Maplesoft
Mathematics • Modeling • Simulation
A Cybernet Group Company

Calculation Management for Electrical Engineers

Electrical engineers are a unique breed. Their work is mathematically demanding, and they constantly face challenging technical problems.

Math software and spreadsheets are often used to support the calculations at the core of their analyses. However, calculations aren't just a collection of isolated mathematical operations. Electrical engineers need to:

- Calculate with high-level math functions
- Document calculations for legibility and readability
- Deploy calculations to a broader audience
- Connect calculations to the entire toolchain to influence upstream and downstream decisions

Fundamentally, calculations need to exist in a structured, managed environment.

This whitepaper examines how electrical engineers use Maple™ for calculation management, transforming what would otherwise be isolated analyses into reusable, shareable and extensible assets.

The paper starts by examining Maple's features for doing, documenting and deploying calculations. Then, several typical electrical engineering applications are discussed.

Features for Electrical Engineers

Capture Design Intent

A Maple document combines live math, text, images and plots in a single document. In effect, Maple captures the inherent assumptions and thought process behind an analysis, as well as the calculations.

Fundamentally, Maple captures design intent, and turns calculations into reusable, shareable, extensible documents.

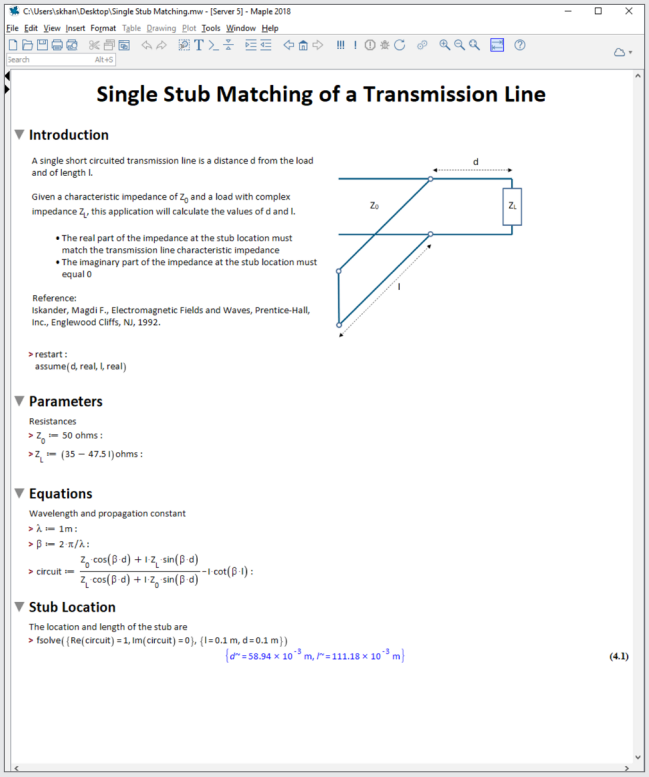

Figure 1. Document Interface

High-Level Math

Maple offers practical high-level tools for numeric and symbolic math, data analysis, and programming. These tools are designed for both simple and complex engineering problems.

For example, Maple can solve the stiff differential equations that typically arise from analyzing electrical circuits.

The symbolic and numeric math engines are seamlessly connected; parameters, equations and calculations can fluidly flow between the two. This means you can derive and numerically evaluate your equations in a single cohesive workflow.

Moreover, Maple's programming language benefits from an interactive development environment and can use any of Maple's high-level math tools, making the code:

- Faster to develop, debug and verify
- Able to use Maple's high level math functions
- Easier to read by humans

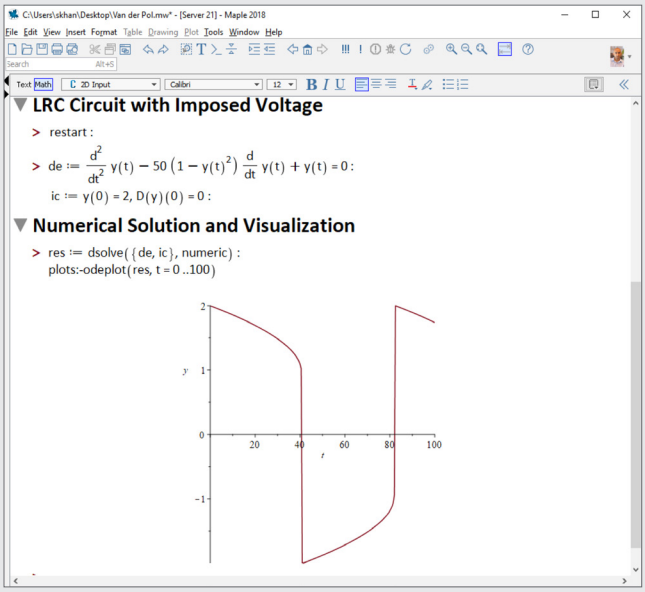

Figure 2. Stiff differential equation from an LRC circuit with an imposed voltage

Reduce Calculation Risk with Units

Nearly every single quantity an electrical engineer encounters – whether it's a resistance, voltage or a length - has a unit.

