Capturing Intellectual Property within the Electronics & High Tech Industry

Abstract

The Electronics and High Tech (E&HT) industry is facing many challenges associated with a product's design as it moves through the various stages of the product development lifecycle. One particular problem that poses significant risk to companies, if not properly addressed, involves the effective capture and management of engineering calculations that are at the core of a product's design.

It is critical that engineers' design calculations, along with the decisions associated with those calculations, are documented, retained and protected in a format that can be easily referenced and understood. Failure to adequately capture and manage the calculations that constitute the basis for an electronic or high-tech product can lead to detrimental consequences for a product, while also impacting design teams, engineering divisions, and ultimately companies as a whole. Unfortunately, the risk of an incorrectly entered formula, causing a critical error to propagate through a design, is a harsh reality. Simple errors can easily be introduced into spreadsheets or other traditional approaches used for calculations, causing expensive and time-consuming redesign.

There are several distinct challenges that contribute to the broader problem of managing engineering calculations. This paper will explore those challenges and will explain how today's advanced engineering calculation software addresses each of these factors.

When companies implement a best-practice engineering calculations solution as a standard across their organization, they can mitigate risks and address challenges in protecting and sharing their IP, so that products can be designed with higher quality, at lower cost, in less time.

Engineering Calculation Challenges in the Electronics & High Tech Industry (E&HT)

Globalization

In today's high-tech economy, companies are saving money and increasing their competitive advantage by establishing geographically dispersed design teams. Consequently, responsibilities are now split among global teams working with a variety of outsourced firms, contract manufacturers, suppliers, and customers. In many instances, this globalization is leading to both a breakdown in communication, and to lapses in adhering to standards and engineering best practices, inevitably resulting in rework. To avoid this pitfall, engineers must communicate via a standard, intuitive platform around engineering calculation information.

As a product's development progresses from one phase to the next, its design calculations must be available in a format that can be easily understood, discussed, analyzed and verified. Additionally, as high-tech companies establish new development organizations in low-cost locations, they struggle with the methods to bring new engineers up-to-speed on engineering processes and decisions made by corporate engineering staff in the past. Successful knowledge transfer of engineering calculations between teams in a global environment is necessary to improve engineering efficiency, reuse IP, minimize rework, and produce a quality product.

Aging Engineering Workforce

Today's high-tech companies are rife with an aging engineering workforce. An article published in American Institute of Physics in 2002 stated that the number of engineering professionals approaching retirement was expected to increase significantly in the coming years. Today, that prediction is holding true as more and more engineers are leaving the workforce, being replaced by novice engineers without the experience or knowledge to fill the intellectual gap.

> "The age structure of the U.S. S&E labor force is likely to produce several major changes in the S&E labor market over the next decade. The number of individuals with S&E degrees reaching traditional retirement ages is expected to triple."
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> -American Institute of Physics, FYI Number 127: November 20, 2002

The fact is, engineers that have worked on a technical design for many years carry with them extremely valuable information around assumptions made during the design process and the logic behind critical decisions. Often, this information is not documented, but is preserved merely by memory and experience. As senior engineers approach retirement in unprecedented numbers, companies must address the issue of losing institutional knowledge and the reasoning behind many engineering design decisions. If the knowledge harbored by senior engineers is not documented and captured in an easy-to-interpret format prior to their departure, engineering teams must consequently invest significant time both in reverse-engineering and in redesign exercises in order to understand and validate work they do not understand.

Knowledge Capture and Transfer

The engineering knowledge that goes into E&HT products is an incredibly valuable asset to every company. The design equations, assumptions, logic and decision-making process constitute unique intellectual property (IP) that belongs to the company. It is very common that this IP is not captured because engineers frequently do not have the proper tools available to make the documenting of equations and engineering decisions a natural and easy part of their workflow. The result is that the knowledge driving a product's design is not documented, and companies lose that IP.

To reduce the cost of producing quality products, companies must be able to leverage and reuse applicable design calculations either from prior product releases or from related projects. In many instances, the original information is not available in a reusable format, and valuable time is spent redesigning and reworking problems that have already been solved. To be successful in the highly competitive field of Electronics and High Tech, companies must deliver products on time and within budget, making it imperative that the knowledge going into a products' design is easily captured in a way that can be shared and reused between team members and across projects.

Compliance with Standards

Today, E&HT companies are required to work within an increasingly challenging legal environment and must adhere to strict regulatory compliance standards imposed upon them. For example, the electric power industry mandates that companies designing and operating electrical power systems comply with reliability standards established by NERC, FERC and the DOE. Failure to comply with the reliability standards could result in fines up to $1 million (US) per violation per day.

