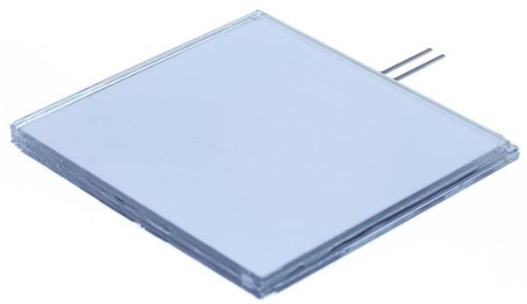
X-FPM(L)/X-FPM(L)-AR

PRODUCT SPECIFICATION



Content

1. Revision history

Revision	*Revision date*	*Revision content*
Initial release	2016-02-15	-

2. Product description

The X-FPM(L) (Extra Fast Polarization Modulator, Linear Output) is a liquid crystal (LC)-based polarization modulator/rotator that controls the light polarization by an externally applied drive voltage. Compared to conventional mechanical modulators/rotators, LC modulators/rotators are electro-optical; they contain no moving parts, are completely vibration-free, and have a small footprint.

The modulator/rotator consists of a polarization modulator in the form of a LC cell together with a linear polarizer. 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 polarization of light passing through the full modulator/rotator structure.

The X-FPM(L) is the fastest single-cell modulator and differs from the FPM(L) model by having higher switching speeds, both response and relaxation. This modulator should be considered for applications in which high-frequency operation between two linear polarization states is desired. While being configured for linear polarization output states, switching between other pre-defined polarization states is also possible; for example between linear and circular polarization as well as between left- and right-handed circular polarization.

The X-FPM(L) is supplied with an input (or exit depending on usage) polarizer as standard. For customers having linearly polarized incident light, the modulator/rotator can be supplied without any polarizer, the 0P reference is then added to model name.

For demanding optical applications, the X-FPM(L) can also be supplied with an optical quality, high-efficiency AR cover glass laminated to both sides of the modulator/rotator. This configuration minimizes surface reflection, beam deviation, and wavefront aberration, and is especially recommended for imaging applications. The suffix -AR is then added to the model name.

3. Ordering information

Product	*Part number*
2x2_X-FPM(L)	LCT-093
2x2_X-FPM(L)-AR	LCT-095
LCC-230 Controller	LCT-030

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

4. Custom designing

Customers not finding their required polarization modulator/rotator properties are advised that other FPM models are available and that further optimization and custom designing are possible, both in terms of electro-optical properties and mechanical dimensions (up to 14”x16” size).

5. General specifications

	X-FPM(L)	*X-FPM(L)-AR*
Technology	Nematic LC	Nematic LC
Polarization output	Linear	Linear
Number of polarization output states	2, -45° and +45°	2, -45° and +45°
Mode of operation	Normally polarization altering	Normally polarization altering
Side 1 polarizer transmission axis[1]	+45°	+45°
LC cell substrate material	Polished soda lime glass	Polished soda lime glass
Polarizer type and material	Absorptive type polymer	Absorptive type polymer
AR substrate material	N/A	Polished soda lime glass
Scratch resistance	≥3H	N/A

6. Absolute maximum ratings[2]

	X-FPM(L)	*X-FPM(L)-AR*
Operating temperature[3]	-10°C to +60°C	-10°C to +60°C
Storage temperature[3]	-30°C to +80°C	-10°C to +60°C
Drive voltage amplitude	≤24V	≤24V
Drive voltage frequency	≤1kHz AC square wave	≤1kHz AC square wave

