

# FOS series model overview

The FOS (Fast Optical Shutter) series is a range of liquid crystal (LC)-based optical shutters (variable filters) that control the light transmittance by an externally applied drive voltage. Compared to conventional mechanical shutters, LC shutters are electro-optical; they contain no moving parts, are completely vibration-free, and have a small footprint.

Most shutter models consist of a polarization modulator in form of a LC cell positioned between polarizers. Applying a drive voltage reorients the birefringent LC molecules, changing the phase retardation of light passing through the LC cell. This results in a change in transmittance of light passing through the full shutter structure. Analog gray-scale operation between fully open and closed states is realized by voltage amplitude modulation, allowing the shutter to be used as a variable filter.

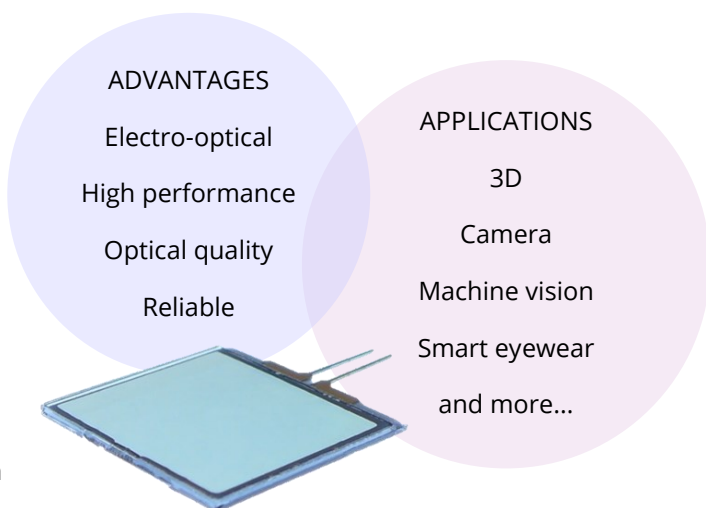
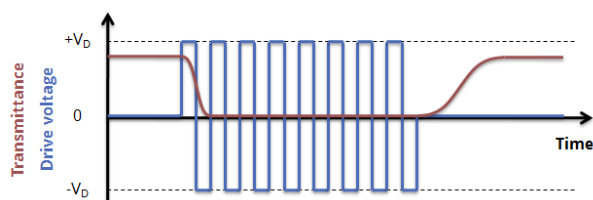
## Standard models and sizes

In order to meet a wide range of requirements for various applications, a series of shutter models possessing different electro-optical properties are offered in a number of standard sizes, all available with short lead times. Customers not finding their required shutter properties are advised that further optimization and custom designing are possible, both in terms of electro-optical properties and mechanical dimensions (up to 14"x16" size). As regards volume supply, any number from a single prototype up to several million units per month can be shipped.

Standard size	Outer dimensions	Clear aperture	Thickness
7x8	7.0mm x 8.2mm	5.0mm x 5.0mm	Model dependent, ranging from 1.3mm to 5.3mm
13x15	13.0mm x 15.0mm	9.8mm x 9.8mm	
1x1	25.4mm x 25.4mm	22.2mm x 20.2mm	
2x2	50.8mm x 50.8mm	47.6mm x 45.6mm	
D1 (circular)	25.4mm diameter	22.2mm diameter	
D2 (circular)	50.8mm diameter	47.0mm diameter	

## Electrical connection

The shutters are normally supplied with contact pins bonded to the device. Several other options are also available, including flexible flat cables (FFC) and soldered wires.

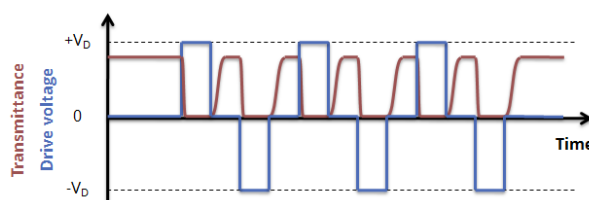


## Top coating and anti-reflective (AR) cover glass

Most models are supplied with an anti-reflective, scratch-resistant, hard-coating on the outer surfaces. For demanding optical applications, the shutters can also be equipped with an optical quality, high-efficiency AR cover glass laminated to both sides. This configuration minimizes surface reflection, beam deviation, and wavefront aberration, and is especially recommended for imaging applications.

## Drive waveform

The shutters possess mono-stable normally white operation, without voltage applied the shutter is in its fully open, light-transmitting state\*. Applying the drive voltage,  $V_D$ , switches it to a closed, light-absorbing state\*\*. This voltage must be kept throughout the duration of the time the shutter is required to be in the closed state. In general, increasing the drive voltage amplitude increases the contrast and shortens the closing time. The transmittance of the shutter reacts to the RMS voltage. In order to prevent ion migration within the LC layer that might impair shutter performance and lifetime, it is recommended to ensure that there is no net DC bias present in the drive signal. This is best achieved via use of one of the two AC square waveforms illustrated below. When the left alternative is used, the recommended minimum frequency is 60Hz if visual flicker is to be avoided. The right option is suitable when cycled operation between open and closed states is desired.



\* The PolarSpeed®-S, PolarView®-ND(212), and FSD models show inverted optical response, i.e. closed without voltage applied (normally black operation).

\*\* The PolarSpeed®-S requires specific dual-signal drive voltage waveforms. See product specification for further information.

