

# Making Better Decisions, Faster: How Electrical Engineers Are Improving Efficiency with Engineering Calculation Software

In September of 2011, miscalculations of electricity supply and demand caused a sudden, nationwide power outage in South Korea. It impacted nearly 1.62 million households, trapped about 3,000 people in elevators, and temporarily shut down hundreds of factories, banks, shops and other businesses.

On the day in question, predicted peak demand was about 3 million kW less than actual demand, while calculated supply was 3.17 million kW more than what was actually available. To avert a total blackout, authorities tapped into reserves and arbitrarily cut power in various regions. Electricity reserves fell to as low as 6 percent of overall demand, well below the 7 percent that was considered the minimum safety margin.

Needless to say, the sparks continued to fly after the man-made disaster: Lawsuits against Korea Electric Power Corp. totaled more than \$14.5 million.

This kind of mistake with extreme consequences is a lesson for all electrical engineering organizations that require precision, high performance and effective knowledge management for success. Can your engineering processes prevent a similar situation from developing? Are you able to provide sufficient documentation to mitigate your mistakes?

The right calculation software can be a powerful tool that enables engineering teams to more easily solve problems, generate ideas, share important data and catch mistakes before they have major consequences. Why then, do so many electrical engineers rely on error-prone, limited and often paper-based legacy calculation methods, like Microsoft® Excel® spreadsheets or even a programming language like Fortran?

This short paper will explain some of the important reasons why modern mathematical software is a much better alternative for electrical engineers – not only for performing complex calculations but also for understanding the intent behind them. You'll learn how more electrical engineering enterprises are finding that their best interests lie not in the incidental information that spreadsheets provide, but in mathematics software that treats every calculation as a key business asset.

## Nine Electrical Engineering Calculations that Are Easier with Dedicated Software

- Equivalent Impedance and Conductance
- Transfer Function Models
- Signal Propagation Delay
- Filter Design
- Component Trade-off Analysis
- AC/DC Circuit Analysis
- Power Dissipation
- Transformer Sizing
- Load Flow

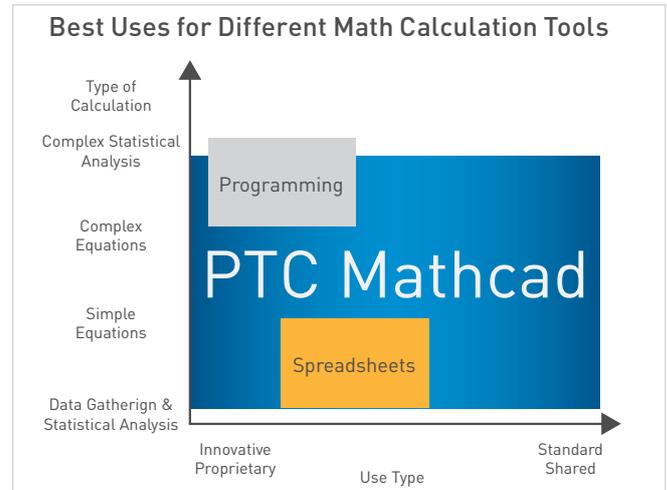
## Success Factor #1: Get designs done at the speed of light

“I have 30 people reporting to me,” says an engineering manager for Arbor Networks, a company that designs Distributed Denial of Service (DDoS) protection for enterprise computer systems. “I’m under pressure to deliver projects on time and to ensure that our engineers have the resources necessary to do their job.”

This should sound familiar to you, since most engineering-oriented companies have the same top-of-mind concerns. Engineers in all disciplines are struggling with decreasing time-to-market deadlines – and many don’t even realize how much time they’re wasting by trying to document calculations done in Excel.

Dr. Robert Phillips, an engineer who spent much of his career reverse engineering cars for General Motors, uses PTC Mathcad® software with his engineering team to save time on every project. When he first came to understand the benefits of the software over his old way of doing things, he realized that “if you can double productivity, you can reduce staff by a factor of eight and keep delivery constant – or keep those people and kill the time to market.”

Because many new products are variants of existing designs, it’s important to capture and organize the original analysis tied to these products for others to find. Legacy calculation methods frequently lead to significant rework, which in turn creates longer development lead times, ties up valuable resources and ultimately slows down the entire design process.