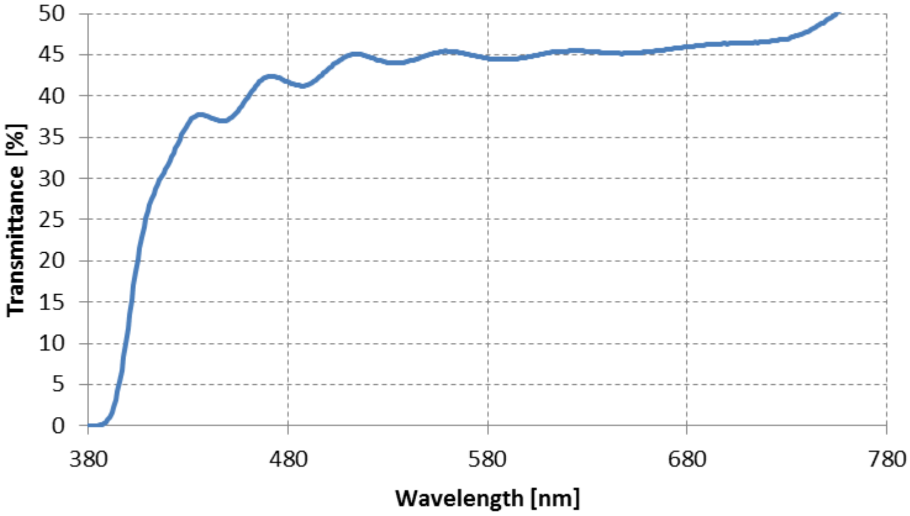
7. Electro-optical specifications[4]

	X-FPM(L)	*X-FPM(L)-AR*
Transmittance[5]	≥43.5%	≥43.0%
Color	u'=0.211 ± 0.01 v'=0.485 ± 0.01	u'=0.211 ± 0.01 v'=0.485 ± 0.01
Polarization contrast		
- Polarization altering, luminous (90° rotation)	≥20:1 @ V_D=0V	≥20:1 @ V_D=0V
- Polarization altering, @ 550nm (90° rotation)	≥100:1 @ V_D=0V	≥100:1 @ V_D=0V
- Non-altering, luminous	≥1,800:1 @ V_D=24V	≥1,800:1 @ V_D=24V
- Non-altering, @ 550nm	≥1,800:1 @ V_D=24V	≥1,800:1 @ V_D=24V
Response time (T_{100}-T_{10})	≤30µs @ V_D=24V	≤30µs @ V_D=24V
Relaxation time (T_0-T_{90})	≤1.8ms @ V_D=24V	≤1.8ms @ V_D=24V
Reflectance per surface	≤2%	≤0.5%
Surface quality	N/A	60/40 scratch/dig
Wavefront aberration and MTF	N/A	Available upon request
RMS average power consumption[6]	≤12mW	≤12mW
Peak current[6]	≥28mA	≥28mA

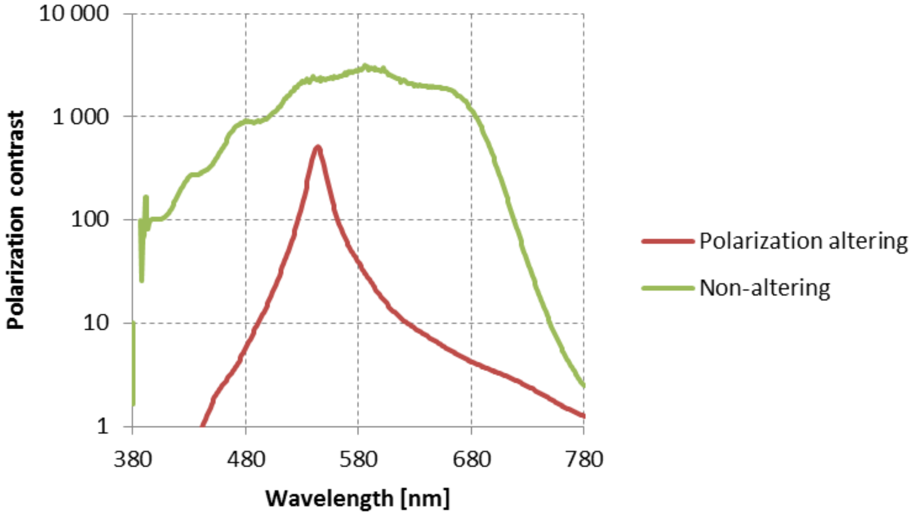
[1] Refer to drawing in section 10.4.
[2] Reliability tests performed over a range of environmental conditions according to standard IEC 61747-5.
[3] Dry, no condensation.
[4] The specified values are valid for the 2x2 size and measured at room temperature (23°C ± 3°C).
[5] Refers to unpolarized incident light, the corresponding value for linearly polarized light is significantly higher.
[6] As measured with f=60Hz, V_D=12V AC square drive waveform with transition slew rate of 3.5V/µs. Actual figures will vary with waveform slew rate, amplitude, frequency, and modulator size. Also see section 9.

