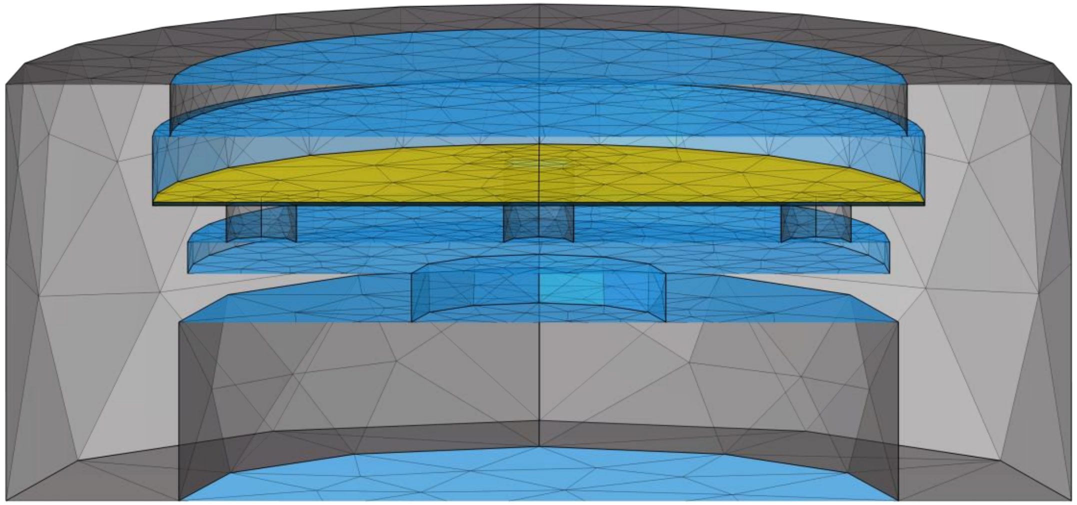
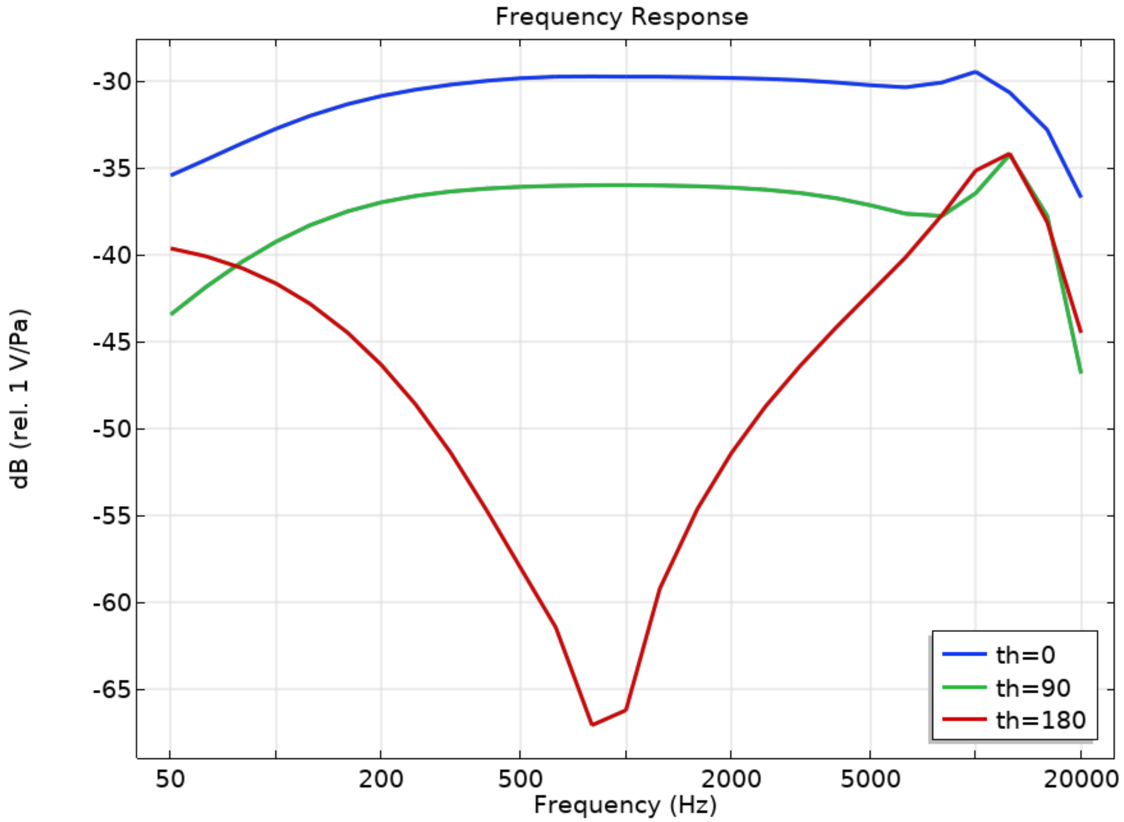
Application for Simulating Acoustic Response of Condenser Microphone Cartridges





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Project Overview

Purpose:

- Reduce number of design iterations to shorten project length for new condenser microphone designs

Goals:

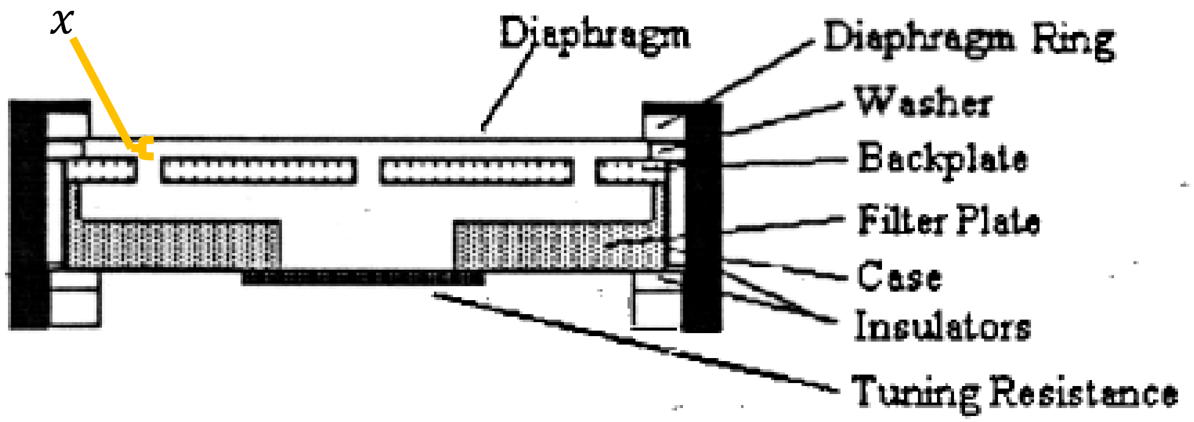
- Use COMSOL to model the frequency and spatial response of a directional condenser microphone cartridge
- Make the model parameterizable and create a GUI for ease of use

Challenges

- Figure out how to build model in a way that geometry changes won’t ‘crash’ it or require setting up the entire model again
- Keep solve time reasonable (minutes) while still getting a result that is close enough to reality that it is worthwhile

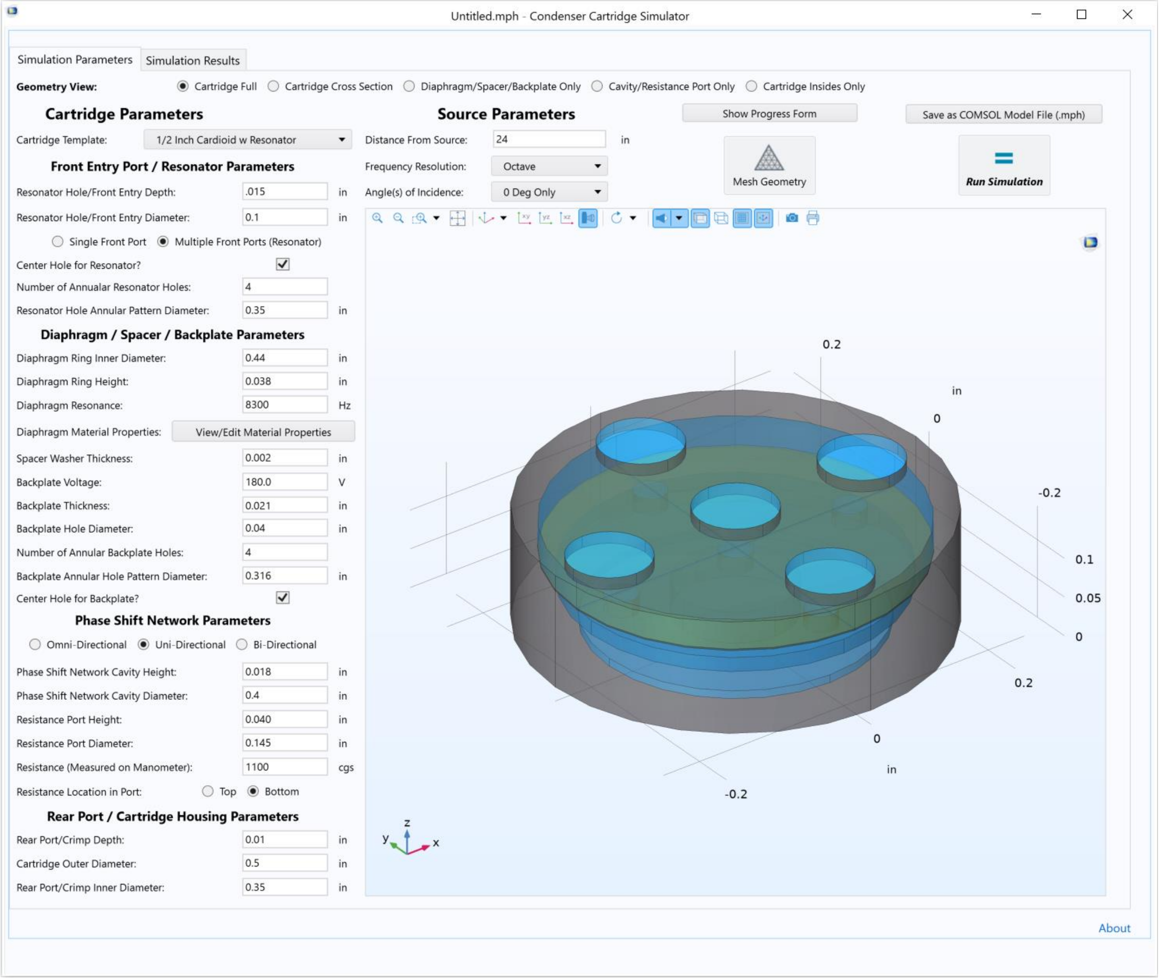
What is a Condenser Microphone?

