

## FOS series

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### 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 the 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. Analogue 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. Some models employ two LC cells for achieving enhanced performance, while other models are polarizer-free for offering higher open state transmittance.

In order to meet a wide range of requirements for various applications, a series of FOS 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.

**To purchase or for more information, please contact us at: [info@lc-tec.se](mailto:info@lc-tec.se) or +46 243 79 40 70.**

#### Advantages

- Electro-optical
- No moving parts
- Vibration-free
- Small footprint
- Low power consumption
- Large design freedom
- Fast switching
- High contrast
- Wide viewing angles
- Excellent optical quality
- Ruggedized
- Reliable

#### Applications

- 3D projection
- Direct-view 3D
- Photography
- Videography
- Industrial cameras
- Machine vision
- Welding
- Microscope
- Eyewear
- Laser attenuation
- R&D
- And more...



## Main electro-optical properties

<i>Model</i>	<i>Open state transmittance</i>	<i>Contrast</i>	<i>Closing time (T<sub>100</sub>-T<sub>10</sub>)</i>	<i>Opening time (T<sub>0</sub>-T<sub>90</sub>)</i>	<i>V<sub>D</sub></i>
FOS	≥39.5%	≥1,000:1	≤6ms	≤30ms	@ 4V
FOS-ETR	≥32.5%	≥850:1	≤6ms	≤35ms	@ 5V
FOS-NIR(1100)	≥37.0%	≥1,200:1	≤500μs	≤40ms	@ 18V
X-FOS(G2)	≥37.5%	≥250:1	≤5ms	≤15ms	@ 5V
X-FOS(G2)-CE	≥30.0%	≥350:1	≤120μs	≤20ms	@ 24V
PolarSpeed®-S	≥37.5%	≥1,800:1	≤50μs	≤1.6ms	@ 18V
PolarView®-ND	≥30.0%	≥120,000:1	≤50μs	≤1.6ms	@ 18V
GH-FOS	≥37.5%	≥300:1	≤30μs	≤30μs	@ 24V
PSCT-FOS	≥25%	≥1,000:1	≤10ms	≤15ms	@ 4.5V
	≥60%	≥4:1	≤50ms	≤250ms	@ 9V
	≥83%	Light scattering	≤7ms	≤9ms	@ 110V

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 detailed product specifications for further information.

## Available standard sizes

<i>Size</i>	<i>Outer dimensions</i>	<i>Clear aperture</i>	<i>Thickness</i>
7x8	7.0mm x 8.2mm	5.0mm x 5.0mm	Model dependent, ranging from 1.3mm to 5.2mm
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	47.6mm diameter	

Note: See detailed product specifications for exact dimensions and tolerances.

## Model descriptions

### ***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. The dynamic electro-optical properties relating to fast switching are similar to those of the X-FOS(G2), but the X-FOS(G2)-CE possesses an unparalleled contrast of 120,000:1. 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.

### ***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 demanding high frame rate applications, such as time-multiplexed stereoscopic 3D, and is compatible with up to 540 FPS operation.

### ***PolarView®-ND (PolarView® Neutral Density Filter)***

The patented PolarView®-ND model is specifically designed for operation as neutral density (ND) filter in various 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. Recommended f-stop range is 3 to 10 stops, corresponding to 12.5% to 0.10% transmittance.

### ***GH-FOS (Guest-Host Fast Optical Shutter)***

The GH-FOS has no polarizers, instead light absorption is realized by mixing a dichroic dye into the LC cell. This model offers higher open state transmittance, but with lower contrast compared to other models. The open-closed state trade-off can be tuned.

### ***PSCT-FOS (Polymer-Stabilized Cholesteric Texture Fast Optical Shutter)***

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

## **Models under development**

### ***FOS-LAS (Fast Optical Shutter - Laser Operation)***

By optimizing both the manufacturing process and material choice, the FOS-LAS is compatible with low-power laser operation without sacrificing product durability or lifetime.

