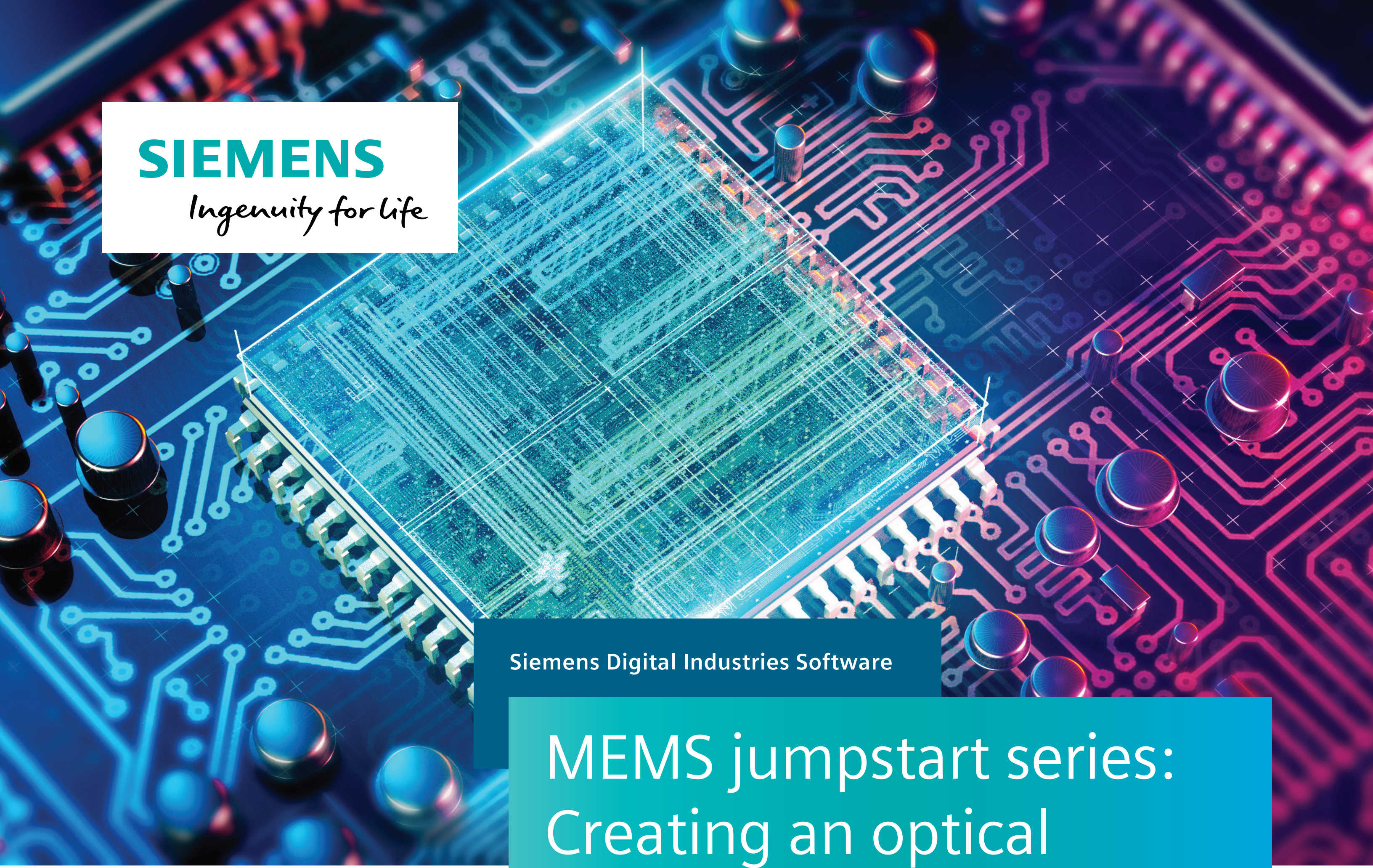

Siemens Digital Industries Software

MEMS jumpstart series: Creating an optical switch

MEMS and Photonic design

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Introduction

High-speed optical networks make it possible for people around the world to instantaneously communicate and share ideas. Tiny MEMS optical switches play a critical role in these enormous optical fiber systems. These switches combine mechanical, optical, and electrical domains, making them a good learning device for MEMS design and simulation using Tanner EDA tools. This paper illustrates the creation and simulation of a 2x2 optical switch shown in figure 1.

There are many ways to create an optical switch. The optical switch that we will study employs a double-sided mirror whose movement is controlled by an electrostatic, comb drive actuator. A set of folded springs controls the actuator movement. The mirror slides out to the intersection of two perpendicular alignment grooves and then retracts when actuated. Two pair of optical fiber emitters and receivers (only one emitter is shown in figure 1) sit in alignment grooves.

