PRELIMINARY

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Fast Electrically Tunable Lens EL-6-18

The curvature of this shape changing polymer lens can be adjusted by applying current. The focal length is accordingly tuned to a desired value within milliseconds. The following table outlines the specifications of the standard EL-6-18-VIS-LD.

Mechanical specifications	**EL-6-18-VIS-LD**	
Dimensions (L x W x H)	18 x 19.3 x 8.7	mm
Clear aperture	6	mm
Weight	6.7	g
Lifecycles (10-90% sinusoidal)	>1'000'000'000	
Vibration resistance	IEC 60068-2-6: 10G (10-50 Hz) in operation	
Drop test	50 drops from 2 m	

Electrical specifications		
Resistance (@ 20°C)	8.8 +/- 0.4	Ω
Control current (typical)	0 to 200	mA
Power consumption	0 to 350	mW
Response time (10%-90% step)	<2	ms
Settling time	<10	ms
Electrical connection	6 way 0.5mm pitch	
Integrated temperature sensor / memory	STTS2002	

Optical specifications		
Focal tuning range at STP[1]	-500 to +50	mm (-2 to 20 dpt)
Wavelength range[2]	400 to 700	nm
Transmission spectrum	See Figure 5	
Dispersion (at 20°C)		
n_F (486.1nm)	1.302	
n_D (589.3nm)	1.300	
n_C (656.3nm)	1.299	
Abbe number V_d	100	
Lens type	Meniscus (concave-convex)	
Full field of view	40°	
Polarization	Preserving	

Thermal specifications		
Operating temperature	-20 to +70	°C
Storage temperature	-40 to +85	°C

Regulatory Requirements	
Materials	Complies with EU directive 2002/95/EC (RoHS)

[1] Different focal tuning ranges available upon request
[2] Different coatings available upon request

Optotune AG | Bernstrasse 388 | CH-8953 Dietikon | Switzerland
Phone +41 58 856 3000 | www.optotune.com | info@optotune.com

Mechanical Dimensions

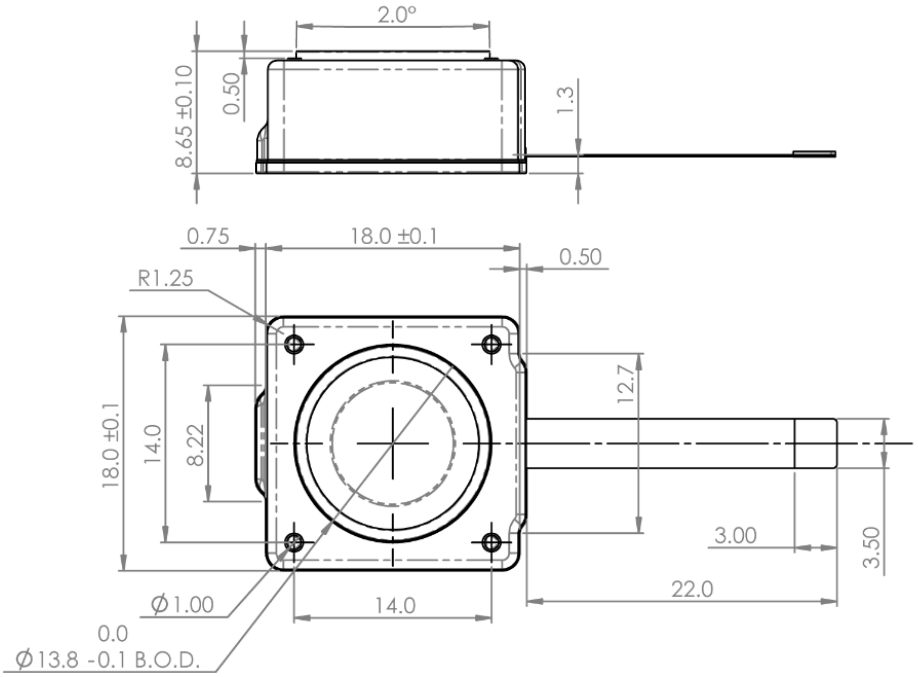
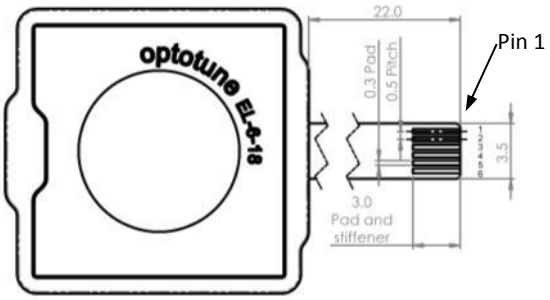


Figure 1: Mechanical dimensions (unit: mm)

Electrical Connection

The EL-6-18 has an FPC connection compatible with Molex 0.5mm pitch 6 way FPC backflip connector (P/N 503480-0600). An adaptor board with integrated connector is included for easy soldering (note: the connector on the adaptor board has top and bottom contacts so it is important that once orientation is established it must be maintained).