8. Typical values (X-FPM(L) @ room temperature and V_D=24V unless other specified)

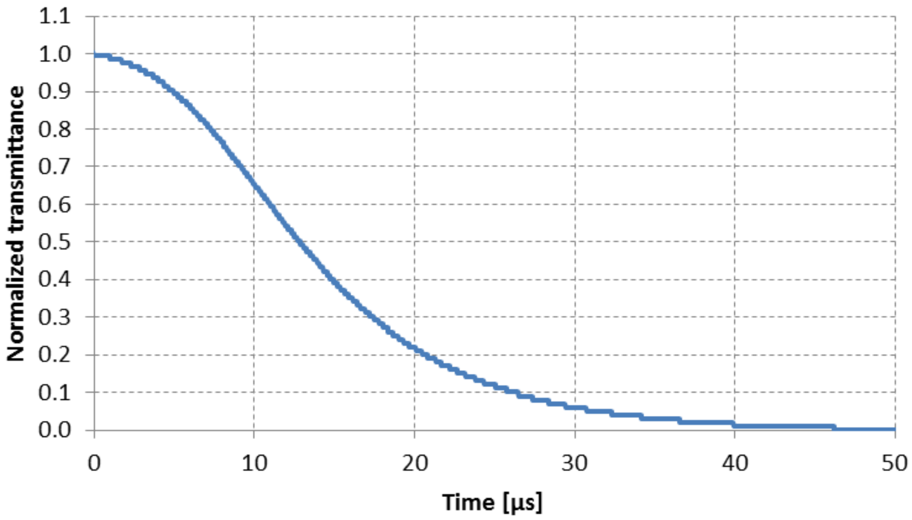
8.1. Transmittance vs. wavelength



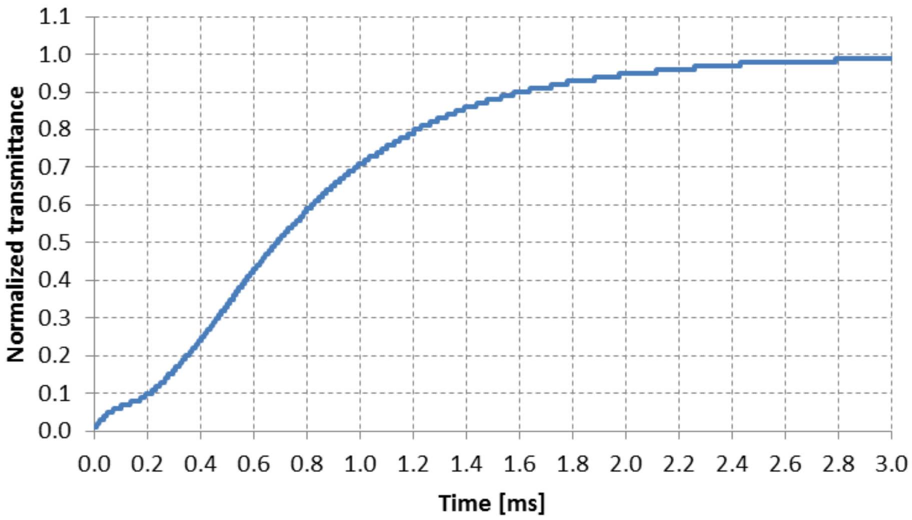
8.2. Polarization contrast vs. wavelength



8.3. Response time at room temperature, normalized transmittance (as observed with crossed external analyzer) vs. time



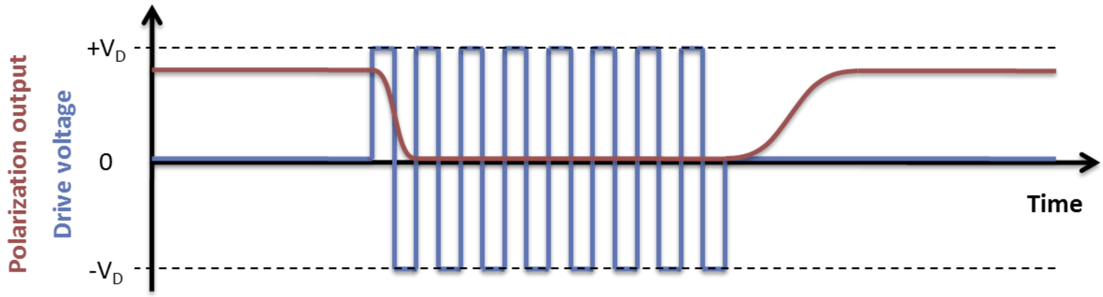
8.4. Relaxation time at room temperature, normalized transmittance (as observed with crossed external analyzer) vs. time