- Transducer that converts sound to electrical signal using electrostatic energy
- Like a parallel plate capacitor, but one of the plates is a moveable diaphragm
  - Output is proportional to the change in the distance *x* between the diaphragm and backplate
  - $\tilde{v} = E * \left(\frac{\Delta C}{C_0}\right) = E * \frac{\Delta x}{x_0}$
- Acoustical networks designed to tune the response of the diaphragm to incoming sound
- Pressure difference at front and back as well as the phase shift network of a cavity and acoustic resistance creates directional response



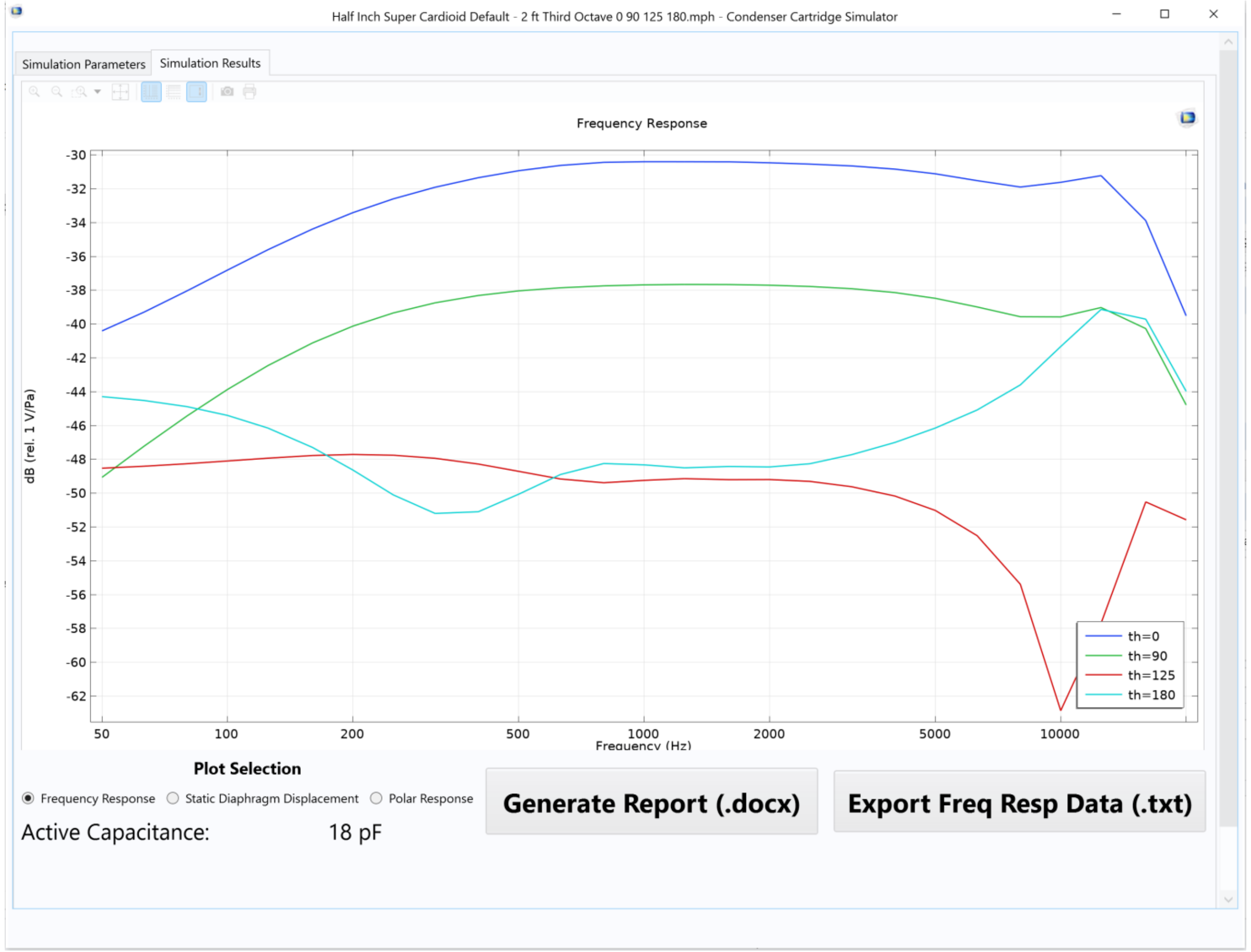
Application Display and User Interface

- GUI create with Application Builder
- Series of textboxes and radio buttons to create the geometry
- Parts are a series of stacked cylinders
- Backplate and Resonator geometry setup as series of annular holes
- Multiple view options
- Set source distance and frequencies
- Can save to edit it in model viewer