In the cross state, the comb drive is unactuated and the mirror sits in the grooves at the intersection. The mirror reflects the light beam from Input 1 to Output 2 and from Input 2 to Output 1. In the through state, the comb drive actuates and the mirror retracts. The light beam from Input 1 is received by Output 1 and Input 2 emits the beam to Output 2.

The optical switch is fabricated using bulk micromachining on the wafer. Masks provide the patterns for the mirror, fiber alignment grooves, comb drive actuator, and the folded springs. An etching process carves the alignment grooves, frees the movable structures, and leaves anchor points for the mechanical components. The final fabrication steps place the fiber emitter and receivers and then coats the mirror with aluminum.

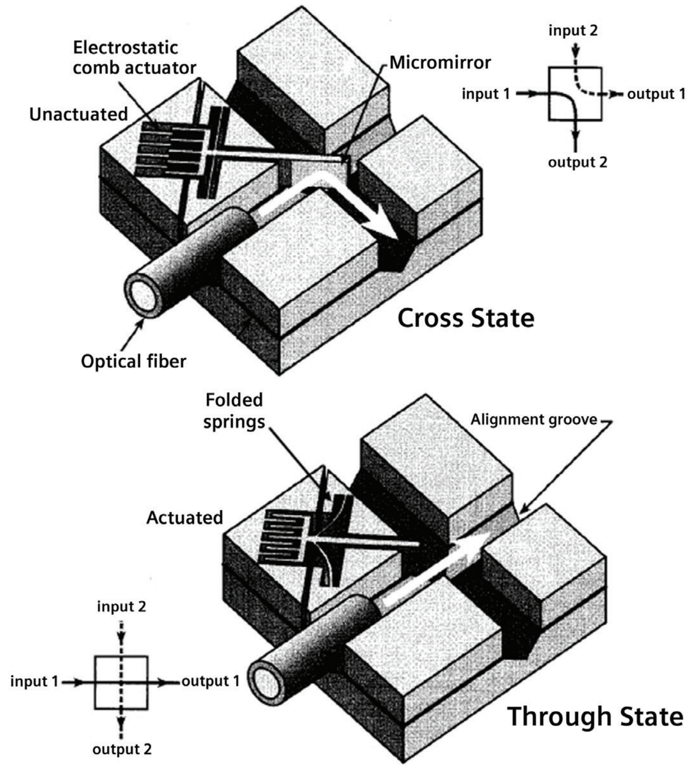

Figure 1: 2x2 optical switch (Source: Introduction to MEMS Optical Switches, M. Tung).

Creating the schematic

The process of creating the optical switch starts with constructing the schematic using S-Edit. This editor provides a rich library of components for quickly assembling the switch. The first step is to instantiate each optical component (figure 2) from the library and then connect them together.

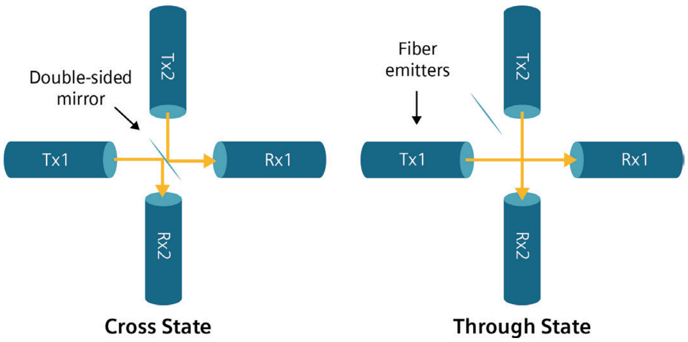

Figure 2: The optical components of the switch.

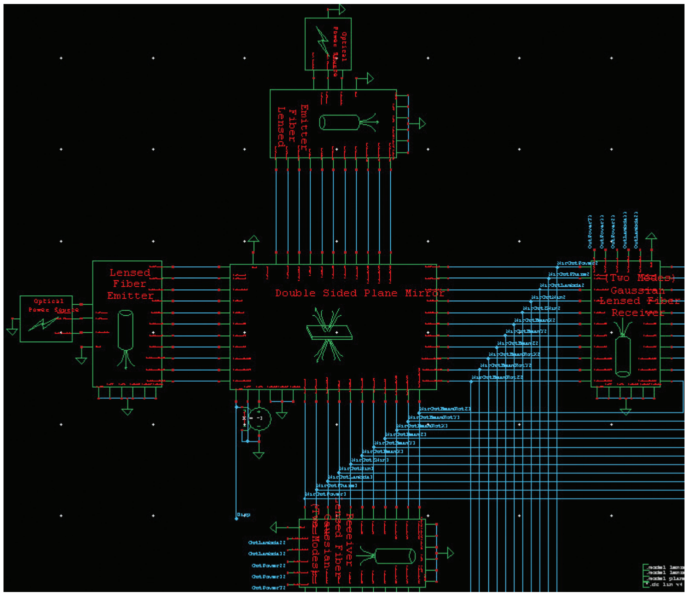

Figure 3: Schematic of the optical components.