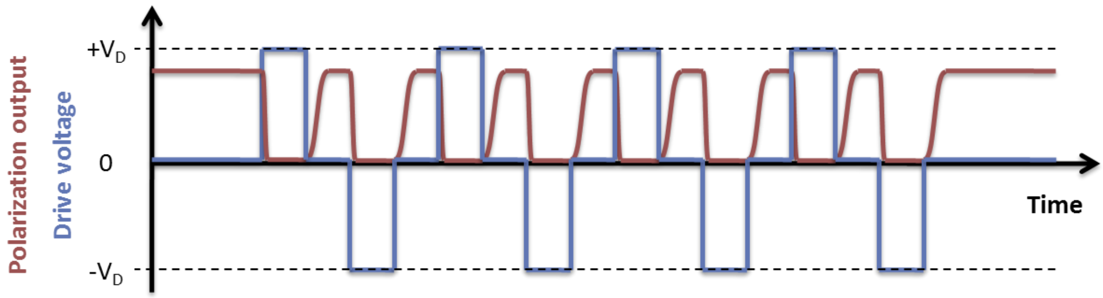


9. Drive voltage and recommended controller

The modulator/rotator possesses mono-stable normally polarization altering operation, meaning that without voltage applied the modulator/rotator is in its polarization altering state. Applying the drive voltage, V_D, switches it to a non-altering state. This voltage must be kept throughout the duration of the time the modulator/rotator is required to be in the non-altering state. In general, increasing the drive voltage amplitude increases the contrast of the non-altering state and shortens the response time.

The polarization output of the modulator/rotator reacts to the RMS voltage. In order to prevent ion migration within the LC layer that might impair modulator/rotator 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 different polarization output states is desired.





The LCC-230 (*LC-Tec Part number LCT-030*) is a flexible, full-featured liquid crystal controller specifically designed to drive all FPM, X-FPM, PolarSpeed®, and VPR models. 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. See user manual for further information.

Note: Customer-developed LC drive stages must be able to deliver at least the peak current of the specific FPM device to be driven. Output-stage ballast capacitors with a maximum ripple current rating at least three times the peak current is recommended.

10. Measurement methods and definitions

10.1. Transmittance, color, and polarization contrast

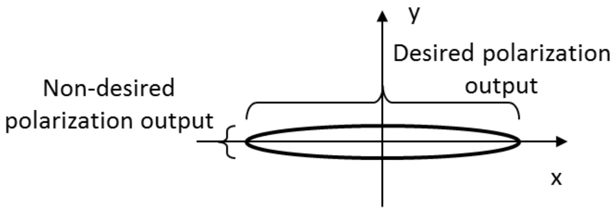
The transmittance is defined as the luminous transmittance of collimated unpolarized light passing perpendicularly through the modulator/rotator according to:

$$T = \frac{\int_{380}^{780} T(\lambda)D(\lambda)P(\lambda)d\lambda}{\int_{380}^{780} D(\lambda)P(\lambda)d\lambda}$$

where T(λ) is the transmittance function of the modulator/rotator, D(λ) is the illuminant spectral distribution, and P(λ) is the photopic response of the human eye. All transmittance values specified are based on the standard illuminant **CIE E** (equal-energy for all wavelengths). The corresponding color is mathematically described using the color matching functions of the CIE 1931 Standard Colorimetric Observer, and is represented by a point in the u',v' chromaticity coordinate system.

