

Tunable MEMS Capacitor

Introduction

In an electrostatically tunable parallel plate capacitor you can modify the distance between the two plates when the applied voltage changes. For tuning of the distance between the plates the capacitor includes a spring that attaches to one of the plates. If you know the characteristics of the spring and the voltage between the plates, you can compute the distance between the plates. This model includes an electrostatic simulation for a given distance. A postprocessing step then computes the capacitance.

The capacitor in this model is a typical component in various microelectromechanical systems (MEMS) for electromagnetic fields in the radio frequency range 300 MHz to 300 GHz.

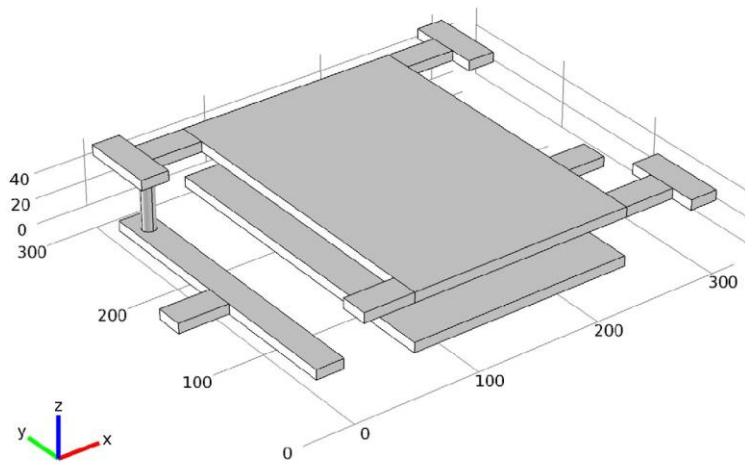


Figure 1: The tunable MEMS capacitor consists of two metal plates. The distance between the plates is tuned via a spring connected to one of the plates.

Results and Discussion

Figure 2 shows the computed electric potential distribution in the capacitor. The potential on each capacitor plate is constant, as dictated by the boundary condition.

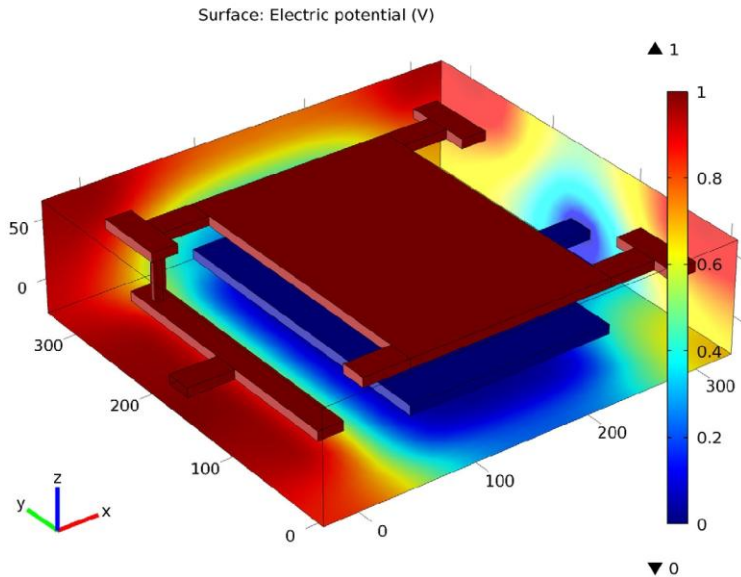


Figure 2: The electric potential is shown as a surface plot.

The capacitance, C , obtained from the simulation is approximately 0.09 pF.

Modeling Instructions

MODEL WIZARD

- 1 Go to the **Model Wizard** window.
- 2 Click **Next**.
- 3 In the **Add Physics** tree, select **AC/DC>Electrostatics (es)**.

- 4 Click **Next**.
- 5 In the **Studies** tree, select **Preset Studies>Stationary**.
- 6 Click **Finish**.

GEOMETRY 1

- 1 In the **Model Builder** window, click **Model 1>Geometry 1**.
- 2 Go to the **Settings** window for Geometry.
- 3 Locate the **Geometry Settings** section. Find the **Units** subsection. From the **Length unit** list, select **µm**.

Block 1

- 1 Right-click **Model 1>Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 22.
- 4 In the **Depth** edit field, type 60.
- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **y** edit field, type 240.
- 7 In the **z** edit field, type 46.
- 8 Click the **Build Selected** button.

Block 2

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 40.
- 4 In the **Depth** edit field, type 22.
- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **x** edit field, type 22.
- 7 In the **y** edit field, type 259.
- 8 In the **z** edit field, type 46.
- 9 Click the **Build Selected** button.

