

Electrically tunable large aperture lens

EL-16-40-TC-VIS-20D

By applying an electric current to this shape changing polymer lens, its optical power is controlled within milliseconds over an optical power range of -10 dpt to +10 dpt. A major hallmark of this shape changing lens is the clear aperture of 16 mm. In order to achieve good repeatability and focus stability, Optotune integrated a temperature sensor allowing for in-situ compensation of temperature effects. The lenses are therefore ideally suited for a large variety of applications where imaging and a large beam diameter is of importance.



Main specifications

Clear aperture	16	mm
Optical power: tuning range @ 30°C with Optotune's Lens Driver 4	-10 to +10	dpt
Wavefront error (@525 nm, 0 mA) Optical axis vertical / horizontal	~ 0.5 / ~ 2.5 (due to gravity coma)	λ RMS
Lens type	plano-concave to plano-convex	
Refractive index & Abbe number	nD=1.300, V=100	
Cover glass coating	420 to 950 ¹	nm
Optical retardance @590nm	6.1	nm
Response time (typical at 30°C, 0 to +/- 250mA step)	7	ms
Settling time (typical at 30°C, 0 to +/- 250mA step)	40	ms
Lifecycles (10%-90% sinusoidal) ²	>1'000'000'000	
Operating temperature ³	-20 to 65	°C
Storage temperature	-40 to 85	°C
Weight	40	G
Temperature sensor & memory	STTS2004 (STMicroelectronics)	

Electrical specifications

Nominal control current with Lens Driver 4	-250 to 250	mA
Absolute max. control current	-300 to 300	mA
Power consumption	0 to 0.7 (nominal), 0 to 1 (absolute max.)	W
Motor coil resistance @ 30°C	11	Ω
Voltage for digital circuitry Vcc	3.3	V

Overview of available standard products

Standard Product	Wavefront error (@525 nm, 0 mA)		
	optical axis vertical	Top thread	Bottom thread
EL-16-40-TC-VIS-20D (standard)	<0.5 λ RMS	None	None
EL-16-40-TC-VIS-20D-C (standard)	<0.5 λ RMS	C-mount male	C-mount female
EL-16-40-TC-VIS-20D-1 (class 1)	<0.25 λ RMS	None	None
EL-16-40-TC-VIS-20D-1-C (class 1)	<0.25 λ RMS	C-mount male	C-mount female

The standard EL-16-40-TC-VIS-20D is targeted to ophthalmic applications, where a larger wavefront error can be tolerated since the human eye only uses a sub-pupil of the lens. For imaging applications and in particular microscopy we recommend the class 1 model with better wavefront quality.

¹ Further coating options available upon request

² Lifecycle tests are ongoing. Very similar results as for the EL-10-30 series are expected, since the core technology is the same

³ Guaranteed tuning range is reduced over operating temperature range by approximately 0.03 dpt/°C

Housing and adapter combinations

The EL-16-40-TC comes with an anodized aluminum housing. The electrical connection and serial communication is established via a FPC flex cable at the side. In addition, customers can attach their own FCC flex cables via the ZIF-FCC-slide connector at the side of the housing. The relevant mechanical drawings are depicted in Figure 1.