In the electronics industry, one particularly demanding standard is RoHS (Restriction of Hazardous Substances). RoHS requires that no hazardous materials (e.g., lead, mercury) be used in electronic equipment and printed circuit boards. To avoid the repercussions of non-compliance, engineers should perform In-Process Compliance (IPC) by designing according to required standards as they do their work. Unfortunately for many companies, the validation against standards is done out-of-process – that is, the compliance check is performed after the work is complete. This out-of-process approach may have severe consequences: 1) Adequate time is not allocated for the compliance validation phase, so a thorough compliance check is not performed, and 2) Compliance issues are discovered after the design phase is complete.

Another aspect of compliance requires that organizations be able to trace calculations and explain decision-making processes for auditing purposes. The potential need to defend against product liability lawsuits makes it very important to fully document the engineering assumptions and decisions that go into designing a product.

Multiple Design Iterations

Minimizing the number of design iterations during product development is critical to reducing costs and delivering products on time. Engineers must be able to vary design parameters and reproduce results using the same set of calculations for each iteration. Additionally, engineers should easily be able to keep design requirements constant, and modify the equations to calculate results that satisfy those requirements.

Traditional Calculation Approaches

Engineers have traditionally used a variety of approaches for performing and documenting calculations. A few of these tools include calculators, general-purpose spreadsheets, and programming languages. Of these, the use of spreadsheets is perhaps the most easily accessible and most commonly used method in engineering design. Repurposing spreadsheets for engineering design work can be inefficient and result in costly consequences. In addition to being inherently error-prone, spreadsheets do not provide high-level visibility to the design calculations, nor do they provide automated support for units. Equations are cryptic, difficult to decipher, and lack context. The structured nature of spreadsheets inhibits knowledge capture and makes reuse a fundamentally inefficient and potentially risky operation. The error-prone nature of spreadsheets, along with their limited functionality with respect to engineering calculations and knowledge capture, puts companies at tremendous risk of failing to design and deliver products efficiently and within budget.

The figure below shows a section from a spreadsheet that calculates the total impedance for an RLC circuit.

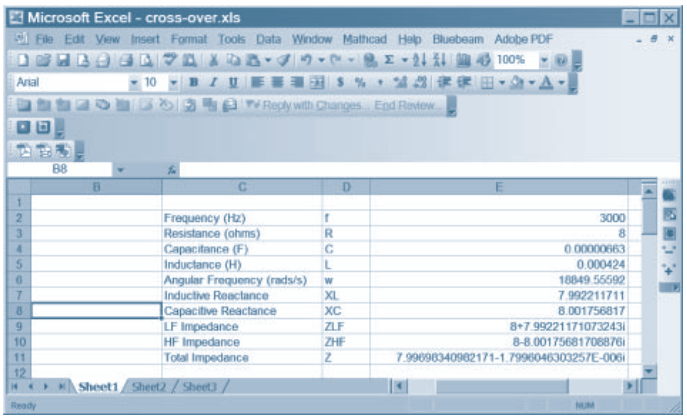

Figure 1. A section from an Excel spreadsheet that calculates total impedance for a first order RLC circuit.

As shown in Figure 1, spreadsheets severely limit visibility into the logic, workflow and equations being used to produce results. Equations and formulas are hidden behind cells, and when viewed, are not intuitive or easily comprehendible. In this example, the equation to calculate Total Impedance, whose result is stored in cell E11, is written using a combination of keywords, parenthesis, commas and mysterious variable names:

=IMDIV(IMPRODUCT(ZLF,ZHF),IMSUM(ZLF,ZHF))

Entering equations in this cryptic format introduces opportunity for errors and does not provide a proficient way to capture and preserve IP.

Traditional calculation methods make companies prone to the following conditions:

- Knowledge capture and IP retention is time-consuming, difficult, and often not achieved
- Calculation reuse is inherently risky
- Calculations are not easily repeatable, auditable, shareable or publishable
- Achieving compliance and validation is a challenge

Using traditional methods for engineering calculations is not in the best interest of E&HT companies. The documentation for these calculations is typically scattered throughout the organization and the work must be repeated to validate these calculations. Unfortunately, the risk of an incorrectly entered formula that causes a critical error to propagate through a design is a harsh reality. Expensive and time-consuming redesign may be required to compensate for the errors.

