



## Welcome

Welcome to CST EM Studio®, the powerful and easy-to-use electromagnetic field simulation software. This program combines a user-friendly interface with unsurpassed simulation performance.

CST EM Studio is part of CST Studio Suite®. Please refer to the *CST Studio Suite Getting Started* manual first. The following explanations assume that you already installed the software and familiarized yourself with the basic concepts of the user interface.

## How to Get Started Quickly

We recommend that you proceed as follows:

1. Read the *CST Studio Suite Getting Started* manual.
2. Work through this document carefully. It provides all the basic information necessary to understand the advanced documentation.
3. Look at the examples provided in the Component Library (*File: Component Library* ⇒ *Examples*). Especially the examples which are tagged as *Tutorial* provide detailed information of a specific simulation workflow. Press the *Help* ? button of the individual component to get to the help page of this component. Please note that all these examples are designed to give you a basic insight into a particular application domain. Real-world applications are typically much more complex and harder to understand if you are not familiar with the basic concepts.
4. Start with your own first example. Choose a reasonably simple example, which will allow you to quickly become familiar with the software.
5. After you have worked through your first example, contact technical support for hints on possible improvements to achieve even more efficient usage of the software.

## What is CST EM Studio?

CST EM Studio is a fully featured software package for electromagnetic analysis and design of electrostatic, magnetostatic, stationary current and low-frequency devices. It simplifies the process of creating the structure by providing a powerful graphical solid modeling front end, which is based on the ACIS modeling kernel. After the model has been constructed, a fully automatic meshing procedure is applied before a simulation engine is started.

A key feature of CST EM Studio is the *Method on Demand* approach, which allows using the solver or mesh type that is best suited to a particular problem. Most solvers support two different meshing strategies:

- Classic tetrahedral meshes, which provide an explicit representation of the geometry and material interface by a surface mesh. Thus, material interfaces are explicitly resolved by the mesh. Curvilinear mesh elements are especially suited to discretize curved geometries. The geometry resolution is continually improved during an adaptive mesh refinement using the *True Geometry Adaptation* technique.
- Hexahedral grids in combination with the Perfect Boundary Approximation (PBA®) feature. With hexahedral (Cartesian) meshes, interfaces of materials and solids are not represented by surface mesh cells. Therefore, the meshing algorithm is very robust, and meshes can be generated even for very complex CAD geometries. The PBA feature significantly increases the accuracy of the simulation in comparison to conventional Cartesian mesh simulators.

The software contains five different solvers that best fit their particular applications:

- Electrostatic solver
- Magnetostatic solver
- Stationary current solver

- LF Frequency Domain solver
  - magnetoquasistatic
  - electroquasistatic
  - full-wave
- LF Time Domain solver
  - magnetoquasistatic
  - electroquasistatic

If you are unsure which solver best suits your needs, please consult the online help or contact your local sales office for further assistance.

Simulation results from each solver can be visualized with a variety of different options. Again, a strongly interactive interface will help you quickly achieve the desired insight into your device.

The last – but certainly not least – outstanding feature is the full parameterization of the structure modeler, which enables the use of variables in the definition of your component. In combination with the built-in optimizer and parameter sweep tools, CST EM Studio is capable of both the analysis and the design of electromagnetic devices.

## Who Uses CST EM Studio?

Anyone who seeks to solve static or low-frequency electromagnetic problems can use CST EM Studio. The program is especially suited to the fast, efficient analysis and design of components like actuators, insulators, shielding problems, sensors, transformers, electrical machines, etc. Since the underlying method is a general 3D approach, CST EM Studio can solve virtually any static and low-frequency field problem.

## CST EM Studio Key Features

The following list gives you an overview of CST EM Studio's main features. Note that not all of these features may be available to you because of license restrictions. Contact a sales office for more information.

