AFTER

Historically in analysis, ground, or the "return", has been modeled as an uninterrupted ideal reference of continuous copper and had very little effect on a signal's fidelity; however, in many modern circuit boards, the power and ground planes that make up the return have undergone significant change in their composition. Shared voltage layers as well as the multi-layer nature of the routing today, has put us in a situation where the assumptions made within the simulation environment may not reflect the conditions seen on the actual board. Fortunately, power-aware simulations provide a solution to identify hard to diagnose power delivery issues that can be easily mistaken for signal quality issues and vice versa.

SIGNAL AND POWER INTEGRITY	
ISSUE	DESCRIPTION
Return Path Discontinuities	Return path discontinuities produce changes in the impedance which can cause signal quality issues.
Voltage Ripple	Small, unwanted variations in the DC output of a power supply causing unstable logic levels, jitter, resets, and noise.
Timing Errors	Variations in propagation time for signal transmission, specifically signal delay and skew, can disrupt synchronization and affect circuit reliability.
Noise	Noise refers to any unwanted electrical interference that distorts or disrupts a signal. Signal and power quality issues can both produce noise.
Increased EMI	Larger return path loops can act like antennas, radiating EMI and potentially causing a product to fail EMC compliance.

While mitigation techniques, such as incorporating shielding, controlled impedance, and routing strategies, can be implemented during PCB layout to minimize the likelihood of SI and PI issues, the design functionality and quality must still be verified. Often this is accomplished by creating a prototype of the design to validate and troubleshoot; however, several of these SI and PI issues are challenging to identify in the lab and many project schedules don't allow for a thorough prototype process. In today's PCB design process, many teams incorporate SI and PI simulations to verify performance before production.

But what happens if a critical issue is found at this point in the design process?

More often than not, the PCB layout will require modification or worst-case scenario a complete redesign to address the signal and power quality issues. This results in significant costs and man-hours added to the project schedule to complete the board respin.

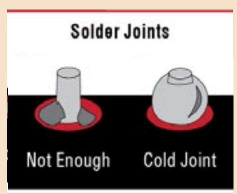
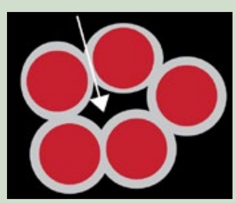
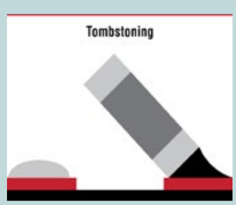
To combat these issues, shift signal integrity and power integrity analysis left and perform critical simulations during the PCB layout. Instead of examining SI and PI issues at the end of the PCB design process, PCB designers can perform SI and PI analyses during layout to identify common issues and modify the design to improve signal quality and power quality when change is easiest. This enables engineers to perform SI/PI analysis directly in the layout software to visualize designs contextually with minimal setup or configuration and prevent respins due to poor functionality later in the design process.

DESIGNING FOR MANUFACTURABILITY FROM DAY ONE

With the PCB layout completed and electrical performance verified, there is still one major question to ask:

Can my PCB design actually be built?

Design for Manufacturing (DFM) requirements are often the final check before production to ensure the board can be fabricated, assembled, and tested according to your manufacturer's capabilities. Not adhering to your contract manufacturer's capabilities and requirements can lead to a plethora of issues, not only affecting the board's ability to be manufactured but also electrical performance:

ISSUES CREATED DURING FABRICATION		ISSUES CREATED DURING ASSEMBLY
Acid Traps		Dendritic Growth
Insufficient Annular Rings		Conveyer Inference
Creation of Antennas		Delamination
Insufficient Solder Fillet		Obstruction of Depanelization Tools
Breakouts or Edge Fraying		Cold Solder Joints
Damaged Fiducials		Reduced Solderability
Pad Damage		Solder Bridging
Shorts or Opens		Poor Solder Deposition
Mask Slivers or Mask Flaking		Incomplete Part Placement
Poor Adhesion of Silkscreen Ink		Wave Soldering Obstruction
Insufficient Copper Pullback		Entrapment of Materials
Copper Shape Damage		Poor AOI Readability
Damage to Pins or Conductors		Tombstoning
Insufficient Aspect Ratio		Component Skew
Via Cracking		Solder Ball Creation
Floating Masks		Insufficient Electrical Clearance

These DFM issues can be hard to identify as they often aren't checked when evaluating electrical functionality and are variable based on your contract manufacturer's capabilities; however, the cost of change compounds exponentially the later DFM issues are identified.