The designer can instantiate and connect the parameterized components from the S-Edit library:

1. Two lensed fiber emitters: each is a single-mode component that outputs a Gaussian beam. The end face of the emitter is curved to act as a lens that focuses the beam.
2. Two lensed fiber receivers: collect the Gaussian beam and generate coupled power.
3. Two optical power sources: provide power to the fiber emitters.
4. One double-sided plane mirror: defines the reflection characteristics of the Gaussian beam.

Figure 3 shows the powered emitter and receiver pairs connected to the double-sided mirror.

To meet optical specifications, the parameters for each component can be changed. For example, the designer can define the size and thickness of the mirror or the Gaussian beam waist (shape).

The next step is to define the motion of the mirror that figure 4 shows.

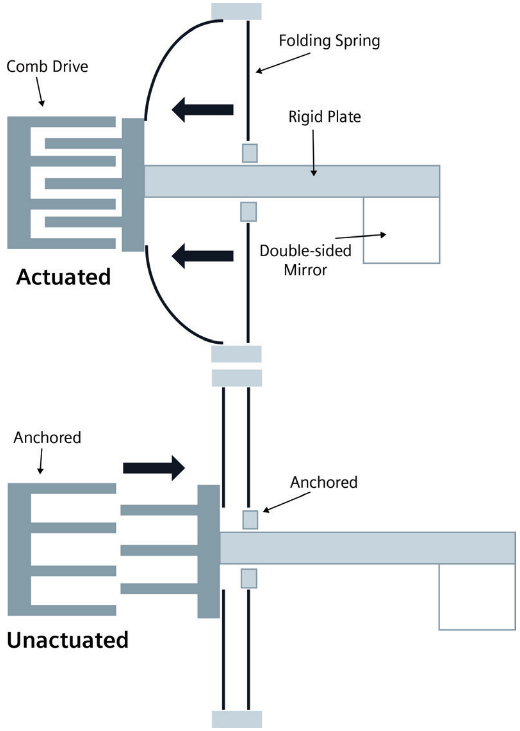

Figure 4: Mechanical motion of the mirror.

In order to move the mirror, the designer can instantiate and connect a set of parameterized mechanical components from the S-Edit library:

- One linear comb drive: defines the electrostatic capacitor plates of the drive. One plate is anchored to the substrate and the other moves in the direction of the comb teeth.
- Two folded springs: each defines a folded suspension beam with one leg anchored and the other free to move.
- One rigid plate: provides infinite stiffness in every direction, transferring forces and moments with no deformation.

In addition, a source is needed to provide the electrical pulse that actuates the comb drive. Figure 5 shows the powered linear comb drive connected to the two folded springs. The stationary plate of the comb drive, the anchored leg of each folded spring, and the mirror connect to the rigid plate.

To meet mechanical specifications, the parameters for each component can be changed. For example, the designer can define the length and width of the folded springs or specify the number of teeth in the comb drive.

The mechanical coupling to the mirror is accomplished by instancing a voltage-controlled voltage source (VCVS) component whose value is controlled by the Gaussian beam and connecting it to the rigid plate (figure 6).

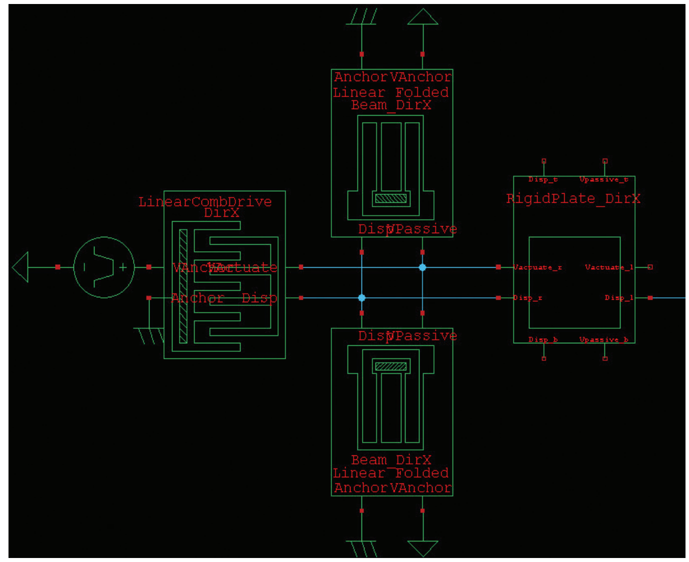

Figure 5: Schematic of the mechanical components.