Units are fluidly integrated into the Maple environment, and can be used in simple calculations as well as numeric equation solving, optimization and visualization.

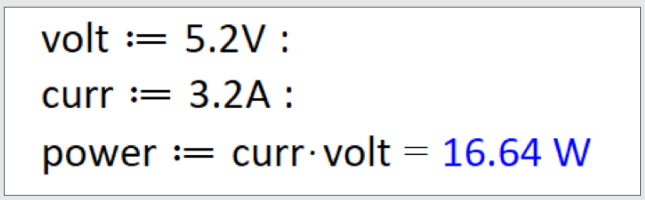

Figure 3. Calculations with Units

Using units in calculations removes the risk of introducing unit conversion errors, and also acts as a check on the physical validity of the equations.

Connect to the Entire Toolchain

You can import and export data to and from spreadsheets, text files, audio data and many other file formats.

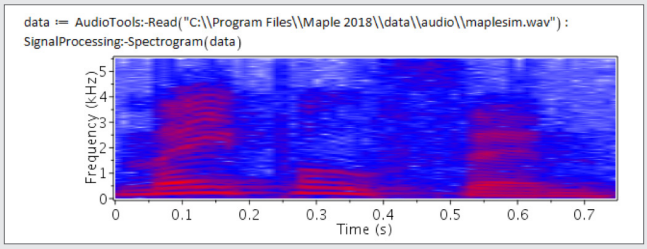

Figure 4. Importing audio and generating a spectrograms

Maple can also call externally defined code (for example external solvers or proprietary data sources defined in a DLL) and connected to dedicated process simulation tools.

Some electrical engineers use Maple to automatically transform SPICE netlists into mathematical expressions – a task that would otherwise be done by hand; these expressions can then be analyzed, manipulated and visualised in Maple.

```
> rc := "
  Vin 1 0
  R 1 2
  C 2 0
  .end" :
> ans := Syrup:-Solve(rc, ac)
```

$$ans := \left\{ v_1 = Vin,\ v_2 = \frac{Vin}{s\,C\,R + 1} \right\}$$

Figure 5. Translating a netlist for a one-pole filter into a transfer function

Compelling Visualizations

Maple boasts a broad range of built in plots. These include:

- 2-D and 3-D plots
- Polar plots
- Periodograms and spectrograms
- Bode, Root-Locus and Nyquist stability charts

These visualizations are fully customizable, and new plot types can be programmatically generated.

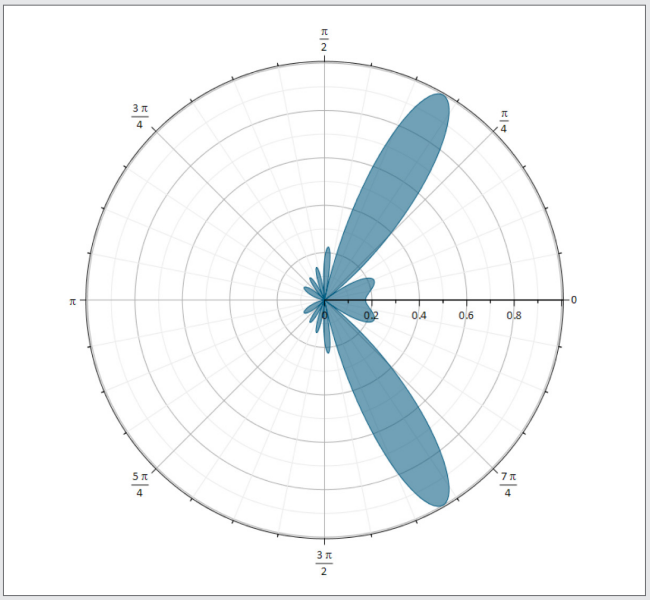

Figure 6. Polar plot of the directivity of an antenna array

Cost-Effective Deployment

Applications can be password protected, while still remaining executable. This means live applications can be distributed while the intellectual property remains securely locked away.

Applications can be distributed royalty-free as interactive desktop tools using the Maple Player™, or deployed over the web.

Moreover, Maple will translate user-developed programs to C, Python®, Java and several other languages.