DESIGNING FOR MANUFACTURABILITY FROM DAY ONE

DFM related changes are inherently late-stage changes, but the cost of change drastically increases the later Design for Fabrication (DFF), Design for Assembly (DFA), and Design for Testing (DFT) issues are identified in the design process.

Best case scenario, identifying DFM issues once the layout is complete will require rework, design modifications, or a complete respin- all of which cost additional engineering hours to modify and verify the design. The cost of change only increases as issues are identified further in the manufacturing process. If issues are identified by your manufacturer, production will be halted as changes are implemented, pushing out the project schedule further. Worst case, DFM issues might not be identified until production is completed and boards are tested, exponentially increasing the cost of the error and compounding the production costs, scrapped components and boards, and redesign hours. All of this can be prevented by shifting design for manufacturing requirements left in the design process.

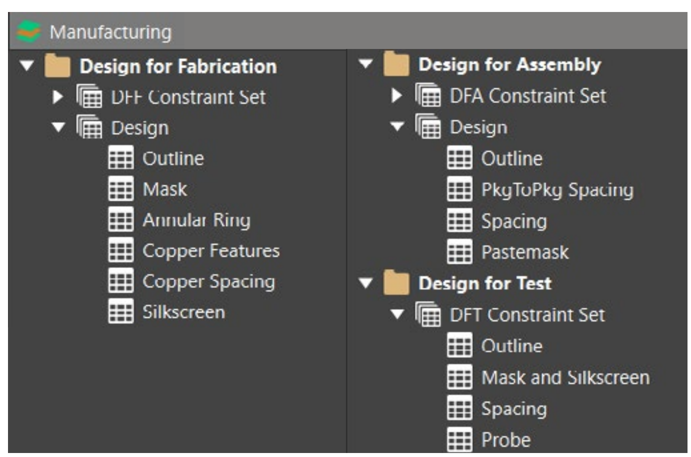
TOP DFM AND DFA MISTAKES THAT DELAY YOUR PCB PRODUCTION

According to Sierra Circuits, an industry leader in PCB manufacturing, the following are the top DFM and DFA mistakes that cause fabrication setbacks, assembly defects, longer turnaround times, and manufacturing delays:

- Unbalanced stackup causing warpage
- Trace spacing violations
- Missing drill and via data
- Solder mask clearance issues
- Mechanical clearance issues
- Incomplete manufacturing documentation
- Wrong information in production files

Shifting DFM left leverages the contract manufacturer's (CM's) capabilities and requirements as a guide throughout the layout process. With this approach, designers can increase manufacturing success, decrease costs, and keep the project on schedule by designing for manufacturing while they work. A successful "shift-left" approach to DFM incorporates the following techniques:

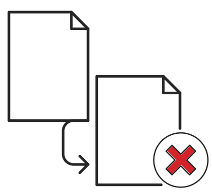
1. Quick and easy incorporation of manufacturing-specific requirements
2. Real-time checking as the design progresses against CM's capabilities
3. Extensive support for DFF, DFA, and DFT rules
4. Incorporation of IPC and industry standard rules



A shift-left approach to DFM will help reduce late-stage design changes and keep your PCB schedule on track by creating a PCB that is correct and manufacturable during the layout process. Once the PCB layout can be deemed manufacturable, it is imperative that the design intent is accurately communicated to manufacturers through thorough documentation packages.

PREVENTING ERRORS IN MANUFACTURING RELEASE

The next step in the PCB development process (once the layout has been completed and approved) is release to manufacturing. Release to manufacturing includes the documentation of the PCB, generation of necessary files, and packaging of information to clearly communicate the requirements to fabricate, assemble, and test the PCB. Manual documentation creation for the PCB and hand-off to contract manufacturers can introduce risk and amplify the opportunity of errors such as:

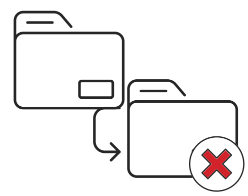


MISMATCHED INFORMATION

It's common for the PCB to still be in review when the fabrication and assembly drawings are created. If there are significant changes made to the PCB before production, these drawings must be updated accordingly. Fabrication and assembly drawings may include:

- Board Outline
- Dimensions
- Tolerances
- PCB Stackup
- Drill Hole Chart
- Assembly Details
- Notes for Fabrication and Assembly
- Intentional Shorts
- Impedance Requirements

With the vast amount of data required for thorough documentation, the potential for human error increases when drawings must be created and updated manually.