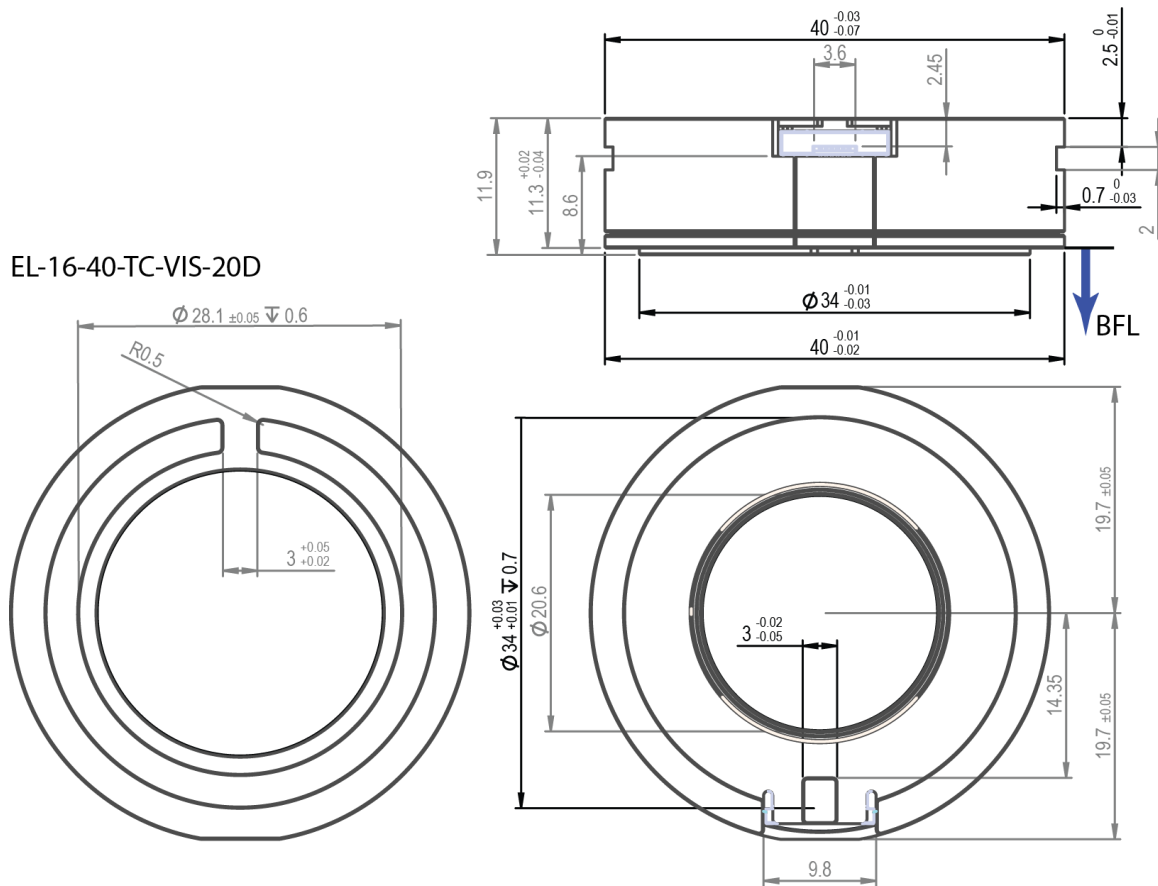


Figure 1: Mechanical layout of the EL-16-40-TC in its most simple version, the EL-16-40-TC-VIS-20D without any thread adapters attached (unit: mm).

A C-mount adapter configuration is realized by mounting the EL-16-40-TC in an M40.5x0.5 tube, which is rotatable and lockable with one setscrew. The EL-16-40-TC-VIS-20D-C is shown in Figure 2. The adapter configuration comes with an extension at the side, providing a 6-pin Hirose connector (HR10G-7R-6P), making it suitable for tough environmental conditions. This can be seen on the right part of Figure 2.