Block 3

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 176.

- 4 In the **Depth** edit field, type 262.
- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **x** edit field, type 62.
- 7 In the **y** edit field, type 19.
- 8 In the **z** edit field, type 46.
- 9 Click the **Build Selected** button.

Block 4

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 40.
- 4 In the **Depth** edit field, type 22.
- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **x** edit field, type 238.
- 7 In the **y** edit field, type 259.
- 8 In the **z** edit field, type 46.
- 9 Click the **Build Selected** button.

Block 5

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 22.
- 4 In the **Depth** edit field, type 60.
- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **x** edit field, type 278.
- 7 In the **y** edit field, type 240.
- 8 In the **z** edit field, type 46.
- 9 Click the **Build Selected** button.

Block 6

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 40.
- 4 In the **Depth** edit field, type 22.

- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **x** edit field, type 238.
- 7 In the **y** edit field, type 19.
- 8 In the **z** edit field, type 46.
- 9 Click the **Build Selected** button.

Block 7

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 22.
- 4 In the **Depth** edit field, type 60.
- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **x** edit field, type 278.
- 7 In the **z** edit field, type 46.
- 8 Click the **Build Selected** button.

Block 8

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 40.
- 4 In the **Depth** edit field, type 22.
- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **x** edit field, type 22.
- 7 In the **y** edit field, type 19.
- 8 In the **z** edit field, type 46.
- 9 Click the **Build Selected** button.

Block 9

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 22.
- 4 In the **Depth** edit field, type 229.
- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **y** edit field, type 41.

7 Click the **Build Selected** button.

Block 10

1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.

2 Go to the **Settings** window for Block.

3 Locate the **Size and Shape** section. In the **Width** edit field, type 40.

4 In the **Depth** edit field, type 22.

5 In the **Height** edit field, type 8.

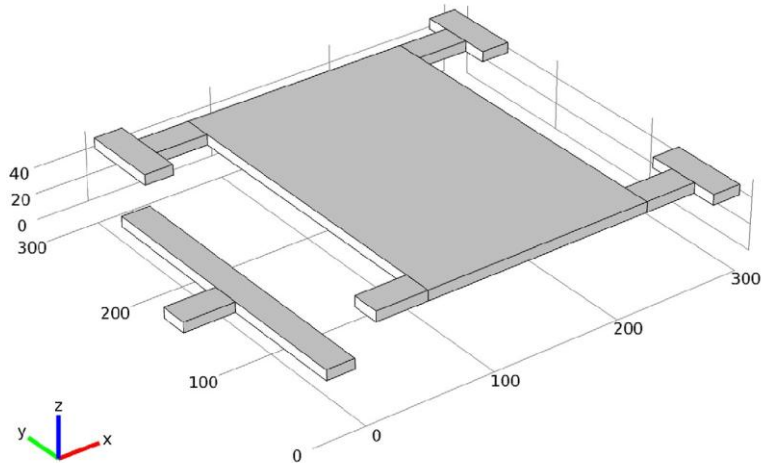
6 Locate the **Position** section. In the x edit field, type -40.

7 In the y edit field, type 139.

8 Click the **Build Selected** button.

9 Click the **Zoom Extents** button on the Graphics toolbar.

Click the **Zoom Extents** button on the Graphics toolbar..



Cylinder 1

1 In the **Model Builder** window, right-click **Geometry 1** and choose **Cylinder**.

2 Go to the **Settings** window for Cylinder.

3 Locate the **Size and Shape** section. In the **Radius** edit field, type 5.5.

- 4 In the **Height** edit field, type 38.
- 5 Locate the **Position** section. In the **x** edit field, type 11.
- 6 In the **y** edit field, type 250.
- 7 In the **z** edit field, type 8.
- 8 Click the **Build Selected** button.

Union 1

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Union**.
- 2 Click the **Select Box** button on the Graphics toolbar.
- 3 Select the objects **blk1**, **blk2**, **blk3**, **blk4**, **blk5**, **blk6**, **blk7**, **blk8**, **blk9**, **blk10**, and **cyl1** only.
- 4 Go to the **Settings** window for Union.
- 5 Locate the **Union** section. Clear the **Keep interior boundaries** check box.
- 6 Click the **Build All** button.

Block 11

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 176.
- 4 In the **Depth** edit field, type 262.
- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **x** edit field, type 62.
- 7 In the **y** edit field, type 19.
- 8 In the **z** edit field, type 8.
- 9 Click the **Build Selected** button.

Block 12

- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.
- 2 Go to the **Settings** window for Block.
- 3 Locate the **Size and Shape** section. In the **Width** edit field, type 181.
- 4 In the **Depth** edit field, type 22.
- 5 In the **Height** edit field, type 8.
- 6 Locate the **Position** section. In the **x** edit field, type 139.
- 7 In the **y** edit field, type 139.