INCORRECT FILE VERSIONS

The fabrication package and assembly package must communicate critical fabrication and assembly information to accurately produce the PCB. These packages often contain several documents depending on your design and manufacturer's requirements such as:

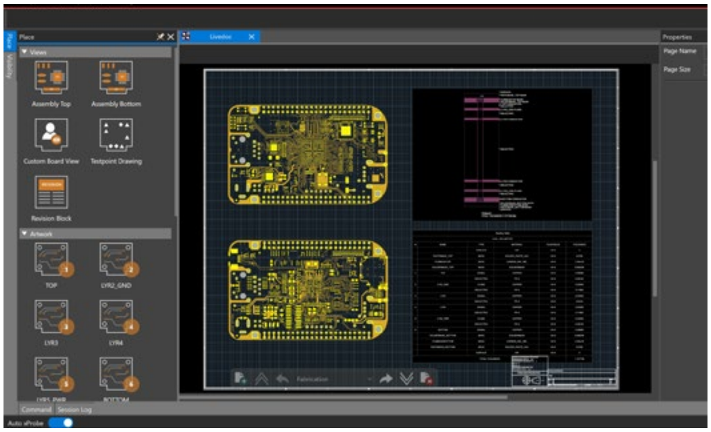
- Fabrication and Assembly Drawings
- Gerber Artwork
- Solder Paste Stencil File
- IPC-2581 or ODB++
- Bill of Material
- IPC-D-356
- Drill File
- X, Y Placement File
- Test Point Location File

With many iterations of the PCB, the potential for error increases with manual creation of manufacturing packages as it's easy to package up a previous or incorrect version of a file.

Contract manufacturers use these drawings and manufacturing packages to accurately produce the PCB to your design intent and specifications. If any errors are present, it can cause confusion, delay production, or result in the production of incorrect PCBs.

PREVENTING ERRORS IN MANUFACTURING RELEASE

A shift-left approach to manufacturing release includes instills best practices for maintaining a single source of truth for the design outputs. These consist of techniques which actively prevent mistakes and reduce the opportunity for human errors. Some of these techniques can include:



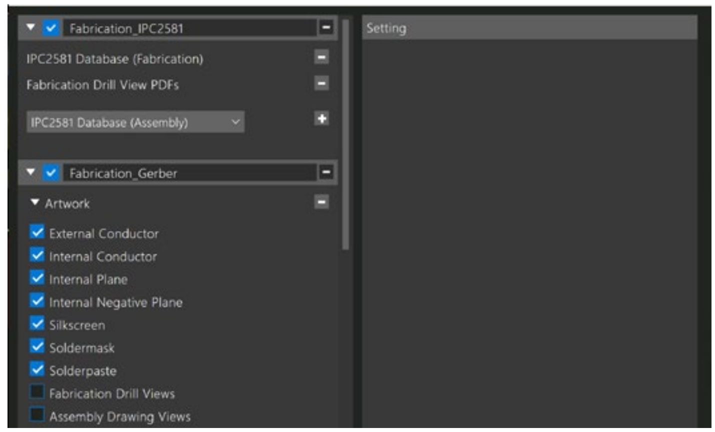
REAL-TIME MANUFACTURING DRAWINGS

Real-time manufacturing drawings provide automatic synchronization between the PCB layout and manufacturing drawings. This eliminates the need to update drawings and documentation when the PCB layout changes. Real-time manufacturing drawings reduce the likelihood of errors as changes are automatically applied to documentation, ensuring documentation is up to date before generation.

PROBLEMS SOLVED WITH REAL-TIME MANUFACTURING DRAWINGS

Real-time manufacturing drawings eliminates the following errors in your PCB documentation:

- Misplaced components or mounting holes
- Incorrect layer stackup
- Errors in dimensioning



AUTOMATED RELEASE TO MANUFACTURING

With automated release to manufacturing, designers can create and package the required documentation in one step. This approach eliminates errors commonly seen when manually gathering and zipping files together. This single operation aims to reduce manufacturing package errors by generating documentation from the active PCB layout and zipping the files together simultaneously.

PROBLEMS SOLVED WITH AUTOMATED RELEASE TO MANUFACTURING

Automated release to manufacturing eliminates the following errors in your manufacturing packages:

- Including unapproved versions of files
- Mismatched file versions
- Selecting files which contain errors

A shift-left approach doesn't stop once the PCB layout is completed, it must continue through to PCB production to ensure a successful product deployment. A clean, clear, and consistent manufacturing release is an important part of the shift-left mindset to ensure the PCB is fabricated, assembled, and tested according to design specifications.