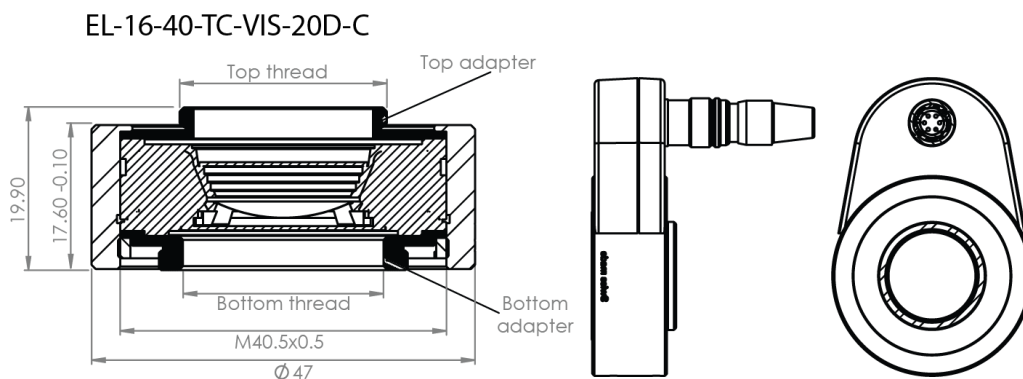


Figure 2: Mechanical layout of EL-16-40-TC-VIS-20D-C configuration (unit: mm).

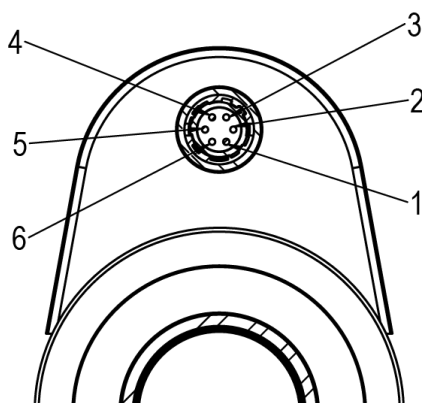
Electrical connection

The electrical connection of the basic version of the EL-16-40-TC without adapters consists of a FPC flex cable with 6 pins suitable for Molex connector no. 503480-0600. Two pins are for the coil of the lens, the other four pins are for the I2C connection to the temperature sensor and EEPROM. The I2C addresses are 0x18 and 0x50, respectively. The detailed pin-out is summarized in the table below.



Pinning flex connector		
Position	Function	Value
1	Gnd	-
2	Max. control current -	-500..500 mA
3	Max. control current +	-500..500 mA
4	I ² C SDA	Digital signal
5	I ² C SCL	Digital signal
6	Vcc	3.3V

Figure 3: Electrical flex connections of the EL-16-40-TC basic version without adapters.



Pinning Hirose connector		
Position	Function	Sensor pins
1	Max. control current +	-
2	Max. control current -	-
3	Gnd	1-4
4	Power	8
5	I ² C SCL	6
6	I ² C SDA	5

Figure 4: Electrical connections of the Hirose connector.

Working principle

The working principle of the EL-16-40-TC is based on Optotune's well-established technology of shape-changing polymer lenses. The core that forms the lens contains an optical fluid, which is sealed off with an elastic polymer

membrane as shown in Figure 5. An electromagnetic actuator is used to exert pressure on the container and therefore changes the curvature of the lens ranging from concave to convex. By changing the electrical current flowing through the coil of the actuator, the optical power of the lens is controlled.

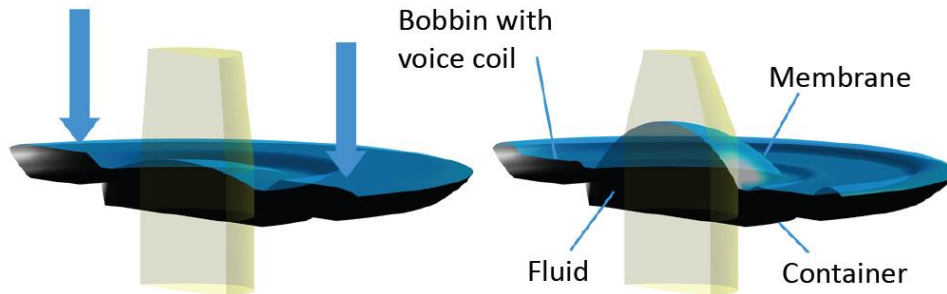


Figure 5: Scheme of the sealed lens container filled with an optical fluid and embedded in an EL-16-40-TC housing.