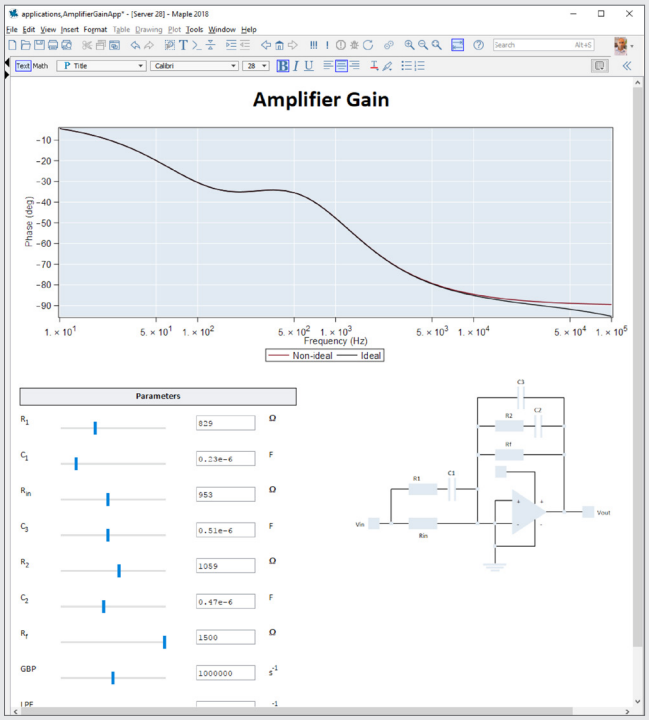

Figure 7. Deployable application for analyzing the gain of an amplifier

Application Focus

In this section, we will discuss how electrical engineers have typically used Maple. First, each application is briefly described. Then, the Maple features used in the application are discussed.

Pyramidal Horn Design

An electrical engineer wanted to calculate the optimum design parameters for an X-band pyramidal horn. The engineer entered the parameters and equations in Maple, and solved the resulting system numerically.

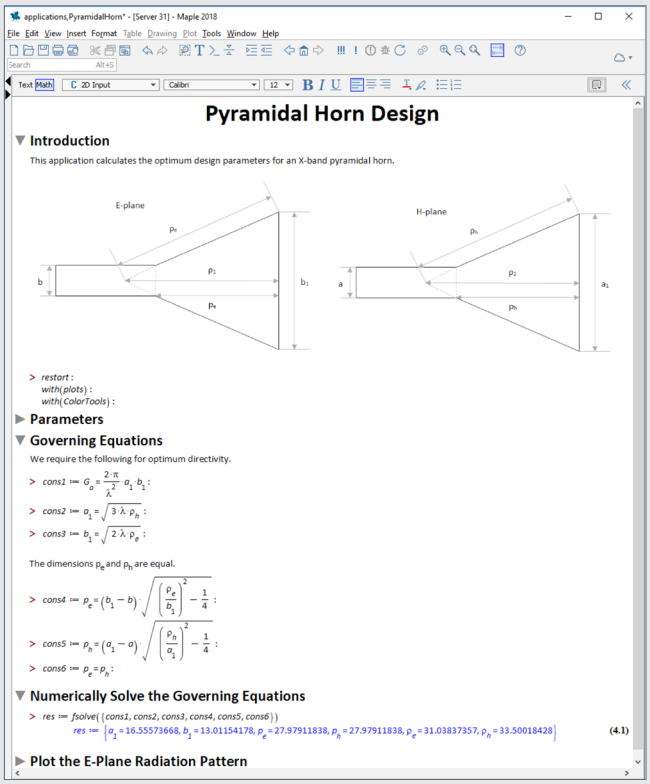

Figure 8. Design of a pyramidal horn

Task	Maple Feature
Set up equations that describe geometrical constraints of pyramidal horn	2-D math notation, units
Extracting speed of light	Built-in scientific data
Finding the optimum design parameters	Numerical equation solver
Visualize e-plane radiation pattern	Polar plot

The governing equations involve parameters that vary by several orders of magnitude, and are challenging to solve. Maple's numerical solver, however, easily solved the equations.

