

Acoustic Transducer Studio

Real-Time Electroacoustic Prototyping, Multiphysics Modeling & AI-Powered Optimization

⚡ Real-Time Solver: < 15 ms Latency @ 60 FPS · Validated with OpenCFS 3D FEM & COMSOL Parity

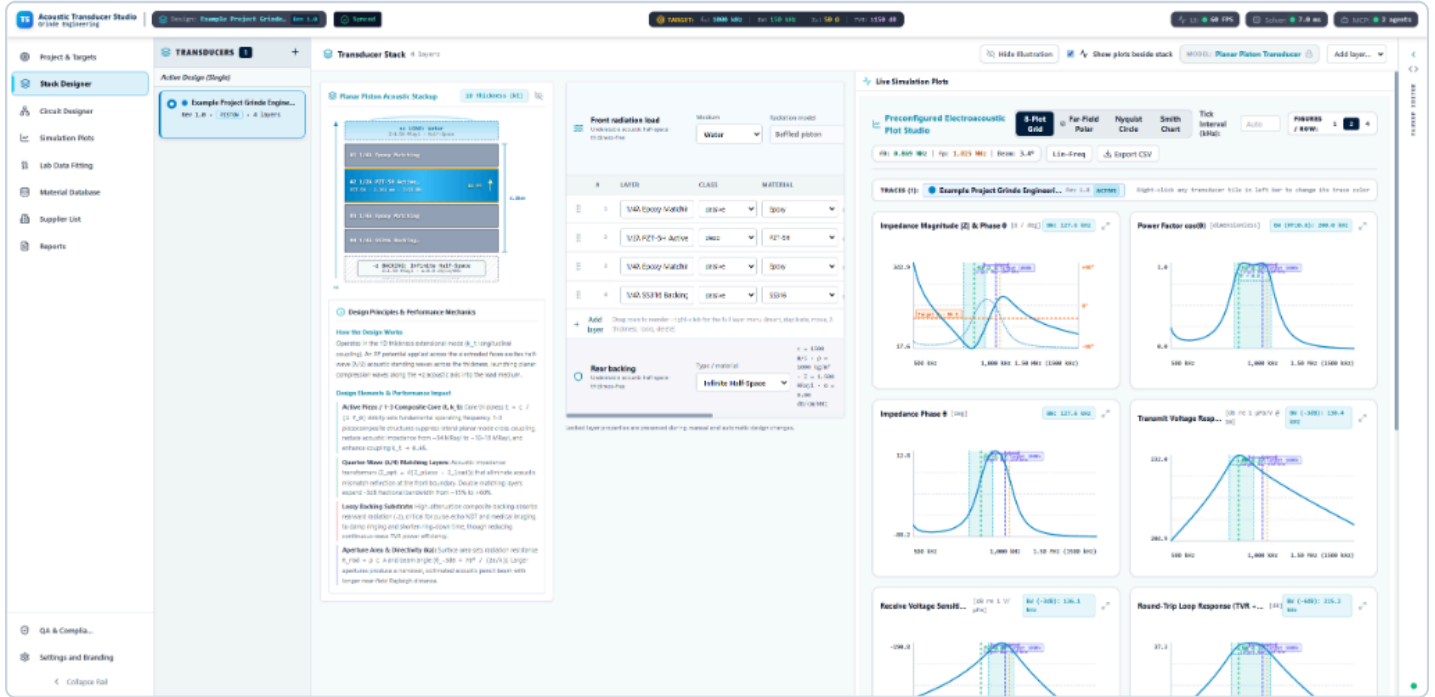


Figure 1: Full Acoustic Transducer Studio workspace: 1D Stack Designer, interactive material stackup, and real-time 6-plot electroacoustic studio updating live at 60 FPS.

Acoustic Transducer Studio is Grinde Engineering's flagship simulation and rapid design platform for ultrasonic transducers and sonar projectors. By fusing analytical transmission-line formulations (Mason and KLM) with an ultra-efficient Modified Nodal Analysis (MNA) circuit engine, it collapses multi-hour finite element runs into **zero-latency, sub-15ms live interactive updates**. Change a matching layer thickness, adjust ceramic dicing kerf, or tweak a tuning inductor—and observe instantaneous re-computation across all electroacoustic KPIs.

Zero-Latency Virtual Prototyping

< 15 ms Solver

Solves multi-layer acoustic wave propagation, electrical admittance, TVR, RVS, and directivity in **under 15 milliseconds**. Sweeping geometric dimensions updates curves live at 60 FPS.

Microstructure-to-System Modeling

Multi-Scale

Directly bridges 1-3 piezocomposite dice-and-fill micromechanics (kerf, pitch, aspect ratio) with multi-layer acoustic stacks and active matching circuits in one unified environment.