A Better Solution for Capturing IP

Mathcad, PTC's engineering calculation software, provides a solution to the calculation challenges discussed above. Mathcad combines an intuitive, easy-to-use interface with a powerful, interactive math engine which lets users simultaneously perform and document calculations. Mathcad is comprehensive, providing support for a broad range of calculations used by engineers. Its unique capabilities differentiate it from the traditional tools used for engineering calculations. Mathcad utilizes an Intuitive User Interface along with Natural Math Notation and Units Intelligence to provide companies with the ideal solution to overcoming the challenges associated with engineering calculations. Each of these features is briefly described below.

Intuitive User Interface: Mathcad's whiteboard interface is intuitive, enabling users to easily insert text, live math and graphics regions anywhere on the worksheet. The interface integrates equations, text and graphical content into a single document, and contains formatting and publishing capabilities for creating professional, distributable reports.

> "For technical presentations, I don't mess around with office-type software; Mathcad's all I need. If necessary, I can readily export it to Word. In an ideal world, everyone would have access to Mathcad and I wouldn't even have to do that."
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> - Kevin Barr, Senior Engineer, Honeywell

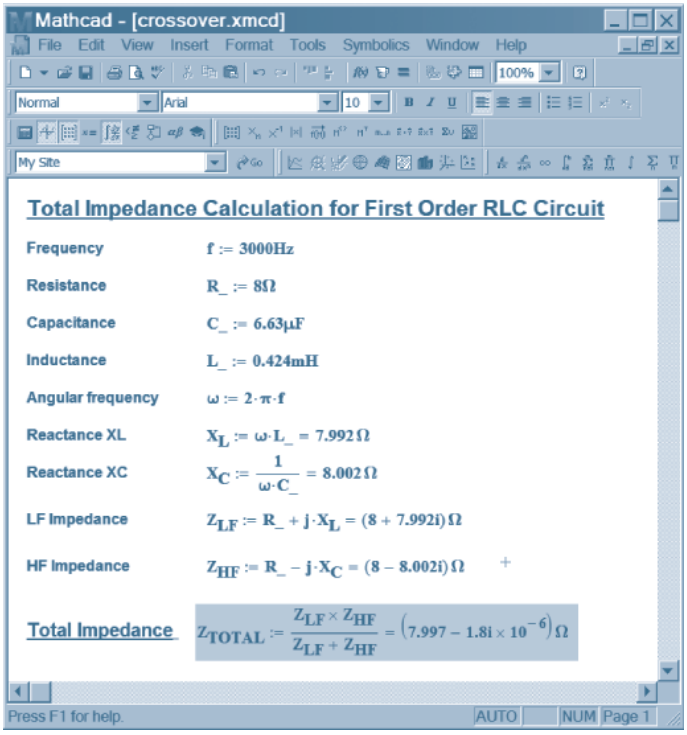

Figure 2. Impedance calculations in Mathcad for an RLC circuit.

Natural Math Notation: Mathcad uses Natural Math Notation – the representation of math equations and expressions in their native format. Natural Math Notation makes calculations easy to validate, share and publish. By capturing math content in this natural format, Mathcad does not require the reader to trace precedents and dependents through a labyrinth of orthogonal cells, or impose the requirement of learning a new scripting language to follow the design and engineering intent.

Units Intelligence: Mathcad is a units-intelligent application; it recognizes the relationships between units across multiple unit systems, performs conversions, carries units through calculations, and flags unit-related errors. Errors are identified early in the design phase and do not propagate throughout the product's development. Traditional calculation approaches do not have this capability, leading to much of the error-potential discussed above. Automated units capabilities permit the engineer to focus less on managing units and more on the engineering and design.

Figure 2 shows how the calculations in Figure 1 (for total impedance) appear in Mathcad.

When the above-mentioned capabilities are combined with those of data exchange, plotting, publishing and interoperability, it is easy to see why the Mathcad application is an exceptional solution to addressing the calculation challenges faced by the industry. Here's how Mathcad solves some of the other key challenges facing E&HT manufacturers:

Globalization: With Mathcad, communication of technical information around a product's design, across the globe, is seamless. Since math is a common language known by every engineer, regardless of geographic location, Natural Math Notation conveys the design and engineering intent easily and quickly. It is exempt from the typical language and culture barriers that cause communication breakdowns.

Aging Engineering Workforce: Because of Mathcad's whiteboard interface, engineering knowledge surrounding a product's development is easily transferred from senior engineers to junior engineers or new hires.