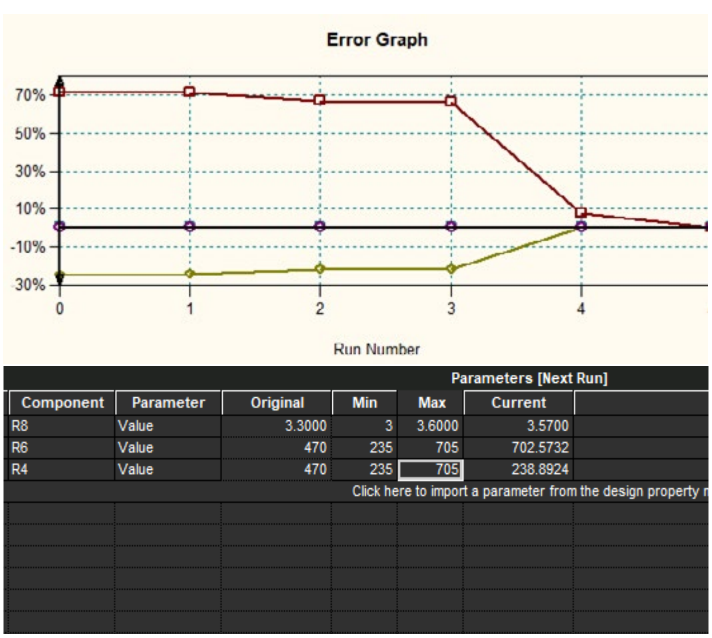
FROM ISSUE PREVENTION TO DESIGN OPTIMIZATION

Shifting left isn't only about avoiding mistakes, it's about designing better boards. Once teams are no longer performing reactive fixes, design can evolve to include proactive optimization. With a shift-left approach to PCB design, early insights create more room to optimize design longevity, product development, electrical performance, and manufacturability.

SUPPLY CHAIN ANALYSIS

After addressing supply chain issues that stall product development, like quantity on hand, lead time, and part multi-sourcing, designers can shift from preventing errors to optimizing part selection. Integrating thorough supply chain analysis during part selection and the schematic design will create a library of sourceable components that can be leveraged in future designs. Additionally, part forecasting can be incorporated to ensure components selected for the design will be available for the duration of the product deployment. This reduces the occurrence of pre-mature redesigns due to unavailable components and improves design longevity.

SPICE ANALYSIS



SPICE analysis can transition from issue prevention to design optimization once a shift-left approach is implemented. When less time is spent troubleshooting hard to find field failures, more time can be allotted for optimizing:

- Component values to produce ideal operation
- Design parameters with automated optimization
- Component tolerances to reduce costs
- Electro-mechanical systems and operation
- Circuit performance over varying environmental conditions.

Advanced SPICE analysis can move past debugging or testing and help designers optimize performance, costs, and full system reliability.

FROM ISSUE PREVENTION TO DESIGN OPTIMIZATION

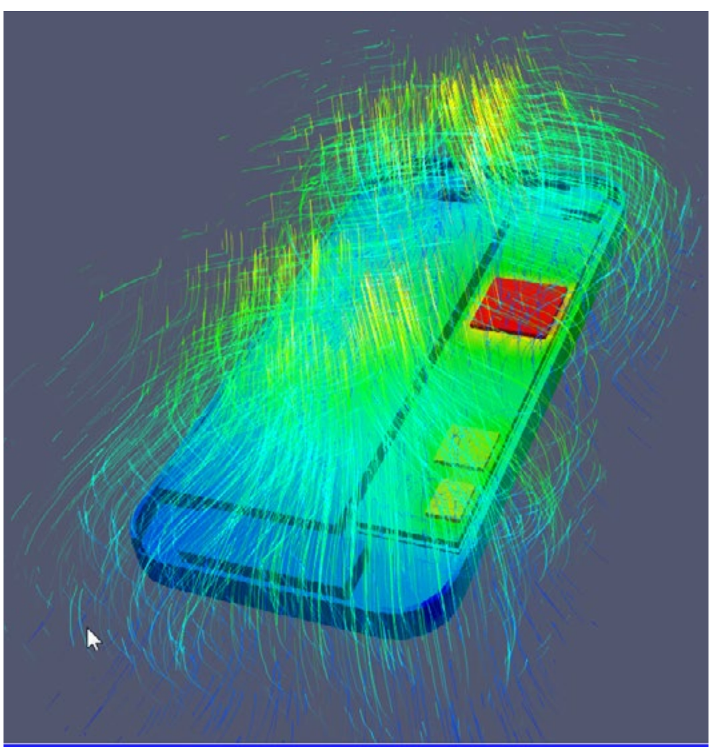
MTBF ANALYSIS

Mean Time Between Failure (MTBF) isn't just theoretical. The results from this analysis can be used to optimize:

- Maintenance schedules to repair failures before they occur
- Warranty definition to optimize what the business can confidently support
- System-level reliability targets such as repair vs. replace strategies

Using MTBF analysis to shift from issue prevention to design optimization can minimize downtime risk, reduce operational costs, and improve customer satisfaction.