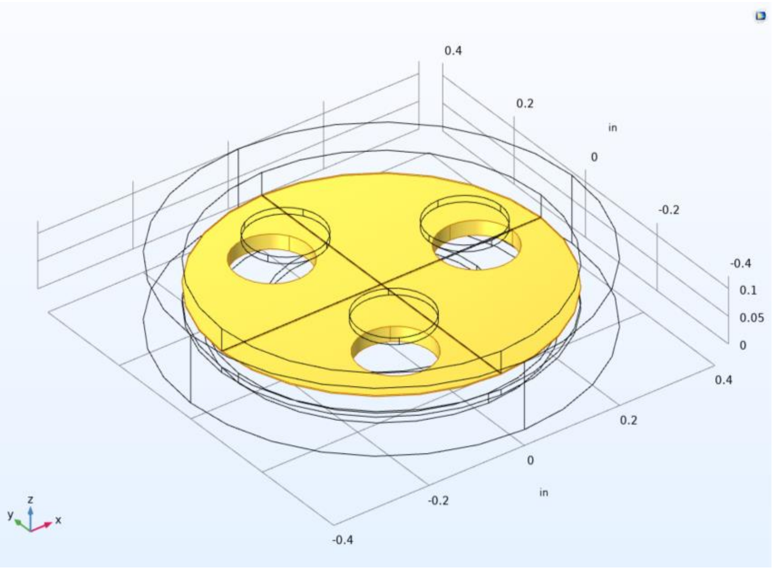
Application Display and User Interface

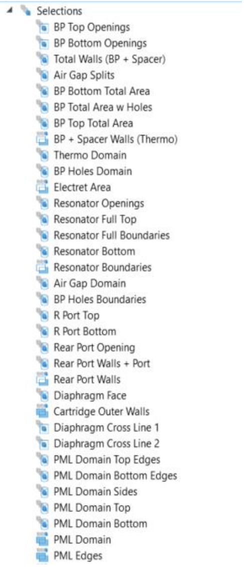
- Results tab shows response plot
  - Plot frequency response, polar or static diaphragm displacement
  - Cartridge Capacitance shown
- Save frequency response data as a .txt file for post processing
- Save COMSOL generated report with geometry parameters and results in a .docx format

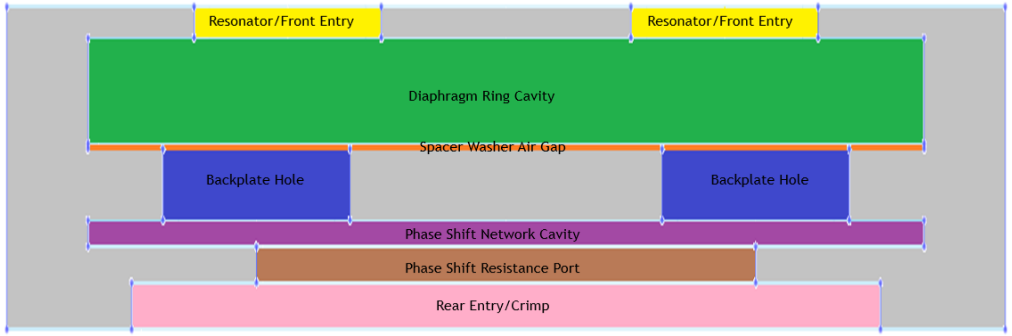


Parameterized Geometry

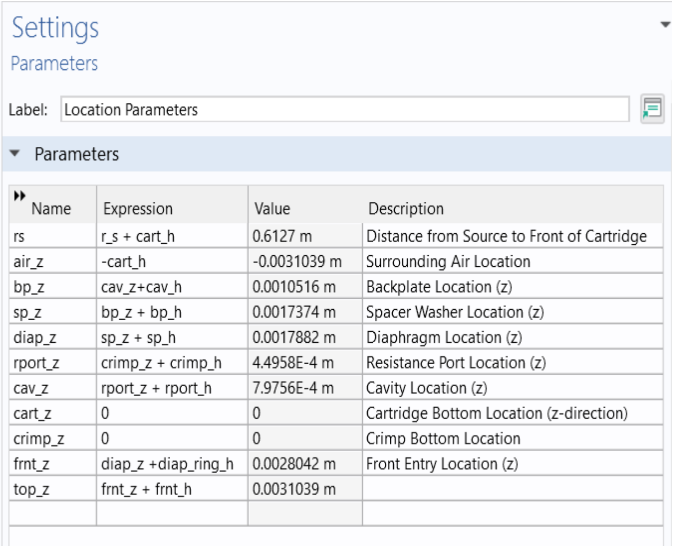
- All geometry is created and selected using parameters
- Limiting, but drastically simplifies geometry creation and allows for easy modifications







Gray – **Cartridge Housing**	Green – **Diaphragm Ring Cavity**	Blue – **Backplate Holes**	Brown – **Resistance Port**
Yellow – **Front Entry / Resonator**	Orange – **Spacer Washer**	Purple – **Phase Shift Cavity**	Pink – **Rear Entry / Crimp**