Knowledge Capture and Transfer: Engineering design calculations are captured in a language that is easy to validate, share and publish. Calculations regarding a product's design are distributed across teams, with no reverse engineering required.

Compliance with Standards: Mathcad's comprehensive interface, along with templates and controls around math content, facilitate standards compliance. Auditing is easy, as Natural Math Notation does not involve proprietary languages.

Multiple Design Iterations: The visual nature of critical calculations facilitates the early detection of design errors. Natural Math Notation circumvents mistakes hidden in equations that could propagate throughout a product's design. Unit-related errors are caught and corrected early, resulting in fewer iterations and fewer problematic prototypes.

Demanding Companies Rely on Mathcad

Today, approximately ninety percent of Fortune 1000 companies are using Mathcad to capture, store and reuse engineering calculations. One leader, Rexroth Hydraudyne BV (Netherlands), recognized for its expertise in designing and manufacturing hydraulic cylinders, uses Mathcad to perform and document cylinder calculations and to minimize the number of design iterations required to produce a cylinder.

> "There are no second chances. In most cases, we only make one cylinder for every job, so we can't test a prototype first. We're a real 'engineering-to-order' organization. It has to be right the first time. That means we make heavy demands of our technical calculations."
>
> -Mark Moolenaar, Engineering Manager, Rexroth Hydraudyne

SkyCross is a leader in the design, development and manufacturing of next-generation RF and antenna technology for consumer electronics products. Engineers at SkyCross use Mathcad to ensure engineering designs are based on sound mathematical principles with fewer errors, fewer iterations, and faster time-to-market.

Mathcad enables SkyCross to address key design challenges:

- Fast-paced development, with high quality and low cost
- Design documentation
- Communication among globally dispersed customers, design teams and manufacturing personnel
- Design optimization, early in the process

Conclusion

A critical component for success in the high-tech arena resides in the competency and effectiveness of engineers. Engineers must produce quality work efficiently, and with minimal design errors during each phase of the product development lifecycle.

Productivity and quality increase significantly if engineers have the proper tools available to do their jobs. Mathcad is designed exclusively to meet the specific needs of engineers and can help E&HT companies improve their product development processes. The result: better products delivered in less time.

Mathcad's distinctive capabilities provide the following key benefits to companies:

1) Engineers simultaneously perform and document engineering calculations using an intuitive approach, thus increasing efficiency and producing higher-quality work.

2) Engineers document assumptions, decisions and intentions as a natural, integrated part of their workflow, while capturing valuable IP and supporting standards compliance.

3) Engineers reuse calculations with minimal risk, and detect errors early in the design process, reducing iterations and cost.

In addition to ensuring that engineers are using the optimal tools for their jobs, E&HT companies must also address the business challenges facing their entire global engineering and product development organization. Today, Mathcad is the global standard used by engineers, designers, and other technical professionals throughout the product development process.

When EHT companies standardize on Mathcad, not only are they providing engineers with the best engineering calculation tool for the job, but they are also enabling engineering organizations to successfully solve today's toughest product development business challenges.

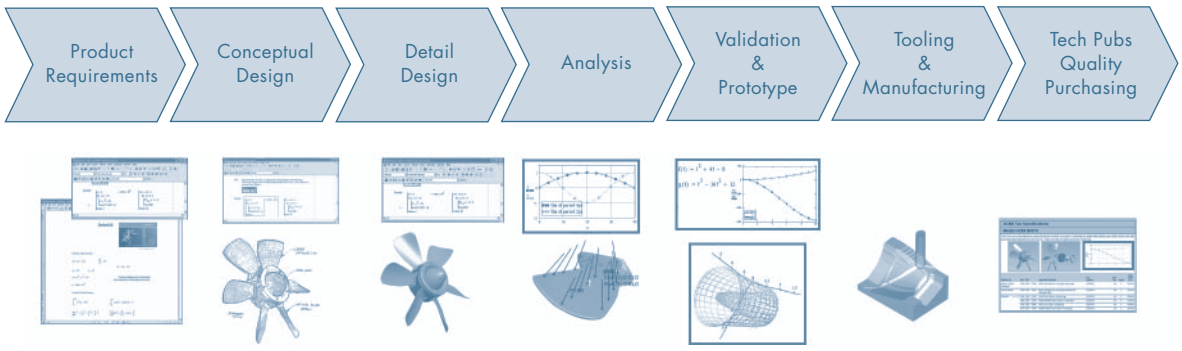

Figure 3. Mathcad captures engineering intent and design throughout the entire product development lifecycle, enabling corporate IP to be retained and reused.