### General

- Native graphical user interface based on Windows 7, Windows 2008 Server R2, Windows 8, Windows 2012 Server, Windows 8.1, Windows 2012 Server R2 or Windows 10
- The structure can be viewed either as a 3D model or as a schematic. The latter allows for easy coupling of EM simulation with circuit simulation.
- Various independent types of solver strategies (based on hexahedral as well as tetrahedral meshes) allow accurate results with a high performance for all kind of low frequency applications.
- For specific solvers, highly advanced numerical techniques offer features like PERFECT BOUNDARY APPROXIMATION (PBA)<sup>®</sup> for hexahedral grids and curved and higher order elements for tetrahedral meshes.

### Structure Modeling

- Advanced ACIS-based, parametric solid modeling front end with excellent structure visualization
- Feature-based hybrid modeler allows quick structural changes.
- Import of 3D CAD data from ACIS SAT (e.g. AutoCAD<sup>®</sup>), ACIS SAB, Autodesk Inventor<sup>®</sup>, IGES, VDA-FS, STEP, Pro/ENGINEER<sup>®</sup>, CATIA<sup>®</sup>, Siemens NX, Parasolid, Solid Edge, SolidWorks, CoventorWare<sup>®</sup>, Mecadtron<sup>®</sup>, NASTRAN, STL or OBJ files
- Import of 2D CAD data from DXF<sup>™</sup>, GDSII and Gerber RS274X, RS274D files
- Import of EDA data from design flows including Cadence Allegro<sup>®</sup> / APD<sup>®</sup> / SiP<sup>®</sup>, Mentor Graphics Expedition<sup>®</sup>, Mentor Graphics PADS<sup>®</sup>, Mentor Graphics HyperLynx<sup>®</sup>, Zuken CR-5000<sup>®</sup> / CR-8000<sup>®</sup>, IPC-2581 and ODB++<sup>®</sup> (e.g. Altium Designer, Mentor Graphics Boardstation<sup>®</sup>, CADSTAR<sup>®</sup>, Visula<sup>®</sup>)
- Import of OpenAccess and GDSII-based integrated-circuit layouts via CST Chip Interface
- Import of PCB designs originating from CST PCB Studio<sup>®</sup>
- Import of 2D and 3D sub models
- Import of Agilent ADS<sup>®</sup> layouts



- Import of Sonnet® EM models
- Import of a visible human model dataset or other voxel datasets
- Export of CAD data by ACIS SAT, ACIS SAB, IGES, STEP, NASTRAN, STL, DXF™, GDSII, Gerber or POV files
- Parameterization for imported CAD files
- Material database
- Structure templates for simplified problem setup

### Electrostatic Solver

- Isotropic and (coordinate-dependent) anisotropic material properties
- Support of hexahedral meshes as well as linear and curved tetrahedral meshes
- Sources: potentials, charges on conductors (floating potentials), uniform volume- and surface-charge densities, capacitive field grading
- Force calculation
- Capacitance calculation
- Electric / magnetic / tangential / normal / open / fixed-potential boundary-conditions
- Perfect conducting sheets and wires
- Discrete edge capacitive elements at any location in the structure
- Adaptive mesh refinement in 3D
- Higher order representation of the solution with tetrahedral mesh
- Automatic parameter studies using built-in parameter sweep tool
- Automatic structure optimization for arbitrary goals using built-in optimizer
- Network distributed computing for optimizations, parameter sweeps and remote calculations
- Coupled simulations with Mechanical Solver from CST MPhysics Studio®
- Equivalent Circuit EMS/DS Co-Simulation for constant material properties

### Magnetostatic Solver

- 3D- and 2D<sup>1</sup>- problem support.
- Isotropic and (coordinate-dependent) anisotropic material properties
- Nonlinear ferromagnetic material properties
- Laminated material properties
- Support of hexahedral meshes as well as linear and curved tetrahedral meshes
- Sources: coils, coil segments, linear and non-linear permanent magnets, current paths, external magnetic fields, stationary current fields, current ports
- Force and force density calculation
- Apparent and incremental inductance calculation
- Flux linkages
- Electric / magnetic / tangential / normal / open boundary-conditions
- Rotational periodicity for 2D and 3D problems
- Adaptive mesh refinement for 2D and 3D solver
- Higher order representation of the solution with tetrahedral and triangular meshes
- Automatic parameter studies using built-in parameter sweep tool
- Automatic structure optimization for arbitrary goals using built-in optimizer
- Network distributed computing for optimizations, parameter sweeps and remote calculations
- Coupled simulations with Mechanical Solver from CST MPhysics Studio
- Equivalent Circuit EMS/DS Co-Simulation for constant and nonlinear material properties