8 Click the **Build Selected** button.

Union 2

1 In the **Model Builder** window, right-click **Geometry 1** and choose **Union**.

2 Select the objects **blk11** and **blk12** only.

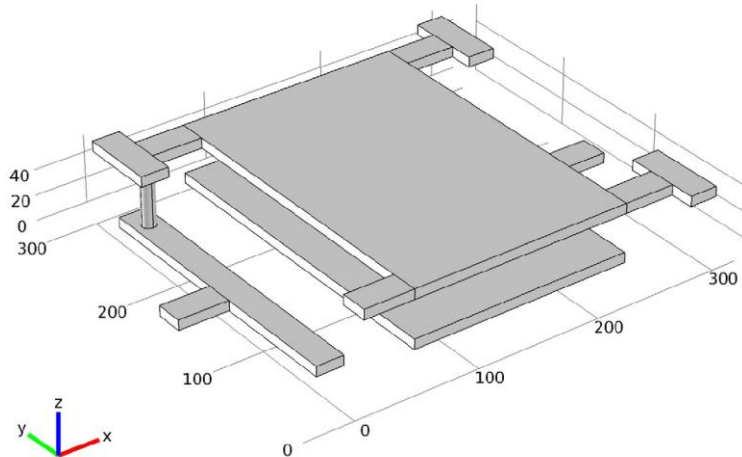
3 Go to the **Settings** window for Union.

4 Locate the **Union** section. Clear the **Keep interior boundaries** check box.

5 Click the **Build Selected** button.

6 Click the **Zoom Extents** button on the Graphics toolbar.

Click the **Zoom Extents** button on the Graphics toolbar.



Block 13

1 In the **Model Builder** window, right-click **Geometry 1** and choose **Block**.

2 Go to the **Settings** window for Block.

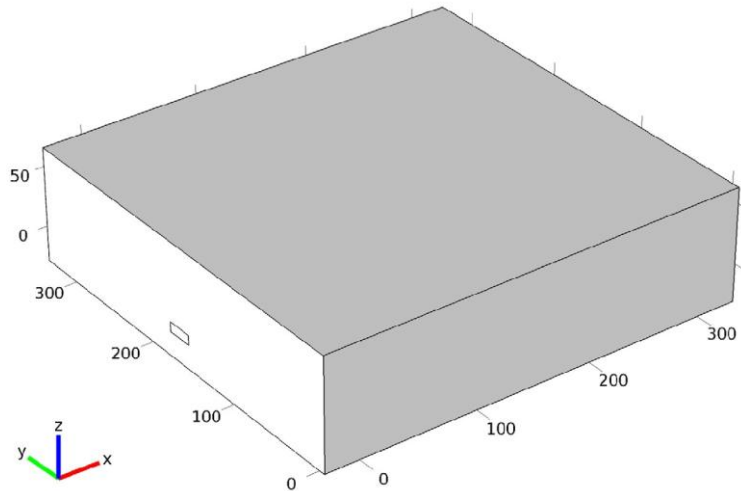
3 Locate the **Size and Shape** section. In the **Width** edit field, type 360.

4 In the **Depth** edit field, type 340.

5 In the **Height** edit field, type 94.

6 Locate the **Position** section. In the **x** edit field, type -40.

- 7 In the **y** edit field, type -20.
 - 8 In the **z** edit field, type -20.
 - 9 Click the **Build Selected** button.
 - 10 Click the **Zoom Extents** button on the Graphics toolbar.
- Click the **Zoom Extents** button on the Graphics toolbar.



DEFINITIONS

Selection 1

- 1 In the **Model Builder** window, right-click **Model 1>Definitions** and choose **Selection**.
- 2 Right-click **Selection 1** and choose **Rename**.
- 3 Go to the **Rename Selection** dialog box and type **Electrode** in the **New name** edit field.
- 4 Click **OK**.
- 5 Go to the **Settings** window for **Selection**.
- 6 Locate the **Geometric Scope** section. From the **Selection output** list, select **Adjacent boundaries**.
- 7 Select **Domain 2** only.

Selection 2

- 1 In the **Model Builder** window, right-click **Definitions** and choose **Selection**.
- 2 Right-click **Selection 2** and choose **Rename**.
- 3 Go to the **Rename Selection** dialog box and type Ground Plane in the **New name** edit field.
- 4 Click **OK**.
- 5 Go to the **Settings** window for Selection.
- 6 Locate the **Geometric Scope** section. From the **Selection output** list, select **Adjacent boundaries**.
- 7 Select Domain 3 only.