Spreadsheets and programming languages are optimized for specific types of calculations, while engineering math software like PTC’s Mathcad are good for virtually all types of calculations – from the simplest to the most complex.

## Success Factor #2: Come up with brighter ideas

Exploring multiple design concepts and what-if scenarios early in the design process is important for projects that demand innovation and design optimization. It can be mission-critical for electrical engineers to solve challenging problems in key industries, such as hydropower, renewable energy, telecommunications, micro-computing, data transfer, control systems, digital signal processing and defense contracting.

Design studies and trade-off analyses are best practices that help engineers make better design choices faster, knowing that they’ve evaluated all the best options. Using mathematical models to establish performance envelopes and cost trade-off curves, engineers can quickly identify the design solution that most efficiently meets product requirements. A well-documented study or analysis should make it clear why the proposed design offers the best tradeoff between performance and cost – and give reviewers a high degree of confidence that a better solution has not been overlooked.

By using mathematical calculation software, electrical engineers can predict the performance of designs.

Calculation software can be used early on to determine the appropriate physical design dimensions and parameters for things like component values, circuit parameters & responses, and signal properties before embarking on a detailed design and simulation phase. Unlike spreadsheets that require complex formulas to convert measurements, mathematical calculation software provides built-in unit conversion and unit intelligence.

### Success Factor #3: Keep stress at low voltage with fewer mistakes

Speed and creativity don't mean much if your designs aren't accurate and easy to understand. Calculation software can also improve the precision and thus performance of individual engineers and engineering teams. Robert Phillips acknowledges that he "can generally clear things up as I work through a Mathcad model, instead of saying, 'Oh no, what's wrong here?' later in the process."

Spreadsheet expert Raymond Panko points out that "every study that has attempted to measure errors, without exception, has found them at rates that would be unacceptable in any organization." Rick Butler, an auditor who writes and speaks widely on the error-prone nature of spreadsheets, concurs, asserting that spreadsheet developers miss more than 80 percent of their own errors, and outside testers miss more than 50 percent of design logic and 34 percent of application errors.

Spreadsheets and programming languages essentially hide the logic behind engineering decisions, which makes it much more difficult for complex work

to be quickly and properly verified. With legacy calculation methods, errors are more likely to show up downstream in a project, when the costs of rework are multiplied exponentially. Or worse, the errors may make their way into the final product. Obviously, even honest mistakes pose a serious risk to most product development organizations, and calculation software does a much better job of keeping them to a minimum.

### A Disaster Waiting to Happen: Why Risk Your Most Important Calculations to Spreadsheets?

- According to researcher Raymond Panko, 94 percent of spreadsheets have errors, and the average cell error rate (the ratio of cells with errors to all cells with formulas) is 5.2 percent<sup>1</sup>;
- Out of 25 operational spreadsheets studied by S.G. Powell, 10 had an error impact ranging from \$216,806 to more than \$110.5 million<sup>2</sup>;
- Olson & Nilsen found a 21 percent cell error rate among experienced spreadsheet users<sup>3</sup>.

### Success Factor #4: Shine a light on data for easier reuse

By standardizing the way calculations are solved and documented, organizations can make valuable engineering information visible and accessible to key people throughout the organization. This makes it easier to check another engineer's calculations, reuse calculations without having to rewrite them, gain management approval and otherwise collaborate more effectively.

The calculation methods available for solving engineering problems aren't always the best tools for capturing and sharing intellectual property. Calculations are valuable to engineering organizations not only because of the end results, but also because of the assumptions, methods and values behind the results.

<sup>1</sup>Panko, Raymond R [2009]. "What We Know About Spreadsheet Errors," Spreadsheet Research (SSR. 2 16 2009), University of Hawaii, February 27, 2009.

<sup>2</sup>Powell, S. G., Baker, K. R., and Lawson, B., [2007b], "Impact of Errors in Operational Spreadsheets." Proceedings of the European Spreadsheets Risks Interest Group, 2007b.