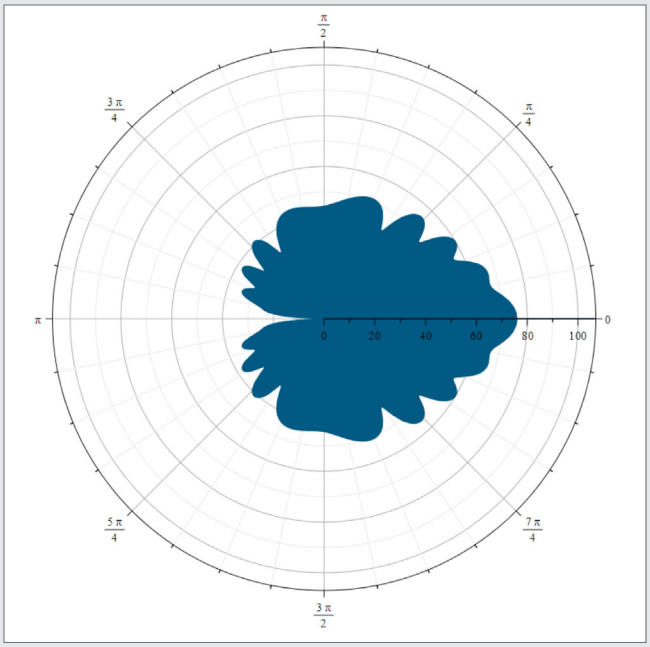

Figure 9. E-Plane radiation pattern for a pyramidal horn

Coaxial Transmission Line Design

An electrical engineer was tasked with developing a web-based app for coaxial transmission line. Specifically, the app needed to help the user determine the optimum dielectric material and the wire size.

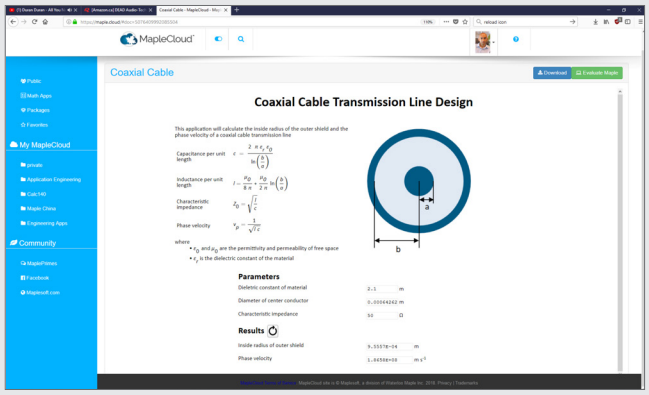

Figure 10. Web-Based coaxial cable transmission line design

Task	Maple Feature
Develop a Maple application to find the dimension and phase velocity of coaxial cable	Programming language, user interface components, numeric equation solver
Values of permeability and permittivity of free space	Built-in scientific data
Deploy Maple application to web	MapleNet™

PV Diode Parameter Estimation

Given experimental values of the forward current (I_f) and voltage (V_f), an electrical engineer needed to estimate parameter values for a photovoltaic diode. The implicit photovoltaic diode equation needed to be rearranged before regression could take place. This used special functions only available in advanced tools like Maple.

$$I_r := \text{solve}\left(I_f = I_{ph} - I_{SD}\left(e^{\frac{V_f + I_f R_s}{n V_t}} - 1\right) - \frac{V_f + I_f R_s}{R_{sh}}, I_f\right)$$

$$I_r := -\frac{-\text{LambertW}\left(-\frac{I_{SD} R_s R_{sh} e^{\frac{R_{sh}\left(I_{SD} R_s + I_{ph} R_s + V_f\right)}{n V_t \left(R_s + R_{sh}\right)}}}{-R_s V_t n - R_{sh} V_t n}\right) + \frac{R_{sh}\left(I_{SD} R_s + I_{ph} R_s + V_f\right)}{n V_t \left(R_s + R_{sh}\right)}}{R_s} n V_t + V_f$$

Figure 11. Rearrange photovoltaic diode equation

Task	Maple Feature
Combine spreadsheet with experimental data and Maple worksheet into one file	Workbook file format
Rearrange the photovoltaic diode equation to give current in terms of voltage using the LambertW function	Natural math notation Symbolic math
Boltzmann constant and electron charge	Built-in scientific data
Regress experimental data to find best-fit parameters	Curve fitting and optimization
Plot experimental data and best-fit curve	Programmatic visualization

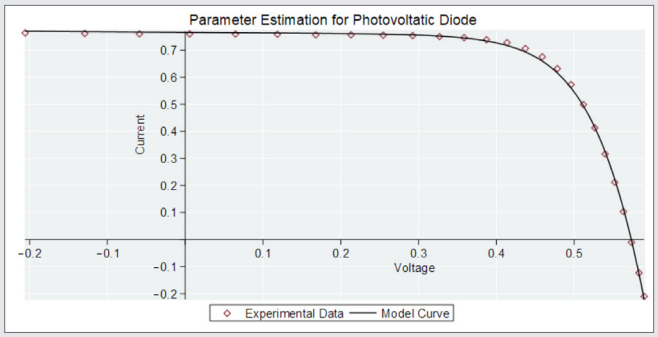

Figure 12. Parameter estimation for a photovoltaic diode

Conclusion

Calculations shape the engineered world around us. Calculations deserve respect, and accordingly need to be managed.

Maple provides a unique calculation environment that captures design intent, provides high-level math tools, and also offers cost-effective deployment targets.

Fundamentally, Maple helps electrical engineers to manage their calculations. This transforms what would otherwise be an isolated analysis into a structured asset that can be reused, extended and shared with clients and colleagues.

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