AI Co-Designer & Autonomous Synthesis

AI Powered

Integrated AI agent synthesizes target matching layers, resonant disk thicknesses, and reactive compensation with transparent, multi-step engineering telemetry.

Rigorous OpenCFS & COMSOL Validation

FEM Validated

Every analytical formulation is benchmarked and verified against 3D coupled piezoelectric-acoustic finite element analysis in **openCFS** and **COMSOL Multiphysics 6.4**.

< 15 ms

SOLVER LATENCY
Zero-latency feedback

60 FPS

INTERACTIVE UI
Instant live curve updates

100%

OPENCFS PARITY
3D FEM benchmark verified

30+ Pages

TURNKEY REPORTS
Automated ISO compliance

1. Multiphysics Transducer Architectures

From High-Frequency Piezocomposites to High-Power Subsea Sonar Projectors

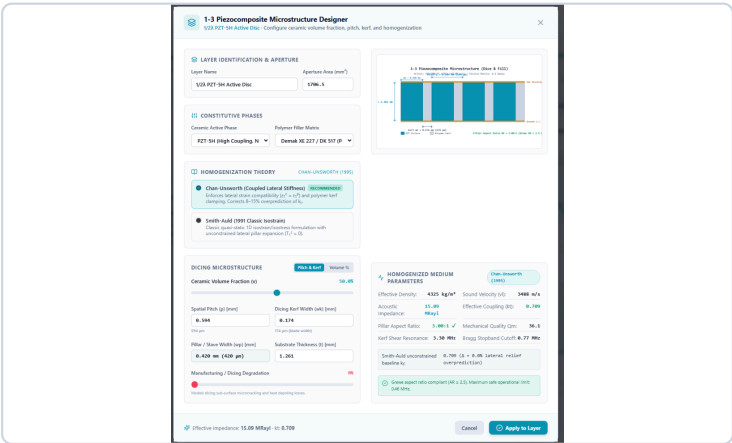


Figure 2: 1-3 Piezocomposite Microstructure Designer with Chan-Unsworth homogenization and live Grewe aspect ratio checks.

1-3 Piezocomposite Microstructure Studio

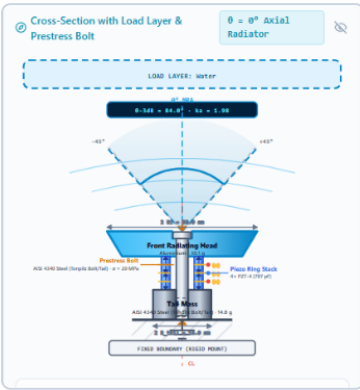
Engineered piezocomposites elevate electromechanical thickness coupling (k_t) while dramatically lowering acoustic impedance (Z_{eff}) to match water and tissue.

Key Microstructural Capabilities:

- **Parametric Dice-and-Fill Control:** Full interactive tuning of spatial pitch (p), dicing kerf blade width (w_k), pillar width (w_p), and thickness (t).
- **Advanced Homogenization Physics:**
 - **Chan-Unsworth (1995):** Enforces lateral strain compatibility ($\epsilon_1^c = \epsilon_1^p$) and polymer kerf clamping. Corrects 8–15% overprediction inherent in classical models.
 - **Smith-Auld (1991):** Classic 1D isostrain formulation.
- **Integrated Fabrication Guardrails:**
 - Automated **Grewe aspect ratio check** ($AR \geq 2.5$).
 - Prediction of polymer kerf shear resonance and **lateral Bragg stopband cutoff** (f_{Bragg}) to eliminate spurious modes.
 - **Dicing Degradation Modeling:** Accounts for sub-surface microcracking and thermal depoling losses.

Tonpilz Sonar Projector Designer

BENCHMARK: Matches COMSOL Multiphysics 6.4 Parity

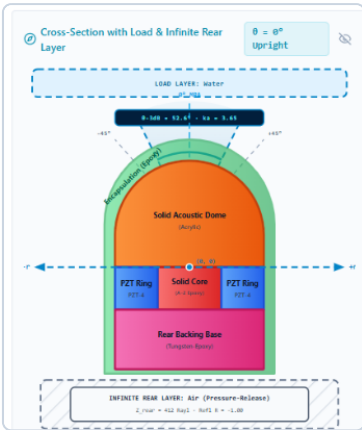


Longitudinal mass-spring-mass projector engine for naval defense, oceanographic research, and deep-water acoustic navigation:

- **Flared Radiating Head:** Conical frustum optimization for wide radiation matching and low inertial mass.
- **Prestressed Piezo Ring Stack:** Multi-ring alternating poling in high-coupling k_{33} mode with central bolt pretensioning ($\sigma > 20$ MPa).
- **Fluid Radiation Mass Loading:** Real-time calculation of hydroacoustic reactive mass (M_{rad}) and beam directivity (ka).