ECAD MCAD COLLABORATION



A shift-left approach that enables a cohesive environment for ECAD and MCAD design will help to create a true virtual prototype. This virtual prototype provides access to a full assembly, allowing both electrical and mechanical teams to analyze the final assembly. Teams can perform simulations which analyze:

- Air flow through the product
- Thermal performance
- Rigid-flex bends

By implementing a shift-left approach to ECAD/MCAD co-design, teams can virtually optimize parameters like fit and performance of the completed assembly before prototyping, accelerating and optimizing the product development cycle.

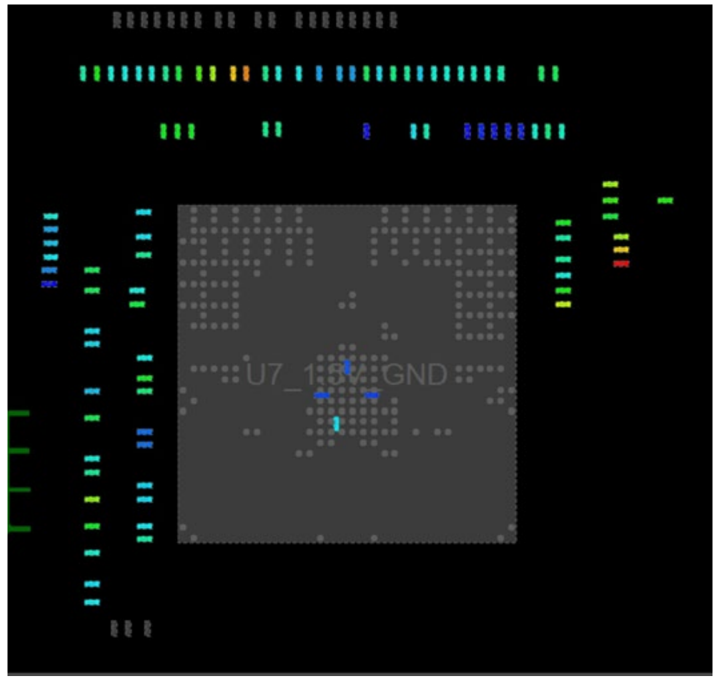
FROM ISSUE PREVENTION TO DESIGN OPTIMIZATION

SI AND PI ANALYSIS

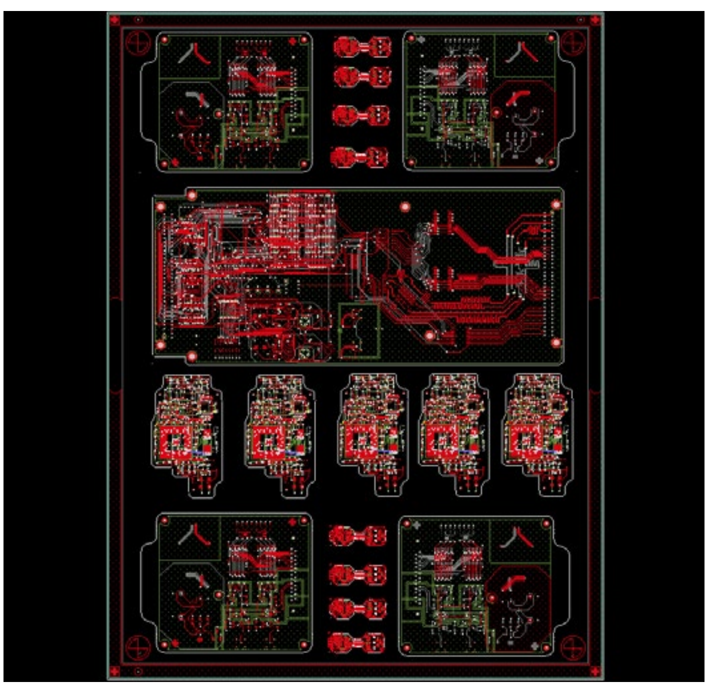
Instead of frantically troubleshooting errors that result in poor PCB performance and functionality, a shift-left mentality enables designers to optimize signal and power integrity during layout. This streamlines PCB development by reducing troubleshooting and frees up time to improve performance including:

- Reducing crosstalk
- Optimizing signal return paths
- Improving decoupling capacitor performance
- Designing for reduced cost

By incorporating signal and power integrity analysis early in the design process, designers can optimize electrical performance and create a reliable design.