Optical power versus current

The optical power of the EL-16-40-TC increases with positive current and decreases with negative current as shown in Figure 6. When using Optotune's Lens Driver 4, the optical power range of the EL-16-40-TC is -10 to +10 diopters for the nominal control current -250 to +250 mA. When driving the lens up to absolute maximum control current, the tuning range increases further (see Figure 6) but significant heat generation has to be considered.

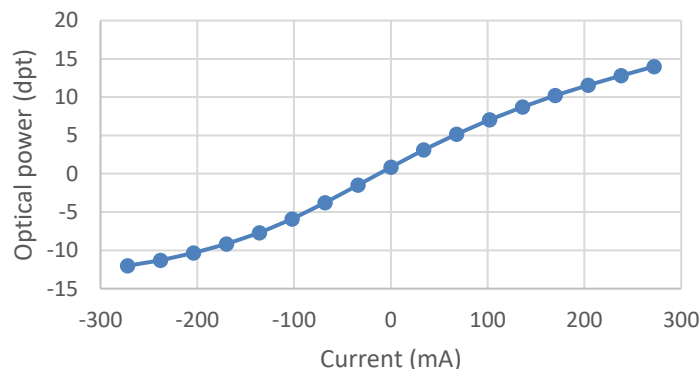


Figure 6: Typical data showing the relation between optical power (in diopters) and electrical current.

Transmission range

Both the optical fluid and the membrane material are highly transparent in the range of 400 to 2500 nm. As the membrane is elastic it cannot be coated using standard processes, hence a reflection of 3 – 4% is to be expected. Cover glasses can be coated as desired. Figure 7 shows the transmission spectrum for the standard broad-band coating.