The polarization contrast is defined as the ratio of the desired polarization output component to its orthogonal non-desired component as when measured using an analyzer in form of a typical high-contrast film polarizer according to:

$$PC = \frac{T_{desired\ polarization\ output}}{T_{non-desired\ polarization\ output}}$$

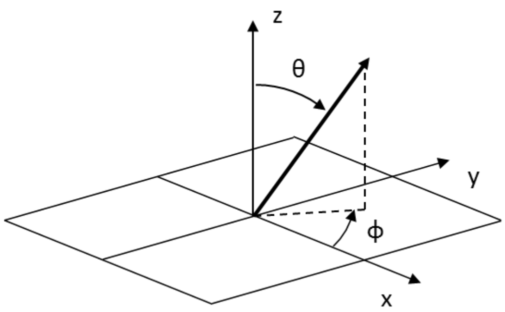


Since the polarization output depends on applied drive voltage, also the polarization contrast is a function of the voltage and usually increases with increasing amplitude (valid for the non-altering output state). Both luminous and narrow-band polarization contrast values are specified.

10.2. Angular dependence

The polarization output is not only a function of light wavelength and applied drive voltage. Since the phase retardation induced by the LC cell also depends on the angle between the direction of light and the long axis of the LC molecules, the polarization output of the modulator/rotator can for a given angle of incidence be described by:

$$PO = PO(\theta, \phi, \lambda, V_D)$$

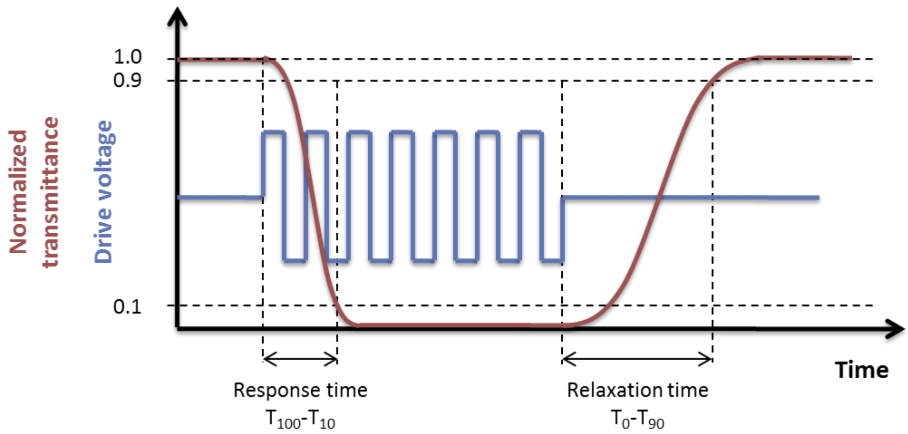


where θ is the polar angle between the light exit direction and the normal vector to the surface, and ϕ is the azimuth angle of the light exit direction as specified in the figure above.

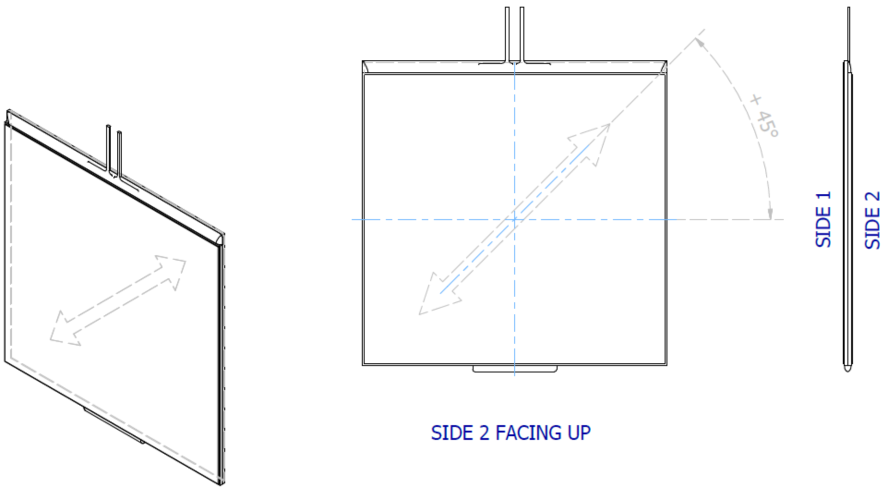
10.3. Switching times

Two switching times are associated with the modulator/rotator. The response time (also called t_{on} time), is defined as the time it takes for the modulator/rotator to switch from the polarization altering to the non-altering state after the drive voltage is applied. The response time is measured as the time it takes to switch from 100% to 10% (T_{100}-T_{10}) of its static open transmittance as observed with a crossed external analyzer after the drive voltage is applied. The response time usually decreases with increasing drive voltage amplitude and increasing temperature.