Settings
Parameters

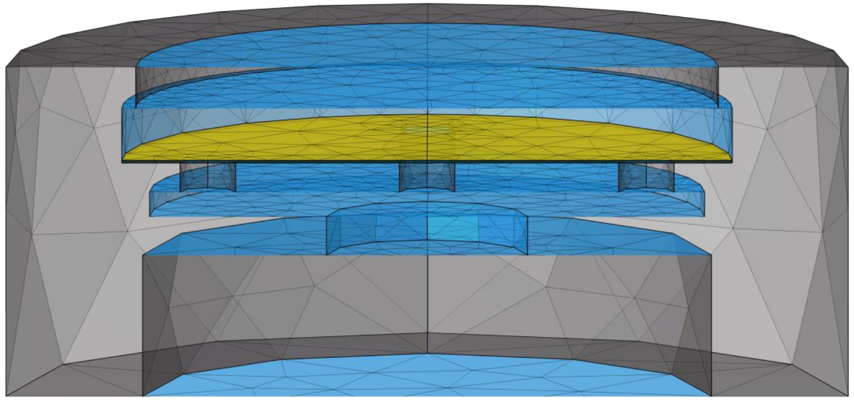
Label: Location Parameters

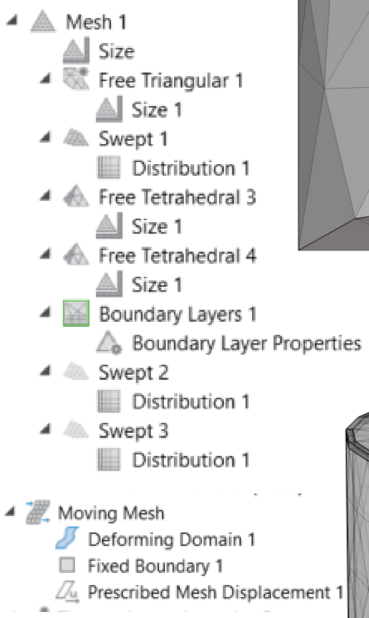
Parameters

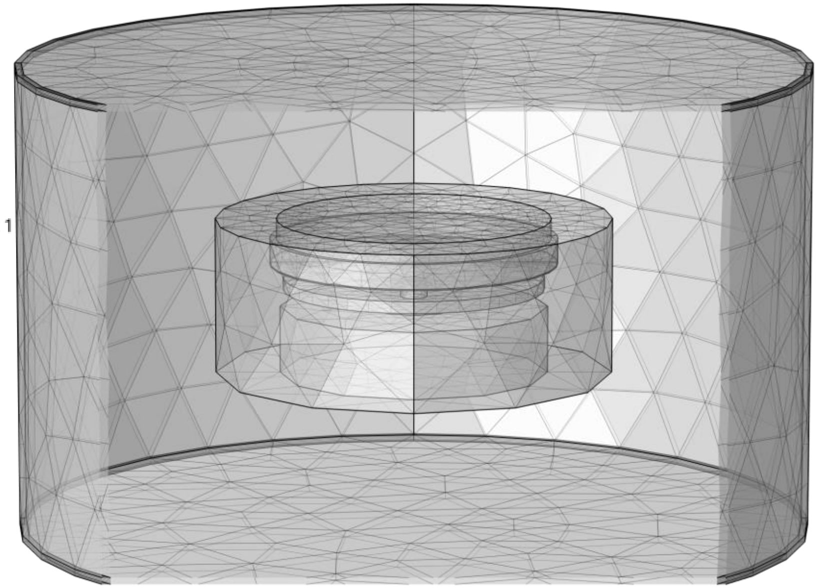
Name	Expression	Value	Description
rs	r_s + cart_h	0.6127 m	Distance from Source to Front of Cartridge
air_z	-cart_h	-0.0031039 m	Surrounding Air Location
bp_z	cav_z+cav_h	0.0010516 m	Backplate Location (z)
sp_z	bp_z + bp_h	0.0017374 m	Spacer Washer Location (z)
diap_z	sp_z + sp_h	0.0017882 m	Diaphragm Location (z)
rport_z	crimp_z + crimp_h	4.4958E-4 m	Resistance Port Location (z)
cav_z	rport_z + rport_h	7.9756E-4 m	Cavity Location (z)
cart_z	0	0	Cartridge Bottom Location (z-direction)
crimp_z	0	0	Crimp Bottom Location
frnt_z	diap_z +diap_ring_h	0.0028042 m	Front Entry Location (z)
top_z	frnt_z + frnt_h	0.0031039 m	

Model Geometry and Mesh

- Meshing is controlled by geometry selections
- Swept mesh used through the diaphragm/backplate air gap and in perfectly matched layer in bounding air volume around the cartridge
- Moving mesh applied to diaphragm
- Boundary Layers applied to backplate hole and air gap boundaries