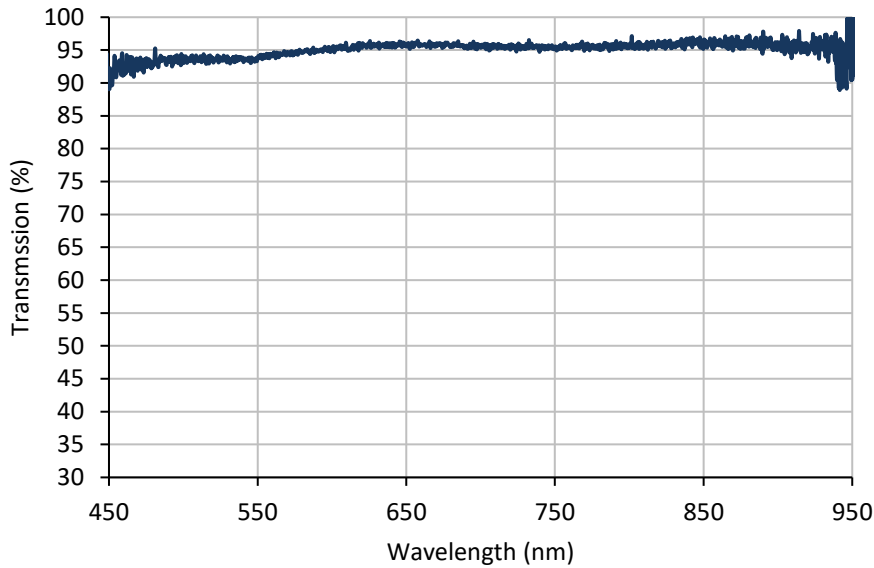


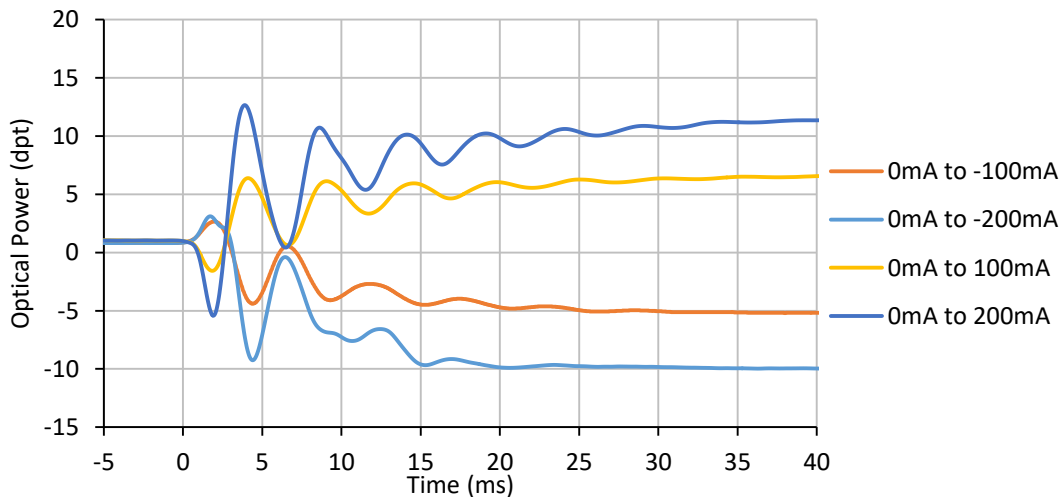
Figure 7: Transmission spectra of EL-16-40-TC standard VIS coating.

Wavefront quality

In principle, Optotune's focus tunable lenses exhibit a spherical lens shape. As the membranes used are elastic, the lens shape is influenced by gravity. With the lens' optical axis vertical, the RMS wavefront error of the EL-16-40-TC is 0.5λ (measured at 525 nm). With the optical axis horizontal a coma term must be added resulting in a wavefront error in the order of 2.5λ (measured at 525 nm). For imaging applications it is therefore highly recommended to work with vertical optical axis. Alternatively, if the orientation of the lens does not change during use, the Y-coma can be compensated to a certain extend by using a wave plate.

Response time

The rise time when applying a current step is about 7 ms. However, it takes about 40 ms until the higher order oscillations of the lens have fully settled. Figure 8 shows the optical response for several current steps measured using a photodiode after a pinhole at room temperature. The settling time can be reduced by typically up to 50% by applying a low-pass filtered step signal as opposed to a rectangular step.



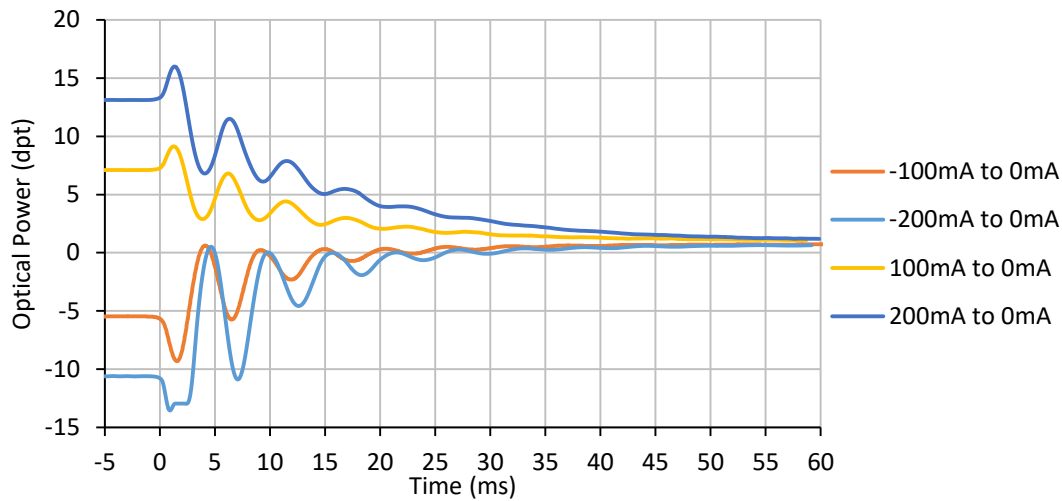


Figure 8: Typical optical response of the EL-16-40-TC-VIS-20D for several current steps. The upper plot shows a series of steps from low to high current and the lower plot for steps from high to low current.