The EL-6-18 also features an integrated STTS2002 temperature sensor with 256 bytes of memory – the sensor is addressable via the pins as detailed below:



Pinning		
Position	Function	STTS2002 Pins
1	STTS2002 Gnd	1-4
2	Lens (- pole)	-
3	Lens (+ pole)	-
4	STTS2002 SDA	5
5	STTS2002 SCL	6
6	STTS2002 Vdd	8

Figure 2: Electrical Connection – To suit Molex 6 x 0.5mm Pitch FPC connector (P/N 503480-0600) or equivalent

The I2C address of the STSS2002 is set as follows:

- Temp Sensor: 0 0 1 1 0 0 0 RW (where is the READ/WRITE flag)
- EEPROM memory array: 1 0 1 0 0 0 0 RW
- EEPROM write protection mode: 0 1 1 0 0 0 0 RW

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Working principle

The EL-6-18 is a shape-changing lens. It consists of an injection-molded container, which is filled with an optical fluid and sealed off with an elastic polymer membrane. The deflection of the lens is proportional to the pressure in the fluid. The EL-6-18 has an electromagnetic actuator that is used to exert pressure on the container. Hence, the focal distance of the lens is controlled by the current flowing through the coil of the actuator.

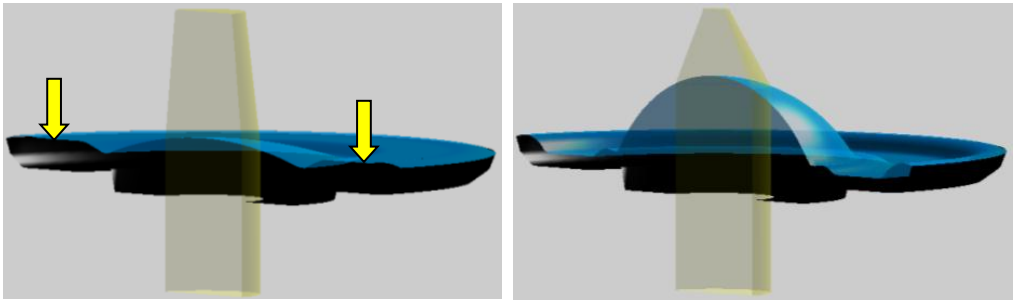
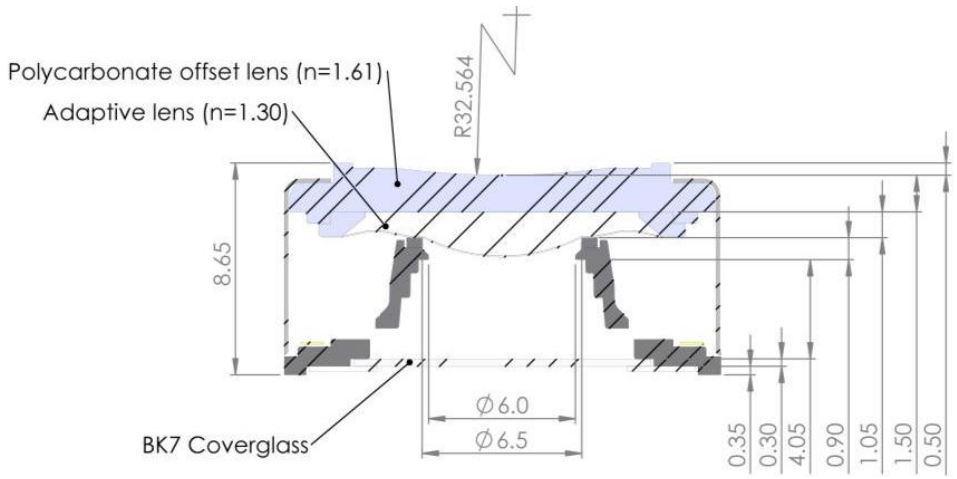


Figure 3: Working principle of the EL-6-18

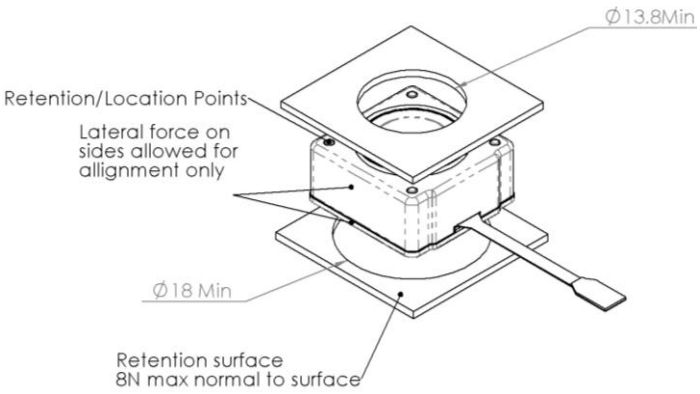
Optical Layout



The focal range of the tunable lens itself is limited to the positive range. To expand the tuning range to negative focal lengths, the EL-6-18 has an offset lens with a negative focal length of -50 mm. All optically relevant dimensions are referenced to a ring on the container, which protrudes the housing.