DESIGN FOR MANUFACTURING



Each step in the manufacturing process has an associated cost and duration. Therefore, something as simple as placing a few components on the bottom of the PCB or using the manufacturer's minimum capabilities is going to have large repercussions on the schedule and budget. With a shift-left approach, designers can begin optimizing for manufacturability to reduce costs and streamline production by:

- Minimizing the required processes
- Reducing manual soldering
- Minimizing specialized equipment

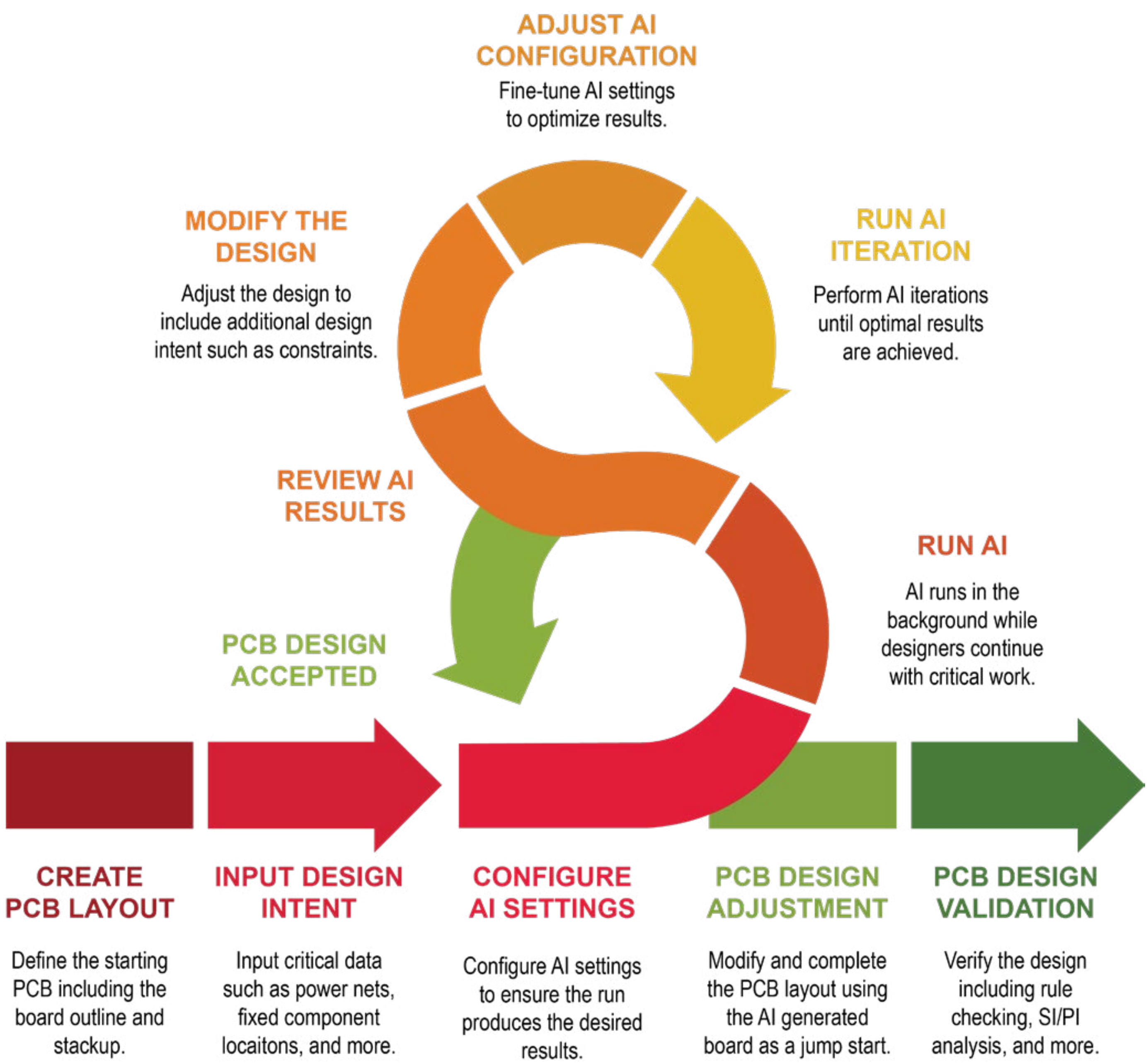
Additionally, with the time saved, designers may begin to optimize panelization- not just saving costs on one design production but multiple.

Early feedback loops created with a shift-left design approach enable more meaningful design iterations and create time for optimization by eliminating late-stage rework. This advances even further with the incorporation of AI.