<sup>3</sup>Olson, Judith Reitman and Nilsen, Erik. "Analysis of the Cognition Involved in Spreadsheet Interaction." Human-Computer Interaction, Volume 3 Issue 4, December, 1987

Mathematical software provides engineering teams with sharable documents that explain everything they need to know about the design process, including text, interactive math calculations, graphs, and actual drawings and models. Reusable worksheets can be saved in several formats, including Microsoft Word, Adobe® PDF, HTML and XML, making it easy to share information with a variety of stakeholders, even if they're using different document management applications, modeling programs and PDM solutions.

### Natural Math Notation Enables Reuse

<code>=IMDIV(IMPRODUCT(ZLF,ZHF),JMSUM(ZLF,ZHF))</code>		
Total Impedance	Z	7.99698340982171-0.00000179960

**Total Impedance:**  $Z_T := \frac{Z_{LF} \cdot Z_{HF}}{Z_{LF} + Z_{HF}}$       $Z_T = (7.997 - 1.8i \cdot 10^{-6}) \Omega$

The logic of engineering calculations, such as total impedance, can get buried in spreadsheets; however it is perfectly clear in computational software.

Using standard math notations, integrated text and graphical displays, calculation software can automatically generate readable documents that are easily understood up and down the management chain and across diverse, multicultural teams.

### Success Factor #5: Lighten your regulatory reporting load

In addition to facilitating knowledge transfer internally, math calculation software makes it easy for organizations to report to regulatory agencies and clients responsible for auditing vendor quality processes.

Spreadsheets lack the controls and documentation capabilities needed for proper traceability. Calculation software, on the other hand, simplifies and streamlines documentation that's critical to communicating and to meeting business and quality assurance standards. All engineering information is in

one place with appropriate annotations: Calculations, methods and values can be shared as the company sees fit with a wide variety of parties outside the engineering division.

### Case Example: Circuitry Redesign for Improved Gaming Performance

An engineer is tasked with redesigning a client's video game controller circuitry, according to specific requirements for improved reliability, lower power consumption and greater interoperability with existing devices. Cost constraints suggest the use of cheaper, off-the-shelf components wherever possible.

Using computational software, the engineer quickly creates design component models in worksheets, drawing from hundreds of math functions and standard electrical equation libraries. One component model focuses on the trade-off analysis of impedance given different off-the-shelf resistors and capacitors. Using familiar, natural math notation, the engineer can zero-in on the design experiments and analysis itself, rather than laboring to "program in" hard-to-read formulas.

To evaluate the impact of any component change, the engineer can easily "swap out" resistance values from a library of off-the-shelf components. Because the software's natural math notation is "live," changes in low-frequency, high-frequency and total-impedance values are reflected immediately throughout the model. As the engineer works, the software's dynamic unit-checking capability reduces errors.

The software automatically calls upon previously defined impedance calculations and a table of frequencies to generate a first-order crossover impedance trade-off plot. If the capacitance is revised, the plotlines for higher frequency impedance and total impedance will update automatically. Thus, the software enables the engineer to quickly evaluate, and easily communicate, component choices.

Anyone, anywhere, viewing the results of this trade-off analysis can clearly understand the formulas, with the entire set of assumptions and calculations clearly

presented – whether it’s for a review of the design study with management, for auditing by a regulatory agency or for communicating with team members across the globe.

### Conclusion: Finding the right math calculation software for electrical engineering

Engineers in all disciplines are struggling with decreasing time-to-market deadlines—and many don’t even realize how much time they’re wasting by trying to document calculations done in Excel.

Spreadsheet developers miss more than 80 percent of their own errors, and outside testers miss more than 50 percent of design logic and 34 percent of application errors.

Using standard math notations, integrated text and graphical displays, calculation software can automatically generate readable documents that are easily understood up and down the management chain.

Modern mathematical software is a much better alternative for performing complex calculations and understanding the intent behind them. Your best interests lie not with the incidental information that spreadsheets provide, but with mathematics software that treats your calculations as key business assets.

Those who do step up to modern math calculation programs, like Robert Phillips did with PTC Mathcad, are often amazed at the results – and how easy it is to hit the ground running. All engineers owe it to themselves to at least take advantage of the [free 30 day trials](#) that the major math calculation packages offer, just to see how the software can take their performance to new levels of success.

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