Installation

The recommended retention system is two opposing surfaces acting on the front and rear surfaces of the lens. The retaining surfaces shall be flat so as to not introduce point loads. The acting surfaces should have a minimum inner diameter of 18 mm and 13.8 mm, respectively, and extend past the perimeter of the mating surface. The axial location may be defined by the outer or inner diameters of the ring protruding from the lens. Orientation of the lens can be set by an alignment feature; this feature shall not introduce extraneous forces on the lens.



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Focal length versus current

The focal power of the EL-6-18 increases with current. The starting point at zero current is set during production and can be varied from lens to lens. The slope of the focal length decrease is influenced by the mechanical properties of the membrane, which can also be varied on request to achieve different ranges of focal length. In open loop systems, a calibration of the lens with look-up tables is recommended.

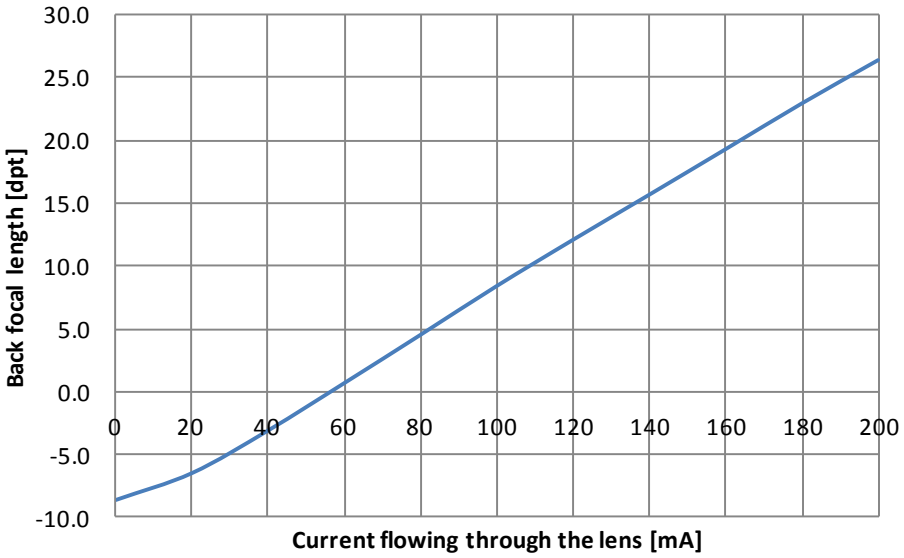

Figure 4: Typical relation of focal length to current of the EL-6-18

Recommended drivers/power supplies

Optotune has launched its own high-precision USB driver with a resolution of 0.1 mA. It includes the I2C readout of the temperature sensor, which can be used for temperature compensation.

There are also many alternative off-the-shelf products available that can be used to control the EL-6-18:

- Precision constant current driver for laser diodes with external control via 0-5 V analog signal (e.g. Edmund Optics NT56-804 or NT84-355)
- For high precision applications (0.1 mA resolution) with manual control: TTi QL355
- For high precision applications (0.1 mA resolution) with USB/RS232 computer control: TTi QL355P
- For low precision applications (1 mA resolution) with manual control: TTi EL301R
- For low precision applications (1 mA resolution) with USB computer control: Quakko HY3005DP http://shop.vendio.com/Evan2002/item/2041700966/?s=1282809362

The lens can also be driven using pulse width modulation (PWM) with a frequency between 20 kHz and 50 kHz. Another very useful component is the ADN8810 programmable precision current source of Analog Devices, which features 12 bits of resolution and can be controlled with an SPI interface.

Temperature effects

Heating up of the lens has two consequences: First, the refractive index of the optical fluid decreases. Second, the fluid expands in volume. While the first effect would increase the focal distance, the second effect reduces it. With the EL-6-18 design, the second effect prevails. The focal distance decreases by approximately 0.25 diopters per °C temperature increase.

This temperature effect is systematic and reproducible. Furthermore, the EL-6-18 has a built-in temperature sensor (STTS2002). Therefore, the focal length can be controlled and temperature stable performance can be achieved.