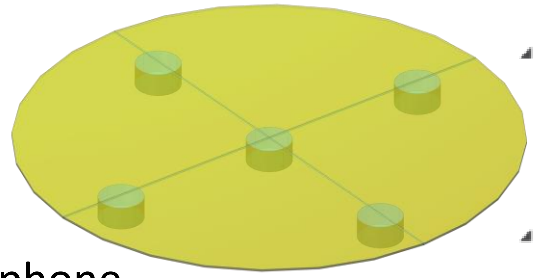


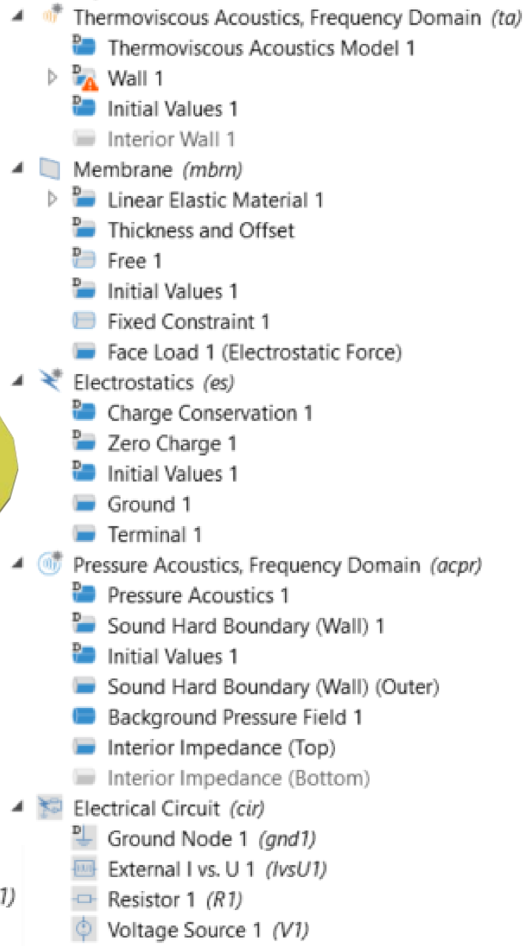


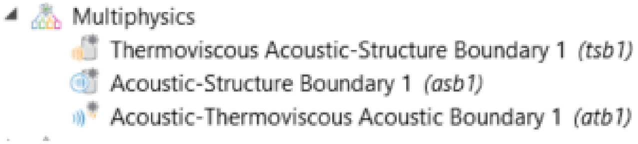


Physics and Multiphysics Couplings Applied

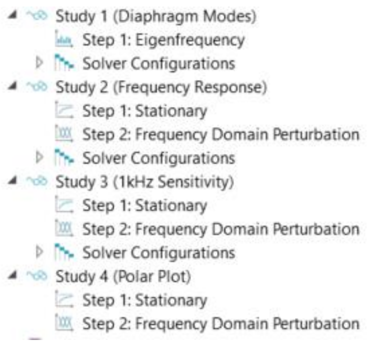
- Thermoviscous Acoustics applied between diaphragm and backplate account for losses in thin air gap region
- Diaphragm uses Membrane Physics
  - Couples to both Acoustics Physics on one side each
- Electrostatics and Electrical Circuit
  - Diaphragm is grounded
  - Bias Voltage applied through circuit
- Reference COMSOL Model: Brüel & Kjær 4134 Condenser Microphone
- Coupled to Pressure Acoustics for the rest of the model
  - Air outside of cartridge allows for diffraction to be accounted for
  - Allows phase difference between sound at front and back to be accounted for



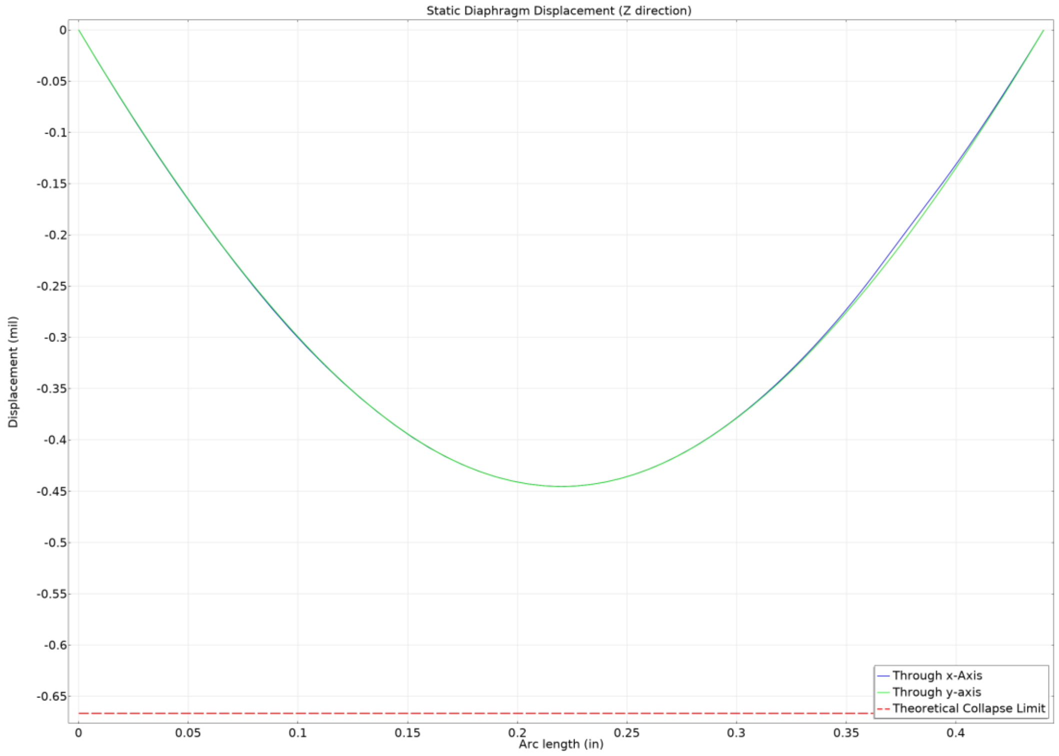




Model Study and Results



- Two study steps
  - Stationary – solves for electrostatic force and deflection of diaphragm
  - Frequency Domain Perturbation – solves for mic response to incoming pressure wave
- Study parameters set in application
  - Frequencies, Auxillary Sweep of Incidence Angles
- Generates plots for the results window
  - Static Diaphragm Displacement
  - Frequency Response
  - Polar Response (if study set for it)