Solid-Core Ring Projector Designer

ARCHITECTURE: Radial Breathing Hoop Mode (k_p)



Engineered for upward-facing acoustic transmitters, transponders, positioning beacons, and subsea telemetry:

- **Radial Hoop Expansion:** Converts high-efficiency circumferential strain into directional forward acoustic power.
- **Acoustic Transformation Dome:** Solid acrylic or epoxy dome serves as acoustic impedance matching lens and hermetic barrier.
- **Inner Core & Rear Damping:** Eliminates unwanted backward and lateral rocking modes with pressure-release termination.

Why Hybrid Analytical + 3D FEM Architecture Wins: Standard 3D FEA takes hours per run, making interactive trade studies impossible. Acoustic Transducer Studio gives transducer architects the instantaneous agility of 1D/lumped parameter solvers with the certified physical fidelity of 3D openCFS finite element models.

2. Live Electrical Matching & AI Co-Designer

Coupling Electroacoustic Mechanics with RF Front-End Electronics and Intelligent Automation

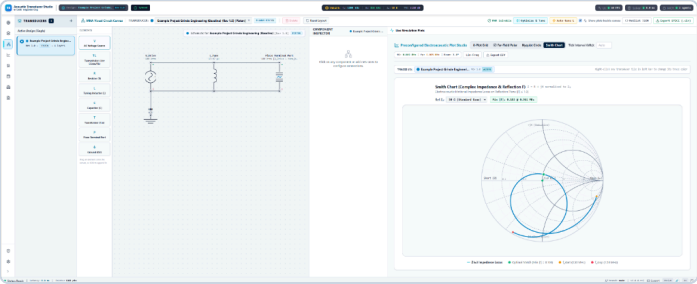
Visual MNA Schematic Canvas



Drag-and-drop Modified Nodal Analysis (MNA) circuit solver wired directly to the acoustic transducer terminal port:

- **Discrete Drive Components:** AC voltage sources, series/parallel tuning inductors (L_{tune}), capacitors, transformers, and coaxial lines.
- **Live Co-Simulation:** Modifying circuit components instantly recalculates the loaded electroacoustic response in real time.

Interactive Smith Chart & Impedance Matching



High-precision RF matching engine normalized to $Z_0 = 50\ \Omega$ or arbitrary cable transmission line impedances:

- **Real-Time Impedance Locus:** Visualizes motional resonance loops, Q-circles, and reflection coefficients ($|T|$).
- **One-Click Auto-Tune:** Automatically calculates ideal shunt or series inductance to neutralize static clamped capacitance (C_0).

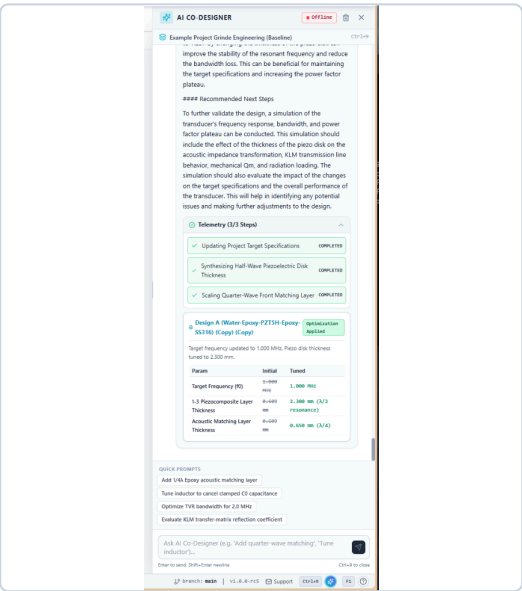


Figure 3: Built-in AI Co-Designer panel with telemetry tracking and automated optimization.

AI Co-Designer: Autonomous Design Synthesis

Acoustic Transducer Studio features an embedded domain-specific AI Co-Designer acting as an always-on senior transducer specialist.