### Stationary Current Solver

- Isotropic and (coordinate-dependent) anisotropic material properties
- Nonlinear electrical conductivity properties
- Temperature dependent materials with coupling to CST MPhysics Studio
- Electric contact resistance
- Support of hexahedral meshes as well as linear and curved tetrahedral meshes
- Sources: current paths, potentials, current ports, coil segments including those created from solids
- Conductance calculation

<sup>1</sup> The 2D solver supports rotational and translational symmetric problems.



- Discrete edge resistances at any location in the structure
- Perfect conducting sheets and wires
- Electric / magnetic / normal / tangential boundary-conditions
- Adaptive mesh refinement in 3D
- Higher order representation of the solution with tetrahedral mesh
- Automatic parameter studies using built-in parameter sweep tool
- Automatic structure optimization for arbitrary goals using built-in optimizer
- Network distributed computing for optimizations, parameter sweeps and remote calculations
- Coupled simulations with Thermal Solver from CST MPhysics Studio
- Equivalent Circuit EMS/DS Co-Simulation for constant material properties

### LF Frequency Domain Solver

- Isotropic and (coordinate-dependent) anisotropic material properties
- Nonlinear material properties (B(H)) and linear equivalent permeability computation
- Temperature dependent nonlinear (B(H)) and linear materials with coupling to CST MPhysics Studio
- Support of hexahedral meshes as well as linear and curved tetrahedral meshes
- Electroquasistatic analysis
- Magnetoquasistatic analysis (eddy current approximation)
- Full wave analysis
- Sources for electroquasistatic analysis: potentials
- Sources for full wave and magnetoquasistatic analysis: coils, coil segments including those created from solids, current ports, current paths, voltage paths, external magnetic source fields
- Impedance calculation
- Broadband impedance calculation for magnetoquasistatic analysis for the setups with stranded coils and segments, current ports and coil segments created from solids
- Broadband source parameters for magnetoquasistatic analysis for the setups with stranded coils and/or current ports
- Authoring of Reduced Order Models as Functional Mockup Units according to FMI standard
- Fast frequency sweep in the broadband solver regime
- Force calculation
- Perfect conducting sheets and wires
- Lumped R, L, C elements at any location in the structure
- Surface impedance model for good conducting metals
- Electric / magnetic / open boundary-conditions
- Adaptive mesh refinement in 3D
- Higher order representation of the solution with tetrahedral mesh
- Automatic parameter studies using built-in parameter sweep tool
- Automatic structure optimization for arbitrary goals using built-in optimizer
- Network distributed computing for optimizations, parameter sweeps and remote calculations
- Coupled simulations with Thermal Solver from CST MPhysics Studio
- Coupled simulations with SIMULIA Abaqus

### LF Time Domain Solver

- Isotropic and (coordinate-dependent) anisotropic material properties
- Magnetoquasistatic analysis (eddy current approximation), 3D- and 2D<sup>2</sup>-problem support
- Electroquasistatic analysis
- Nonlinear material properties (B(H), E(J), J(H, T))
- Recoil model for nonlinear hard magnetic material properties (permanent magnets)
- Iron Loss computation
- Support of linear and curved tetrahedral meshes
- Sources for the magnetoquasistatic analysis: coils, coil segments including those created from solids, current ports, current paths, voltage paths, permanent magnets, external magnetic source field

<sup>2</sup> The 2D solver supports rotational and translational symmetric problems.