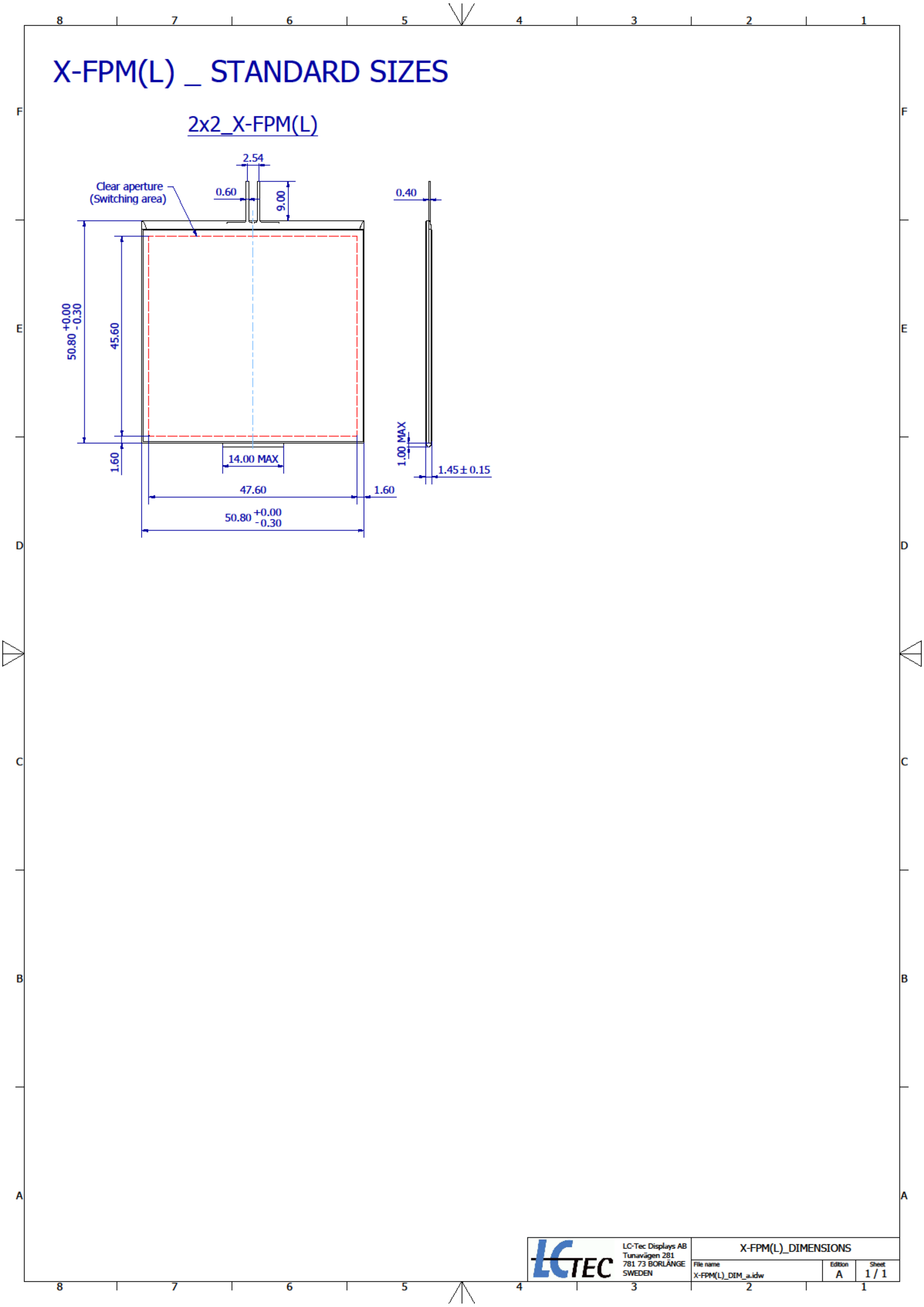
The corresponding time for switching back to the original polarization output, relaxation time (also called t_{off} time), is defined as the time it takes for the modulator/rotator to switch from the non-altering to the polarization altering state after the drive voltage is switched off. The relaxation time is measured as the time it takes for the modulator/rotator to switch from 0% to 90% (T_0-T_{90}) of its static open transmittance as observed with a crossed external analyzer after the drive voltage is switched off. The relaxation time is less dependent of the drive voltage amplitude, but decreases with increasing temperature.