Selection 3

- 1 In the **Model Builder** window, right-click **Definitions** and choose **Selection**.
- 2 Right-click **Selection 3** and choose **Rename**.
- 3 Go to the **Rename Selection** dialog box and type Dielectric in the **New name** edit field.
- 4 Click **OK**.
- 5 Go to the **Settings** window for Selection.
- 6 Locate the **Geometric Scope** section. From the **Selection output** list, select **Selected domains**.
- 7 Select Domain 1 only.

M A T E R I A L S

Material 1

- 1 In the **Model Builder** window, right-click **Model 1>Materials** and choose **Material**.
- 2 Right-click **Material 1** and choose **Rename**.
- 3 Go to the **Rename Material** dialog box and type Dielectric in the **New name** edit field.
- 4 Click **OK**.
- 5 Go to the **Settings** window for Material.
- 6 Locate the **Geometric Scope** section. From the **Selection** list, select **Dielectric**.

- 7 Locate the **Material Contents** section. In the **Material Contents** table, enter the following settings:

PROPERTY	NAME	VALUE
Relative permittivity	epsilon	4.2

ELECTROSTATICS

- 1 In the **Model Builder** window, click **Model 1>Electrostatics**.
- 2 Go to the **Settings** window for Electrostatics.
- 3 Locate the **Domains** section. From the **Selection** list, select **Dielectric**.

Terminal 1

- 1 Right-click **Model 1>Electrostatics** and choose **Terminal**.
- 2 Go to the **Settings** window for Terminal.
- 3 Locate the **Boundaries** section. From the **Selection** list, select **Electrode**.
- 4 Locate the **Terminal** section. From the **Terminal type** list, select **Voltage**.

Ground 1

- 1 In the **Model Builder** window, right-click **Electrostatics** and choose **Ground**.
- 2 Go to the **Settings** window for Ground.
- 3 Locate the **Boundaries** section. From the **Selection** list, select **Ground Plane**.

MESH 1

The default mesh gives a sufficiently accurate solution for the purposes of this example. To examine mesh convergence you can optionally go back later and re-solve the model with a finer mesh.

RESULTS

- 1 In the **Model Builder** window, right-click **Study 1** and choose **Compute**.

To see the capacitor, suppress the display of the enclosing boundaries.

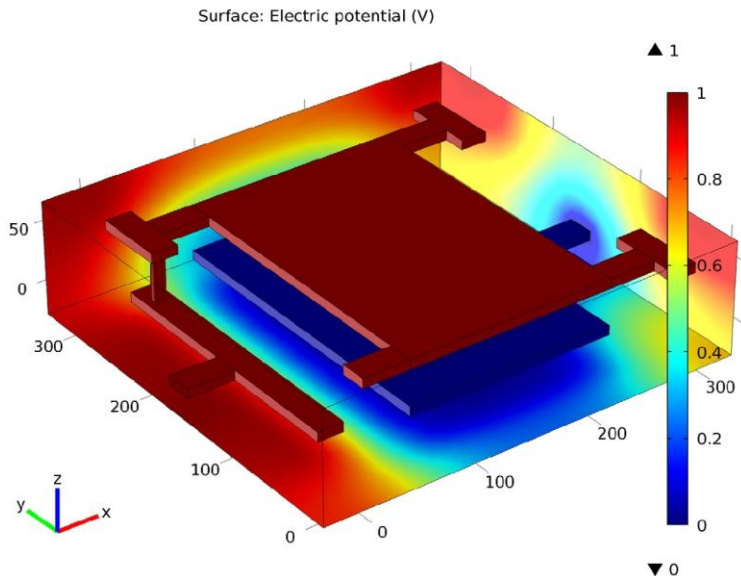
Data Sets

- 1 In the **Model Builder** window, right-click **Results>Data Sets>Solution 1** and choose **Add Selection**.
- 2 Go to the **Settings** window for Selection.
- 3 Locate the **Geometric Scope** section. From the **Geometric entity level** list, select **Boundary**.
- 4 From the **Selection** list, select **All boundaries**.

5 Select Boundaries 3 and 5–78 only.

This is easiest done by removing boundaries 1, 2, and 4 from the list once you have selected all.

3D Plot Group 1



Derived Values

Having solved the model, you can now extract the capacitance.

- 1 In the **Model Builder** window, right-click **Results>Derived Values** and choose **Global Evaluation**.
- 2 Go to the **Settings** window for Global Evaluation.
- 3 In the upper-right corner of the **Expression** section, click **Replace Expression**.
- 4 From the menu, choose **Electrostatics>Capacitance (es.C11)**.
- 5 Click the **Evaluate** button.

The capacitance evaluates to 0.09 pF.