### ***PolarSpeed®-S-VN (PolarSpeed® Shutter - VIS/NIR)***

Based on LC-Tec's proven PolarSpeed® technology, the patented PolarSpeed®-S-VN version is a fast-switching optical shutter alternately transmitting visible and near infrared light.

## **Electrical connections**

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

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

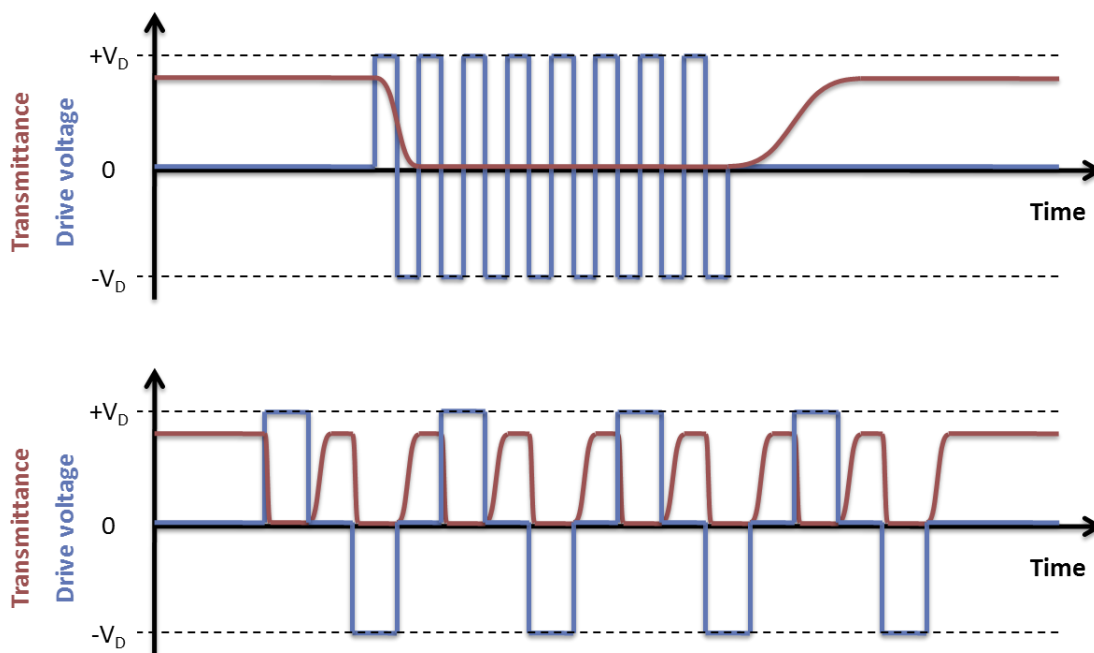
Most models are supplied with an anti-reflective, scratch-resistant hard-coating on the outer surfaces. For demanding optical applications, the shutters can also be supplied with an optical quality, high-efficiency AR cover glass laminated to both sides. This configuration minimizes surface reflection,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

## Drive voltage

The shutters possess mono-stable normally white operation, meaning that 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 usually 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 top alternative is used, the recommended minimum frequency is 60Hz if visual flicker is to be avoided. The bottom option is suitable when cycled operation between open and closed states is desired.

\* The PolarSpeed®-S, PolarView®-ND, and PSCT-FOS models show inverted optical response, i.e. closed without voltage applied (normally black operation). \*\* The PolarSpeed®-S has a different operating principle and requires specific dual-signal drive voltage waveforms. For details, see the PolarSpeed®-S specification.



## Recommended controller

The LCC-230 is a flexible, full-featured liquid crystal controller specifically designed to drive all FOS, X-FOS, PolarSpeed®, and PolarView® models (except the PSCT-FOS, requiring high-voltage driving). The LCC-230 incorporates two independent LC channels, each with  $30V_{RMS}$  of range and fully short-circuit protected.

The controller is operated by the LCDriver2 application via a full-speed USB 2.0 compliant interface. LCDriver2 permits dynamic editing of programs up to 96 lines in length. Three trigger modes (internal, line, program) determine how program lines are executed. Up to nine programs may also be pre-stored on the LCC-230 for stand-alone operation.