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Transmission range

Both the optical fluid and the membrane material are highly transparent and hardly absorbing in the range of 250 – 2500 nm. As the membrane is elastic it cannot be coated using standard processes, hence a reflection of 3 – 4% is to be expected. The standard cover glasses have a broadband anti-reflection coating for visible light.

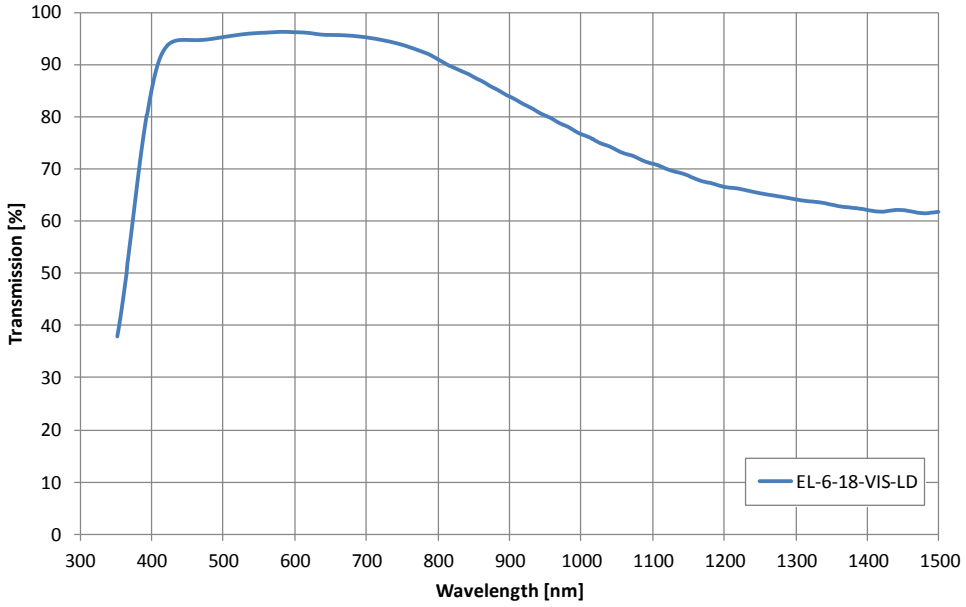

Figure 5: Transmission spectrum of the EL-6-18 for standard VIS coated cover glasses (400-700 nm)

Step response time

The rise time on a current step is about 2 ms. However, it takes about 10ms until the lens has fully settled. The following graph shows the optical response on a current step measured using the astigmatic lens approach with a cylinder lens and a quadrant diode[3].

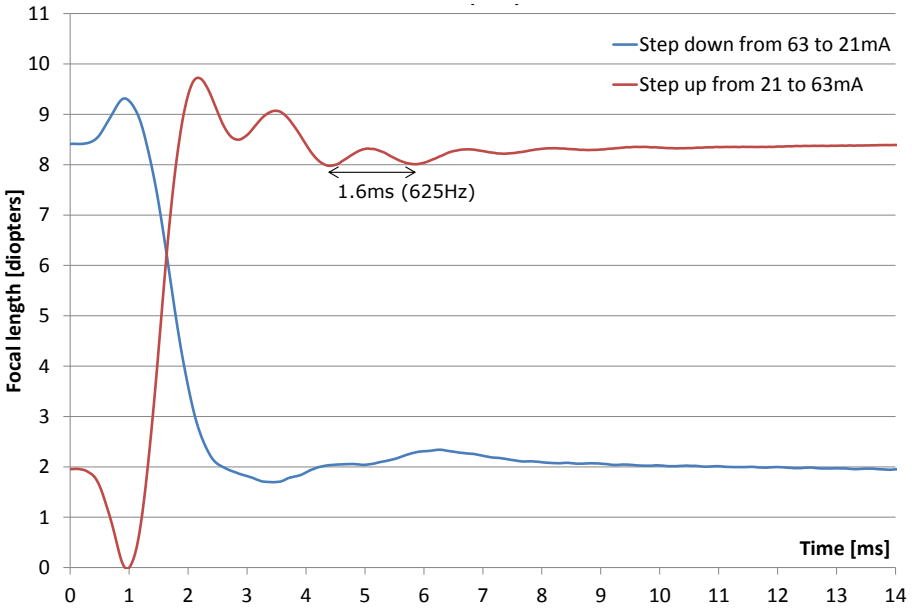

Figure 6: Optical response of the EL-6-18 to a current step from 21 to 63 mA and back

[3] See Donald K. Cohen „Automatic focus control: The astigmatic lens approach“, Applied Optics Vol. 23, No. 4, February 15, 1984

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