Focus Tunable Lenses

Focus tunable lenses are shape-changing polymer lenses – the lens curvature can be adjusted within milliseconds by applying a current (or manually), thus the focal length can be tuned to your desired values very quickly. This unique principle enables the design of faster and more compact optical systems without complex mechanics. Whether electrically or manually tuned, there are many advantages of tunable lenses over traditional optics:

- Compact design
- Less mechanics
- Fast response
- Low power
- Less tolerance sensitivity

The working principle of tunable lenses is based on shape-changing polymer lenses. The core contains an optical fluid, which is sealed off with an elastic polymer membrane. An electromagnetic actuator is used to exert pressure on the container and changes the curvature of the lens. The optical power of the lens is controlled by changing the electrical current flowing through the actuator core.



The following table summarizes the main specifications of tunable lenses:

Series	STOT-EL-3-10	STOT-EL-12-30- TC	STOT-EL-16-40- TC	STOT-ML-20-37
Picture		Coprocurs		
Tunable Type	Electrically	Electrically	Electrically	Manually
				lunable
Size (ØxH)	10x4.0mm	30x5.8mm	40x11.9mm	37x8mm
Clear Aperture	3mm	11.6mm	16mm	20mm
Lana Tura	Plano convex to	Plano-concave to	Plano convex to	Plano convex to
Lens Type	plano concave	plano-convex	plano concave	plano concave
Focal Length Range	-77mm to +77mm	-167mm to +100mm	-500 to +333 +mm	-40 to +40mm
Refractive Index	1.300	1.45	1.300	1.38

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1. Electrically Tunable Lens STOT-EL-3-10

The compact STOT-EL-3-10 lens was designed for OEM integration into optical systems for various applications. It is extremely reliable and robust, suitable for applications in harsh environments over large temperature ranges.

Applications

- Imaging up to 1/1.8" sensors
- Biometric systems
- Optical coherence tomography (OCT)
- Laser illumination

Mechanical specifications

- Clear aperture: 3.0 mm
- Outer diameter: 10 mm (11mm on flange)
- Height: 4 +0/-0.2 mm
- Weight: 1.25 g
- Lifecycles (10-90% sinusoidal): >1'000'000'000 CL

Electrical specifications

- Control current (typical): -120 to +120 mA
- Operating voltage: -1...1 V
- Coil resistance at 30°C: 7.1 Ohm
- Power consumption (full tuning range): 0 to 100 mW (P = R_{Coil} x i²)
- Power consumption (+/- 5 dpt tuning range): 0 to 15 mW
- Settling time: 2/4 ms (Low pass filtered / normal step signal)

Optical specifications

- Focal tuning range (@20°C): -∞ to -77 mm, +77 mm to +∞
- Focal power range (@20°C): -13 to +13 dpt
- Wavelength range: 420 to 1600 nm
- Wavefront error @525nm (vertical/horizontal): <0.2/<0.2 λRMS (Tighter spec available upon request (e.g. 0.07 λRMS))
- Refractive index nD (589.3nm): 1.300
- Abbe number Vd: 100
- Optical damage threshold: >1 kW/cm2
- Operating temperature: -20 to +65 °C
- Storage temperature: -50 to +85 °C

Part Number	Tuning range	Flex	Cover	Container- and/or	Wavefront
	3	cable	glass	cover glass coating	error ⁴
STOT-EL-3-10-VIS-26D-FPC	-13 to +13 dpt	Yes	Yes	420 – 900 nm ¹	<0.2/<0.2 λ
STOT-EL-3-10-NIR-26D-FPC	-13 to +13 dpt	Yes	Yes	850 – 1600 nm ²	<0.2/<0.2 λ
STOT-EL-3-10-VIS-26D-OEM	-13 to +13 dpt	No	No	420 – 900 nm ¹	<0.2/<0.2 λ
STOT-EL-3-10-NIR-26D-OEM	-13 to +13 dpt	No	No	850 – 1600 nm ²	<0.2/<0.2 λ
STOT-EL-3-10-VIS-26D-OEM-	-13 to +13 dpt	No	Yes	420 – 900 nm ¹	<0.2/<0.2 λ
CG					

Remark:

¹ 420-900 nm T>94%

² 850-1600 nm T>94%

³ Optical power ranges of up to +/- 35 dpt are available on request

 4 Wavefront error in λ RMS @525 nm across the whole optical power range with optical axis vertical / horizontal



Mechanical drawings

STOT-EL-3-10 OEM version, without FPC cable:



STOT-EL-3-10, with FPC cable:



Mounting

Driver

The compact STOT-EL-3-10 lens can be driven with our STOT-EL-E-4 lens driver by simply connecting the flex cable of the lens to the Molex connector on the lens driver. In our software interface, the current to the lens can be adjusted to drive the lens. It's important to note that +/-120 mA are required to tune across the whole optical power range. As the lens driver can output more current, it has to be connected to the PC without the lens connected first. Then, in the "Hardware Configurations" tab, the software limit has to be set to +/-120mA. Afterwards the lens driver can be disconnected, the lens connected to the

lens driver and the lens driver connected back to the PC. The current will now only be adjustable from +/- 120mA, hence an overdriving of the lens can be prevented.