### **FOS (Fast Optical Shutter)**

The basic FOS model offers high contrast between open and closed states even at moderate drive voltage amplitude together with fast switching from open to closed state. It is suitable for customers seeking a general purpose optical shutter without having extreme requirements for fast switching. The FOS is available in a wide-view version, the FOS-WV, having more uniform light extinction over the viewing angles in the closed state. Also a faster switching, color-neutral version, the FOS(G2)-CN, is offered.

### **FOS-ETR (Fast Optical Shutter - Extended Temperature Range)**

With both storage and operating temperature range covering -40°C to +100°C, the FOS-ETR is designed to withstand extreme environments.

### **FOS-NIR(1100) (Fast Optical Shutter - Near Infrared Operation, 1,100nm optimized)**

The FOS-NIR(1100) provides broadband visual-near infrared (up to 2,000nm) operation with high open state transmittance optimized for wavelengths around 1,100nm.

### **X-FOS(G2) (Extra Fast Optical Shutter, 2<sup>nd</sup> generation)**

The second-generation X-FOS(G2) is the fastest single-cell shutter and differs from the FOS model by having higher switching speeds, both closing and opening. This shutter should be considered for applications in which high-frequency operation between open and closed states is desired.

### **X-FOS(G2)-CE (Extra Fast Optical Shutter, 2<sup>nd</sup> generation - Contrast Enhanced)**

The X-FOS(G2)-CE incorporates a dual-cell structure in order to achieve exceptionally high light extinction in the closed state. It is ideal for applications in which extra fast closing together with an extremely dark closed state is needed, e.g. eye protection during welding.

### **X-FOS(G2)-LAS (Extra Fast Optical Shutter, 2<sup>nd</sup> generation - Laser Operation)**

The X-FOS(G2)-LAS is compatible with laser operation without sacrificing product durability or lifetime.

### **PolarSpeed®-S (PolarSpeed® Shutter)**

Based on LC-Tec's patented PolarSpeed® technology, this dual-cell shutter offers unprecedented 30µs symmetrical switching times in both directions, closing as well as opening. The PolarSpeed® shutter is especially suitable for high frame rate applications, such as time-multiplexed stereoscopic 3D, and is compatible with up to 540 FPS operation.

### **PolarView®-ND(212) (PolarView® Neutral Density Filter, 2 to 12 stop range)**

The patented PolarView®-ND(212) model is specifically designed for operation as neutral density (ND) filter in camera applications. It offers uniform angular transmittance properties together with small color shift, not only at the fully open and closed states, but also at intermediate gray-levels. The high-contrast PolarView®-ND(212) model covers a f-stop reduction range from 2 to 12 stops, corresponding to 25% to 0.024% transmittance.

### **PolarView®-ND(14)-F (PolarView® Neutral Density Filter, 1 to 4 stop range - Flexible)**

The PolarView®-ND(14)-F is a high-transmittance version of the ND(212) model. Manufacturing on flexible substrates allows uniaxial bending for use as an electronic dimming filter in various smart eyewear applications, including augmented reality glasses and sunglasses. The standard dimming range is between 50% and 5%, but can be tuned if desired.

### **FSD (Fast Switchable Diffusor)**

The polarizer-free FSD switches between clear and light-scattering states. The open state exhibits over 83% transmittance while the closed state effectively diffuses light.

<b>Model</b>	<b>Open state transmittance</b>	<b>Contrast</b>	<b>Closing time (T<sub>100</sub>-T<sub>10</sub>)</b>	<b>Opening time (T<sub>0</sub>-T<sub>90</sub>)</b>	<b>V<sub>d</sub></b>
FOS	≥39.5%	≥1,000:1 ≥1,800:1	≤6ms ≤150µs	≤30ms ≤35ms	@ 4V <sub>RMS</sub> @ 24V <sub>RMS</sub>
FOS-ETR	≥32.5%	≥850:1 ≥1,200:1	≤6ms ≤500µs	≤35ms ≤40ms	@ 5V <sub>RMS</sub> @ 18V <sub>RMS</sub>
FOS-NIR(1100)	≥37.0%	≥250:1 ≥350:1	≤5ms ≤120µs	≤15ms ≤20ms	@ 5V <sub>RMS</sub> @ 24V <sub>RMS</sub>
X-FOS(G2)	≥37.5%	≥1,800:1	≤50µs	≤1.8ms	@ 18V <sub>RMS</sub>
X-FOS(G2)-CE	≥30.0%	≥120,000:1	≤50µs	≤1.8ms	@ 18V <sub>RMS</sub>
X-FOS(G2)-LAS	Under development				
PolarSpeed®-S	≥37.5%	≥300:1	≤30µs	≤30µs	@ 24V <sub>RMS</sub>
PolarView®-ND(212)	≥25%	≥1,000:1	≤10ms	≤15ms	@ 4.5V <sub>RMS</sub>
PolarView®-ND(14)-F	≥50%	≥10:1	≤200ms	≤700ms	@ 7V <sub>RMS</sub>
FSD	≥83%	Light scattering	≤7ms	≤9ms	@ 110V <sub>RMS</sub>

Note: The values above are valid for the 1x1 size at room temperature, incident light is unpolarized. Transmittance and contrast correspond to luminous data for all models except for the FOS-NIR(1100), where the performance is measured at the design wavelength of 1,100nm. See product specifications for further information.