The frequency response over a broad range is presented in Figure 9, showing a resonance peak at 200 Hz. Note that this resonance is from a higher order mode, which can generally not be used for imaging over the entire clear aperture. When applying a current step it is recommended to damp frequencies above 100 Hz by using a low pass filter. This avoids excitation oscillations as seen in Figure 8.

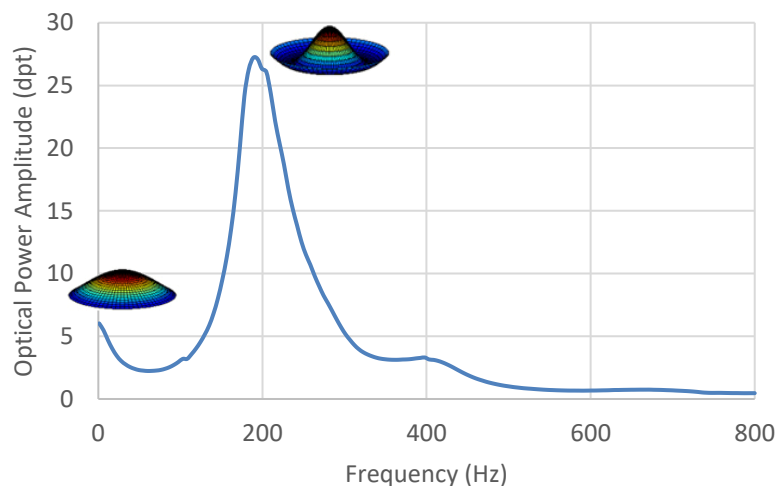


Figure 9: Typical frequency response of the EL-16-40-TC-VIS-20D. The driving amplitude is -50 to 50 mA.

Temperature effects

Residual temperature effects influence the long term drift of optical power stated in the specification table. These temperature effects are quantified by the temperature sensitivity S (dpt/°C), giving the change in optical power per degree Celsius. Figure 10 shows the dependence of S with optical power. Generally, temperature effects can be minimized when the EL-16-40-TC is thermally connected to a heat sink. The mounting itself can be used as a heat sink. Large mass and high thermal conductivity of the material dissipates the heat more efficiently. Optotune's Lens Driver 4 offers automatic thermal compensation to achieve a repeatability of typically ± 0.1 dpt.

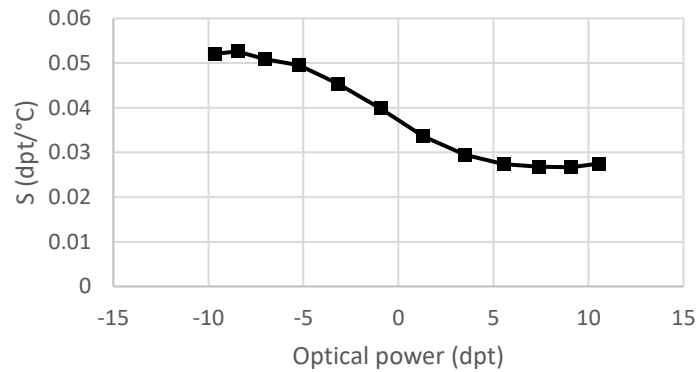


Figure 10: Temperature sensitivity S as a function of optical power.

Optical layout

Zemax simulations to model the EL-16-40 lens series within an optical design are available upon request.

Autofluorescence

The EL-16-40 is not auto fluorescent and can be used for fluorescence microscopy.

Safety and compliance

The product fulfills the RoHS and REACH compliance standards. The customer is solely responsible to comply with all relevant safety regulations for integration and operation.

For more information on optical, mechanical and electrical parameters, please contact sales@optotune.com.