THE FUTURE OF SHIFT LEFT PCB DESIGN
HOW AI MOVES ISSUE DETECTION EVEN EARLIER

In today's fast-paced development market, manual checks and human-only workflows limit how far teams can shift left. Adopting AI enables earlier insight into PCB design and allows design teams to change when and how PCB issues are identified.

Design teams can create an AI-assisted design flow which leverages today's AI optimization with engineer's guidance and extensive knowledge. This reduces the cognitive load on engineers and streamlines mundane tasks while increasing design confidence by identifying issues even earlier in the PCB design process. In an AI-assisted design flow, the engineer provides critical inputs and design intent and leverages AI's powerful engines to perform design tasks, analysis, and optimization quickly.



THE FUTURE OF SHIFT LEFT PCB DESIGN

HOW AI MOVES ISSUE DETECTION EVEN EARLIER

TOP WAYS AI ENABLES EARLIER INSIGHT IN SCHEMATIC DESIGN

COMPONENT OPTIMIZATION

AI can recommend components based on availability, lifecycle status, cost, and past usage. It also flags risks like obsolescence or long lead times, helping avoid supply chain issues early in the design. AI can be used for part forecasting to ensure components selected will be available for the design lifecycle.

SCHEMATIC CAPTURE

AI can help create the schematic based on a system-level block diagram. Some AI engines aim to generate schematics based on design intent and requirements. Additionally, AI helps interpret the schematic and extract intent such as identifying critical nets, power domains, and high-speed interfaces.

SCHEMATIC REVIEW

AI for schematic review has moved well beyond simple ERC/DRC checks and understands intent, datasheets, and system context. The current AI-enhanced offerings for include datasheet-aware rule checking, connectivity and intent validation, and conversational or agent-based schematic review.

TOP WAYS AI ENABLES EARLIER INSIGHT IN PCB LAYOUT

FEASABILITY STUDIES

AI enables rapid evaluation of design alternatives including different stackups, via strategies, routing topologies, board outlines, component placements, & more. This helps teams make better trade-offs between cost, performance, and manufacturability early.

ROUTING OPTIMIZATION

AI-driven routing tools can auto-route critical nets with awareness of constraints, suggest optimal trace paths, maintain impedance and minimize crosstalk. Rather than replacing the designer, it acts like a co-pilot, handling repetitive work while the engineer focuses on critical decisions.

PLACEMENT OPTIMIZATION

AI can analyze thousands of component placement possibilities quickly. AI can optimize for signal flow and timing paths, thermal distribution, PDN efficiency, manufacturability, and more to reduce the number of manual iterations needed to reach a solid floorplan.