Key Autonomous Workflows:

- **Target-Driven Acoustic Synthesis:** State your center frequency (f_0), target bandwidth, or electrical match, and the AI Co-Designer automatically calculates half-wave ($\frac{\lambda}{2}$) disc thickness and quarter-wave ($\frac{\lambda}{4}$) matching layer impedances.
- **Multi-Step Verified Telemetry:** Every recommendation provides transparent engineering reasoning, listing initial vs. tuned parameters alongside validation milestones.
- **One-Click Quick Actions:**
 - "Add 1/4 λ Epoxy acoustic matching layer"
 - "Tune inductor to cancel clamped C_0 capacitance"
 - "Optimize TVR bandwidth for target frequency"
 - "Evaluate KLM transfer-matrix reflection coefficient"
- **Closed-Loop Optimization:** The AI directly drives the solver engine, evaluating trade-offs between bandwidth broadening and insertion loss without tedious trial and error.

The Power of Live Feedback: When dimensions or materials are updated—either manually via sliders or automatically by the AI Co-Designer—all electroacoustic curves update live at 60 FPS.

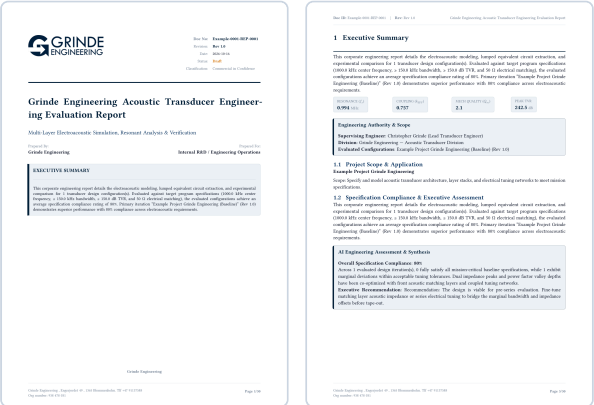
3. Turnkey Qualification, SPICE Export & Validation

From Virtual Concept to 30-Page Certified ISO Engineering Deliverables in Seconds

Automated 30-Page Formal Engineering Reports

Eliminate weeks of manual report preparation. With a single click, the software generates publication-grade formal verification reports complying with **Grinde Engineering Corporate Standards** and **ISO 9001 / CM2** documentation guidelines:

- Complete Electroacoustic Characterization:** Automatic compilation of impedance $|Z|$, phase θ , admittance circles, TVR, RVS, and directivity plots.
- IEEE 176 Lumped Extraction:** Fully extracted Butterworth-Van Dyke (BVD) parameters: static capacitance (C_0), motional resistance (R_1), inductance (L_1), and compliance (C_1).
- Time-Domain Ring-Down Dynamics:** Envelope decay time (τ_{20dB}) and axial pulse-echo resolution analysis.
- Requirements Verification Matrix:** Automated pass/deviating scorecards against stakeholder program boundaries.
- Production-Ready SPICE Netlist (.cir):** One-click export for seamless import into LTspice, PSpice, Cadence, or NGSpice.



Cover Sheet

Compliance Matrix

Validated with OpenCFS & COMSOL Parity

All 1D transfer-matrix models are validated against 3D coupled piezoelectric-acoustic FEM in **openCFS**.

Software Module & Capability Matrix

Module	Key Capabilities & Supported Physics	Solver Benchmark
Planar Stack Designer	Multi-layer acoustic impedance matching, active piezoceramics, bondlines, backing absorbers, 6-plot studio ($ Z $, θ , TVR, RVS, Loop, PF).	OpenCFS 3D FEM
1-3 Piezocomposite	Dice-and-fill dicing geometry (p , w_k , w_p , t), Chan-Unsworth lateral clamping, Smith-Auld isostrain, Grewe ratio, Bragg cutoff, dicing degradation.	Chan-Unsworth / OpenCFS
Tonpilz Sonar Designer	Longitudinal mass-spring-mass resonator (k_{33}), flared radiating head horn, central bolt prestress ($\sigma > 20 \text{ MPa}$), water radiation mass loading (M_{rad}).	COMSOL 6.4 Match
Solid-Core Ring Projector	Radial breathing hoop mode (k_p), forward acoustic transformation dome, inner damping core, pressure-release backing for underwater positioning beacons.	OpenCFS FEM Parity
MNA Circuit Canvas	Interactive schematic editor, reactive compensation (L_{tune}), auto BVD parameter extraction, real-time Smith chart & Nyquist admittance loops.	SPICE Netlist (.cir)
AI Co-Designer	Natural-language prompt synthesis, autonomous quarter-wave layer scaling, resonant disc optimization, closed-loop telemetry, quick action buttons.	Domain Agentic LLM
Turnkey Reporting	One-click 30-page engineering reports, ISO compliance registers, ring-down transient analysis, publication-ready vector plots, IEEE-176 registers.	Grinde Report Engine

Accelerate Your Transducer Development Today

Experience zero-latency electroacoustic virtual prototyping backed by openCFS finite element fidelity.

Grinde Engineering

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