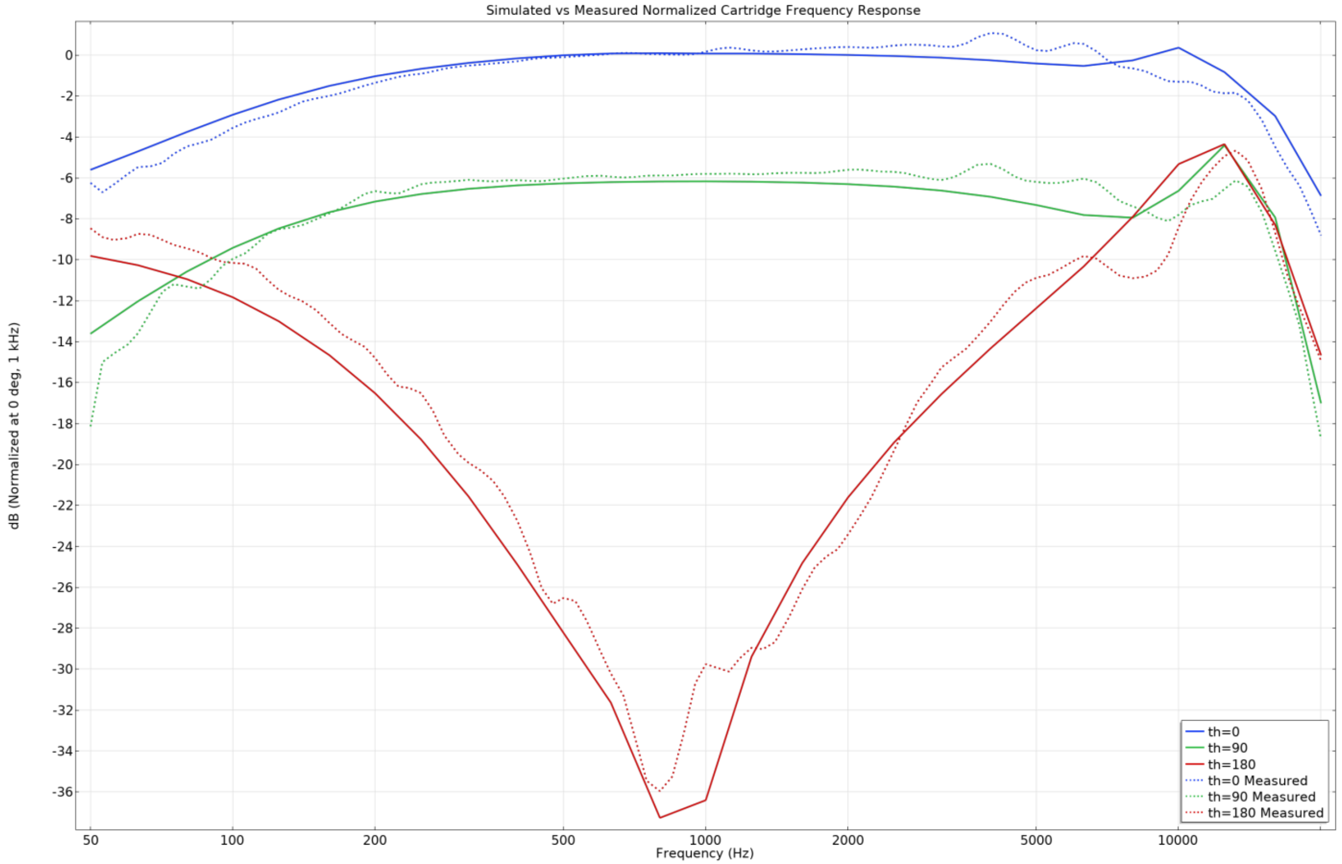


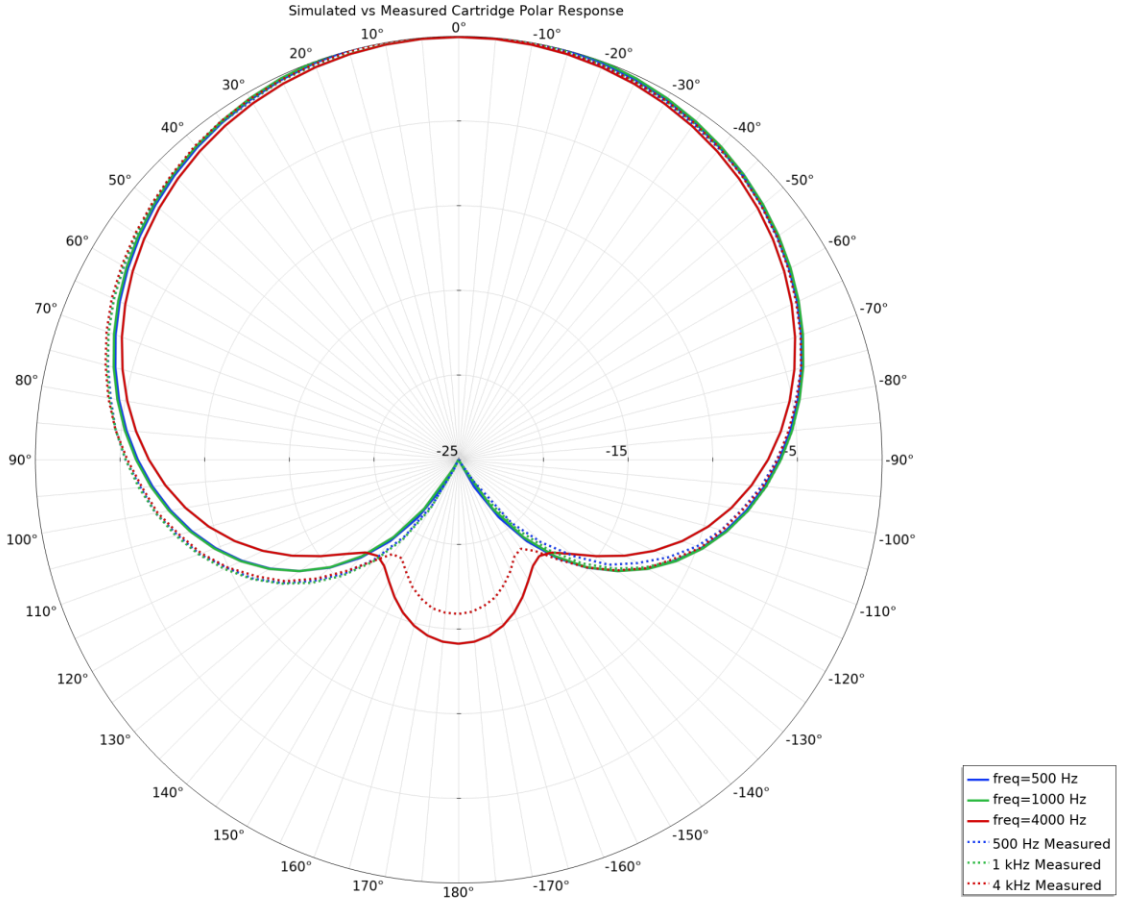
Validation of Sample Half Inch Design

- As a quick check of the model, simulation of a design was compared to a measured prototype
- ½" diameter, cardioid polar pattern cartridge built and tested
- Model simplifies features of the geometry, but created quickly
  - Some edges chamfered and features like contact pin omitted
  - Phase shift network cavity geometry simplified
  - Acoustical parameters measured and included

Validation of Sample Half Inch Design

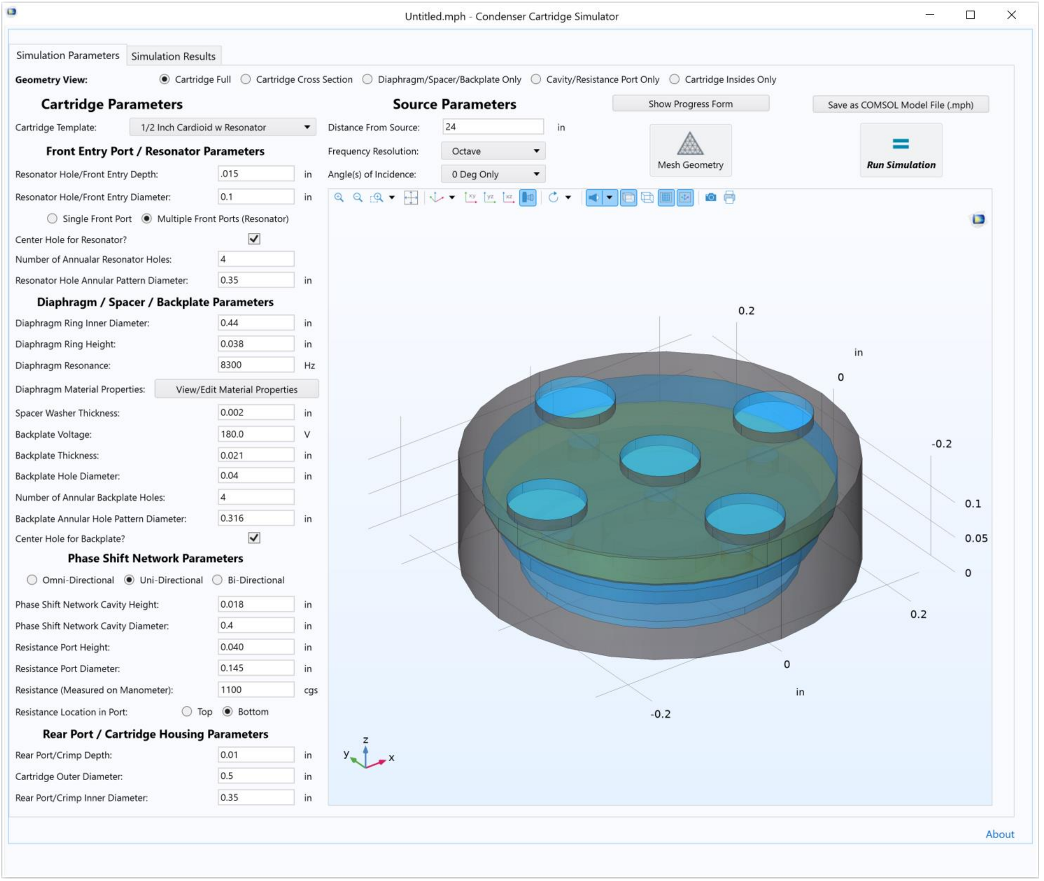
- Simulation vs Measured difference is only a dB or two at most frequencies
- Simulated – Solid lines; Measured Response – Dashed lines





Conclusion

- Parameterized geometry and the application GUI can drastically simplify a complex model and allow for quick edits
- Directionality of a microphone cartridge can be simulated well in COMSOL
- Condenser cartridge frequency responses can be simulated with a reasonable correlation to built prototypes
- Methodology in the model could be used to simulate more complex geometries
- Additional Work: examining thermal losses in the phase shift network cavity for smaller designs



Thank You!

Questions?