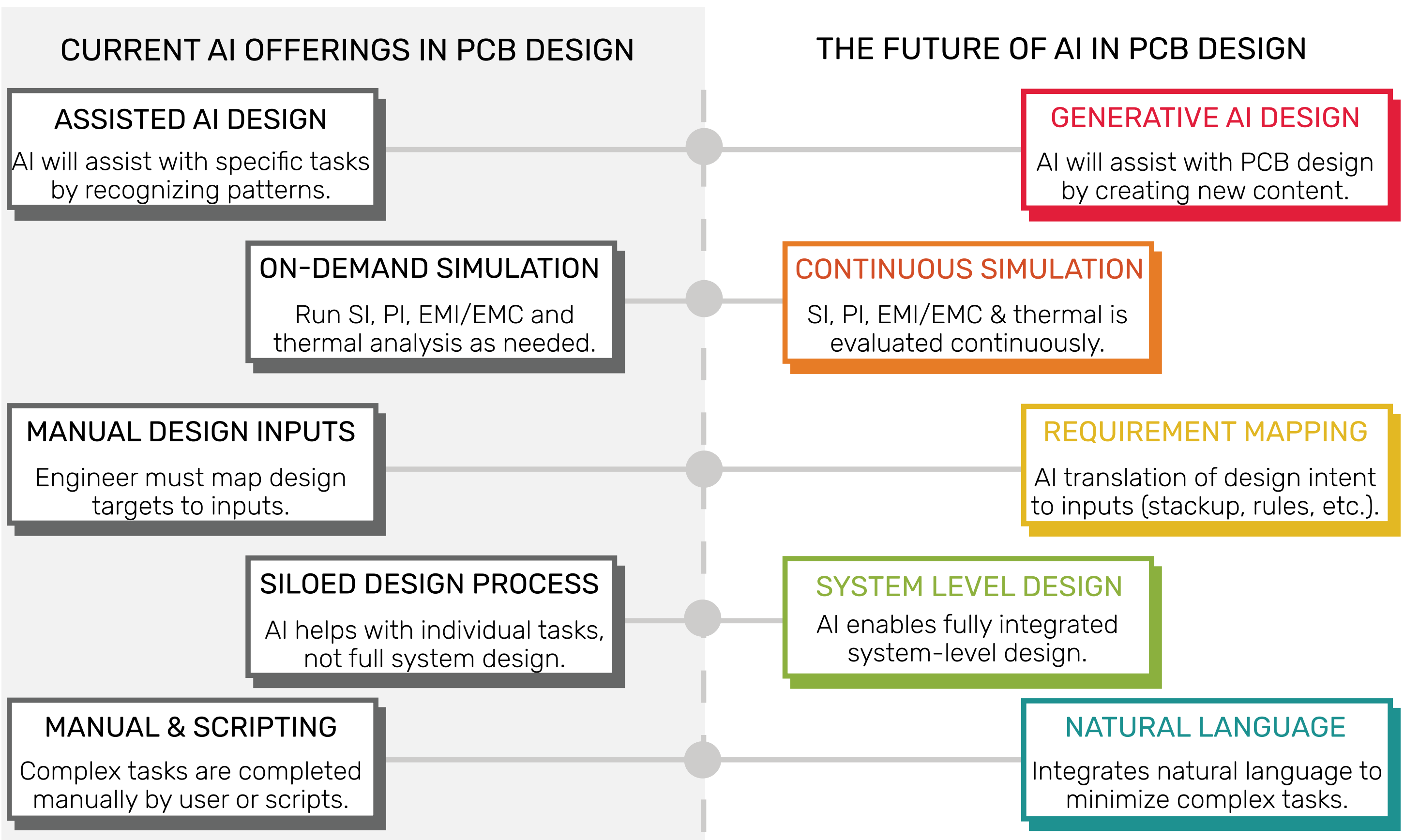
THE FUTURE OF SHIFT LEFT PCB DESIGN

HOW AI MOVES ISSUE DETECTION EVEN EARLIER

AI -supported workflows help teams make better decisions earlier without slowing innovation. Adopting an AI-Assisted workflow not only enhances the shift-left process but prepares design teams for an AI-enabled, shift-left future as AI offerings are rapidly developing. The future of an AI-enabled, shift-left design process is quickly evolving with new technology on the rise:

THE CURRENT AND FUTURE OF AI-ENHANCED PCB DESIGN

TIMELINE COMPARISON ROADMAP



As AI takes over the execution-heavy tasks, engineers spend less time with mundane actions like routing traces and more time on system architecture, analyzing design trade-offs, and fostering innovation. This aligns with the shift-left mentality, moving away from an iterative, manual, and reactive design process and creating a design flow that is predictive, automated, and insight-driven.

> "[X AI] capabilities—parallel iterations, multiple placement and routing strategies, and rapid evaluation of design options—empowered Qualcomm to explore optimized solutions efficiently."

QUALCOMM

-Case Study of Allegro X AI

MAKING SHIFT-LEFT A STANDARD PCB DESIGN PRACTICE

Late stage design errors can be costly, with consequences increasing exponentially during the design process. The later issues are found, the greater the effect on project costs and schedule. The most common PCB issues include unavailable components selected, incorrect mechanical fit, poor electrical performance, inability to manufacture, and discrepancies in release to manufacturing packages. Detecting these issues earlier in the design process with a shift-left approach drastically changes the outcome of product development. Implementing shift-left methods not only keeps costs and time to market aligned with the project goals but allows engineers to optimize the design throughout development.

LONG TERM BENEFITS OF SHIFTING LEFT

- Faster design cycles
- Fewer respins
- Higher design confidence
- Lower costs
- Higher profitability

While altering your full design process can seem daunting, making shift-left a standard PCB design process doesn't have to be. Design teams can begin shifting left without overhauling everything at once by incorporating shift-left principles throughout different stages of the design process depending on the biggest pain-point you are facing.

Allegro X and OrCAD X enable a "shift-left" PCB design approach by embedding intelligence, analysis, manufacturability awareness, and AI-assisted automation directly into the workflow. Allegro X and OrCAD X integrate shift-left functionality directly in the ECAD environment to seamlessly identify errors earlier in the design process.

- Integrated Supply Chain Analysis
- Integrated Advanced SPICE & MTBF Analysis
- Bi-directional ECAD MCAD Collaboration
- In-Design SI & PI Analysis
- DesignTrue DFM Analysis
- Real-Time Manufacturing Documentation
- Automated Release to Manufacturing
- Integrated AI for Placement, Pours, & Routing

With Cadence PCB Design Solutions, engineers gain better visibility, stronger collaboration with mechanical teams, and more time to focus on optimization rather than rework by implementing shift-left principles throughout the PCB design process.