- Sources for electroquasistatic analysis: potentials
- Magnetoquasistatic analysis: perfect conducting sheets and wires
- Electric / magnetic / open boundary-conditions
- Higher order representation of the solution with tetrahedral mesh
- User defined excitation signals and signal database
- Adaptive time stepping
- Dedicated time stepping algorithm for time periodic problems
- Rigid body motion for 2D and 3D models with nested rotation and translation
- Periodic boundary condition (translation) and subvolume (rotation)
- Demagnetization monitors
- Network distributed computing remote calculations
- Coupled simulations with Thermal Solver from CST MPhysics Studio
- Coupled simulations with SIMULIA Abaqus

**Note:** some solvers or features may be available for hexahedral and some may be available for tetrahedral meshes only.

### CST Design Studio View

- Schematic view that shows the circuit level description of the current CST EM Studio project
- Allows additional wiring, including active and passive circuit elements as well as more complex circuit models coming from measured data (e.g. Touchstone or IBIS files), analytical or semi-analytical descriptions, or from simulated results (e.g. CST Microwave Studio, CST Cable Studio or CST PCB Studio projects)
- Offers many different circuit simulation methods
- All schematic elements as well as all defined parameters of the connected CST EM Studio project can be parameterized and are ready for optimization runs
- Geometry creation by assembling the components on the schematic in 3D
- Flexible and powerful hierarchical task concept offering nested parameter sweep / optimizer setups

### SAM (System and Assembly Modeling)

- 3D representations for individual components
- Automatic project creation by assembling the schematic's elements into a full 3D representation
- Manage project variations derived from one common 3D geometry setup
- Coupled multi-physics simulations by using different combinations of coupled Circuit/EM/Thermal/Stress projects

### Visualization and Secondary Result Calculation

- Multiple 1D result view support
- Online visualization of intermediate results during transient simulations
- Import and visualization of external xy-data
- Copy & paste of xy-datasets
- Fast access to parametric data via interactive tuning sliders
- Automatic parametric 1D result storage
  
- Various field visualization options in 2D and 3D for electric fields, magnetic fields, potentials, current densities, energy densities, etc.
- Animation of field distributions
- Display of source definitions in 3D
- Display of nonlinear material curves in xy-plots
- Display of material distribution for nonlinear materials
  
- Display and integration of 2D and 3D fields along arbitrary curves
- Integration of 3D fields across arbitrary faces



- Hierarchical result templates for automated extraction and visualization of arbitrary results from various simulation runs. These data can also be used for the definition of optimization goals.

## Result Export

- Export of result data such as fields, curves, etc.
- Export of result data as ASCII files
- Export screen shots of result field plots

## Automation


- Powerful VBA (Visual Basic for Applications) compatible macro language including editor and macro debugger
- OLE automation for seamless integration into the Windows environment (Microsoft Office®, MATLAB®, AutoCAD®, MathCAD®, Windows Scripting Host, etc.)

## About This Manual

This manual is primarily designed to enable a quick start of CST EM Studio. It is not intended to be a complete reference guide to all the available features but will give you an overview of key concepts. Understanding these concepts will allow you to learn how to use the software efficiently with the help of the online documentation.

The main part of the manual is the *Simulation Workflow* (Chapter 2), which will guide you through the most important features of CST EM Studio. We strongly encourage you to study this chapter carefully.

## Document Conventions

- Buttons that should be pressed within dialog boxes are always written in italics, e.g. *OK*.
- Key combinations are always joined with a plus (+) sign. Ctrl+S means that you should hold down the Ctrl key while pressing the S key.
- The program's features can be accessed through a Ribbon command bar at the top of the main window. The commands are organized in a series of tabs within the Ribbon. In this document, a command is printed as follows: *Tab name: Group name ⇒ Button name ⇒ Command name*. This means that you should activate the proper tab first and then press the button *Command name*, which belongs to the group *Group name*. If a keyboard shortcut exists, it is shown in brackets after the command.  
Example: *View: Visibility ⇒ Wire Frame (Ctrl+W)* 
- The project data is accessible through the navigation tree on the left side of the application's main window. An item of the navigation tree is referenced in the following way: *NT: Tree folder ⇒ Sub folder ⇒ Tree item*.  
Example: *NT: 2D/3D Results ⇒ E-Field [Es] ⇒ Abs*

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