10.4. Polarizer transmission axis



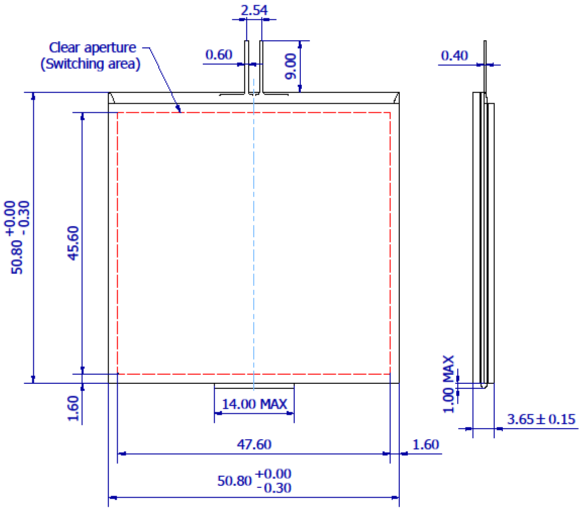
11. Mechanical dimensions[7]



[7] Refers to available standard sizes. Custom designing up to 14"x 16" size is offered.

X-FPM(L)-AR _ STANDARD SIZES

2x2_X-FPM(L)-AR



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12. Electrical connection and wiring

The desired waveform should be applied to the modulator/rotator via the connectors present on the LC cell. The modulators/rotators are supplied with contact pins as standard as illustrated in the mechanical dimensions drawings. The pin design is compatible with readily available 2.54mm pitch connectors (for example Molex Part Number 90123-0102). Customers can also solder wires to the pins, alternatively connect them directly to a dedicated printed circuit board (PCB) if desired.

Custom designed connector solutions, including variations of pins, flexible flat cable (FFC), and wires, can be provided upon request.

13. Handling precautions

The following provides recommendations for handling of this product.

LC polarization modulator/rotator handling and cleaning precautions

- A protective film is supplied on both sides of the modulator/rotator and should be left in place until the modulator/rotator is required for operation.
- Even though the polarizers have a hard-coating on the outer surface, please guard against scratching, do not rub with abrasives.
- The -AR version has an optical quality, high-efficiency AR cover glass laminated to both sides of the modulator/rotator, please guard against scratching, do not rub with abrasives.
- Keep the modulator/rotator surface clean. Do not touch without protective gloves.
- Should the surface become contaminated, wipe lightly with a soft cloth moistened with solvent (isopropyl alcohol or ethyl alcohol) in order to clean the modulator/rotator surface.
- Do not wipe the modulator/rotator surface with dry or hard materials that may damage the surface. Do not use the following solvents for cleaning: water, aromatics, acetone or other ketone.
- Since this modulator/rotator contains glass substrates, avoid applying mechanical shock or pressure. Do not drop, bend, twist or press on the modulator/rotator.

Storage

- Avoid exposure to direct sunlight or high temperature and humidity. Recommended storage conditions: temperature range +5°C to +45°C with humidity <60%RH.
- Do not store the modulator/rotator near organic solvents or corrosive gases.
- Keep the modulator/rotator protected from vibration, shock, and pressure.

Operating precautions

- It is important to operate the modulator/rotator within the specified voltage limits; higher voltages may significantly reduce the lifetime of the modulator/rotator.
- The use of direct current drive (DC voltage) should be avoided since a reaction stimulated by such current significantly reduces the lifetime of the modulator/rotator.
- The switching speed of the modulator/rotator will be reduced at lower temperatures, and the modulator/rotator will show a dark color when observed through an analyzer at higher temperatures. However, the modulator/rotator will revert to normal operation once the temperature conditions return to the range for normal operation.

Safety

- Should the modulator/rotator become damaged and the skin is exposed to liquid crystal material, it is recommended to immediately wash off the liquid crystal material using soap and water.
- If the liquid crystal material should come into contact with the eye, flush the eye using running water for at least five minutes. Seek medical advice.