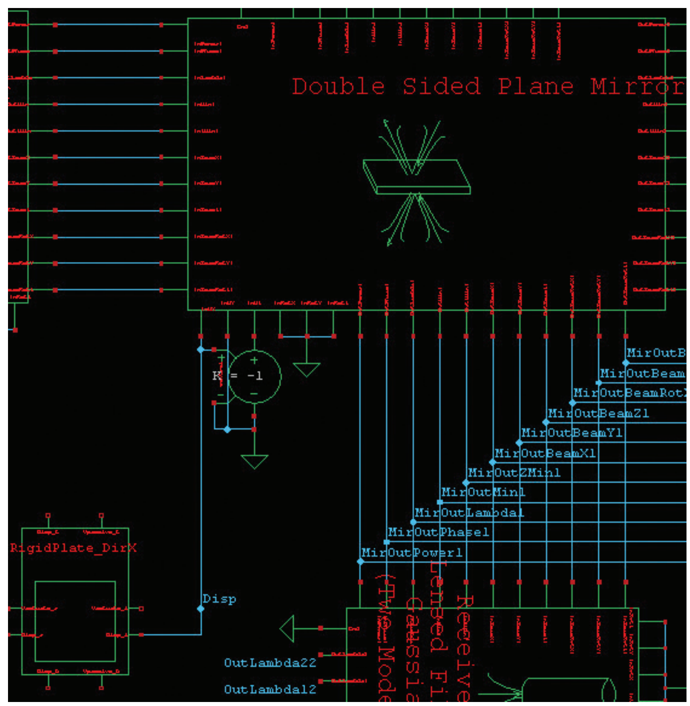

Figure 6: Connecting the mechanical components to the mirror.

Verifying the schematic

The next step is to simulate the schematic with T-Spice and then analyze the design with the Waveform Viewer in order to determine if the optical switch works as expected. Figure 7 shows the results of the transient simulation.

The top waveforms show the Through and Cross State values based on the actuation of the mirror and the relative displacement of the comb drive. The bottom waveforms show the power values of the fiber receivers based on the states.

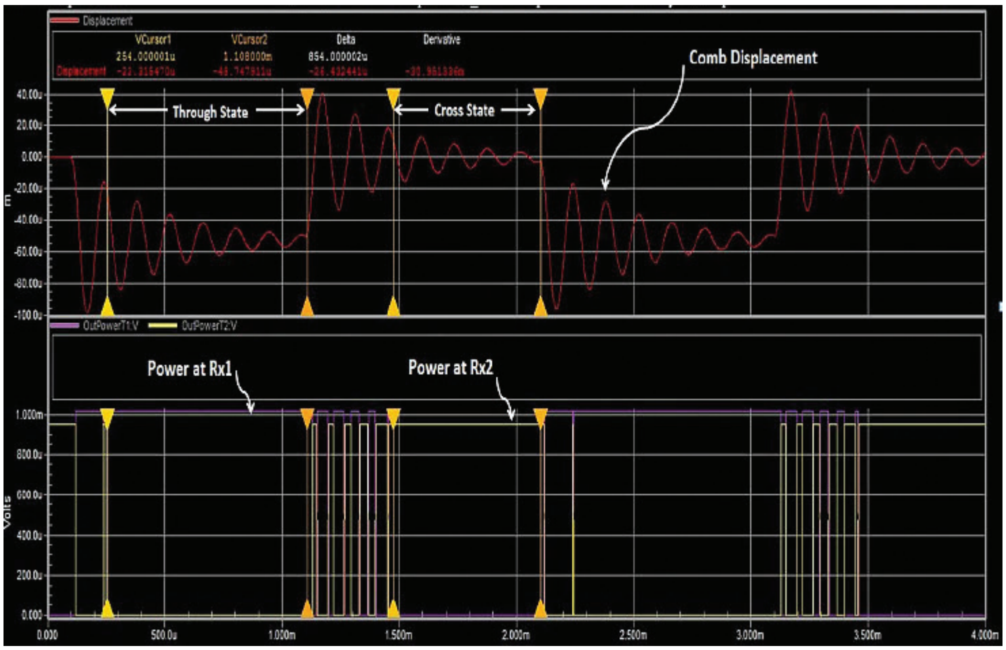

Figure 7: Waveform analysis to verify the design.

Conclusion

The optical switch is one of the fundamental MEMS devices needed in a toolbox of elements to assemble systems. The Tanner design flow lets designers quickly expand that toolbox to create amazing systems of almost unlimited variety.

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