Response time

The rise time when applying a current step is <1 ms and it takes only about 4 ms until the lens has fully settled. The graphs of the step response measurements below show the optical response of the STOT-EL-3-10 lens. Low pass filtering of the drive signal to the lens allows to damp the oscillations seen in the step response graphs below and as a result drive a controlled 80% step in <2ms.



Optical power versus current

The optical power of the STOT-EL-3-10 increases with positive current and decreases with negative current as shown as follows. The specified optical power range is from +13 to -13 diopters.



2. Electrically tunable lens STOT-EL-12-30-TC

The compact STOT-EL-12-30-TC lens is designed for OEM integration into optical systems for various applications. The working principle is based on the wellestablished shape-changing lens technology. The curvature of the lens is adjusted by applying an electrical current. Thereby, the focal length is tuned to a desired value within a few milliseconds. The lens architecture is "push pull" which means that the lens curvature is deflected from concave to convex. With actuators based on proven voice-coil technology, the STOT-EL-12-30-TC focus tunable lens is extremely reliable and robust, well suited even for applications in harsh environments over large temperature ranges.



Lens specifications

Clear aperture	11.6	mm
Focal power range:	-6 to +10	dpt
(25°C, ±250 mA)		
Focal power @ 0 mA (25°C,	-1 to +2	dpt
typical)		
Transmission range	VIS: 450 to 1050	nm
Wavefront error @ 0 dpt	0.15 / 0.23	λ RMS @ 532 nm
(Optical axis vertical /		
horizontal)		
Lens type	plano-concave to plano-convex	
Refractive index / Abbe number	nD = 1.45 / v = 55	
Response time (typ. at 25°C, 0	3	ms
to ±250 mA step)		
Settling time (typ. at 25°C, 0 to	10 (with signal conditioning) 20	ms
± 250 mA step, ± 0.1 dpt)	(rectangular step)	
Lifecycles (-200mA to + 200mA,	> 1'000'000'000	
sinusoidal, 20Hz)		
Operating temperature	-20 to 65	0°
Storage temperature	-40 to 85	0°
Weight	10.5	g

Electrical specifications

Nominal control current	-250 to 250	mA
Absolute max. control current	-300 to 300	mA
Motor coil resistance @ 25°C	15	Ω
Power consumption for 5 dpt range	55	mW
(±60mA)		
Max power consumption (@ 250 mA)	940	mW
Memory	ON Semiconductor:	
	CAT24C64C4CTR (or similar)	
Temperature sensor	Maxim Integrated:	
	MAX31875R2TZS+T (or similar)	
Absolute maximum voltage (coil)	6	V
Absolute maximum voltage (memory	4	v
& sensor)		

Ordering Information

Part Number	Tuning range	Тор	Bottom Thread	Controller
		Thread		
STOT-EL-12-30-TC-VIS-16D	-6 to 10 dpt	None	None	-
STOT-12-30-TC-VIS-16D-C	-6 to 10 dpt	C-mount	C-mount female	-
		male		

STOT-EL-12-30-TC-VIS-16D-C-E		STOT-ECC-1C
		in Hirose
		adapter

All models are available with NIR coating or custom coating upon request

3. Fast electrically tunable lens STOT-EL-16-40-TC

With a clear aperture of 16 mm we presents the world's largest electrically focus tunable lens. Its design has been optimized in many ways:

- The 60% larger aperture than its predecessor, the STOT-STOT-EL-10-30, allows for 2.5x more light throughput
- The tunable lens can be shaped from a flat zero-state into a plano-concave or plano-convex lens, resulting in a focal tuning range of up to -10 to +10 diopters (at -250 to +250mA)
- The design was optimized to minimize thermal drift effects to as little as 0.02 dpt/°C and with the built in temperature sensor, an overall reproducibility of typically +/- 0.05 diopters is achievable
- Response & settling times are 5 & 25ms, respectively, which is still magnitudes faster than most mechanical alternatives
- Integration of the lens shaper inside the container allows for the highest possible positioning accuracy of the tunable lens

The STOT-EL-16-40-TC is available in its compact form for OEM integration but also with multiple thread adapters and a robust Hirose connector for industrial use, where the tunable lens can be easily combined with off-the-shelf imaging lenses.





STOT-EL-16-40-TC (OEM version)

STOT-EL-16-40-TC with thread adapters (industrial version)

The following table summarizes the main specifications of the STOT-EL-16-40-TC series:

Standard products*	Tuning range	Wavefront error**	Top thread	Bottom thread
STOT-EL-16-40-TC-VIS-5D	-500 to 333 mm -2 to 3 dpt	<0.25 / <0.5 λ	None	None
STOT-EL-16-40-TC-VIS-20D	-100 to 100 mm -10 to 10 dpt	<0.50 / <2.5 λ	None	None
STOT-EL-16-40-TC-VIS-5D- M25.5	-500 to 333 mm -2 to 3 dpt	<0.25 / <0.5 λ	M25.5x0.5 male	M40.5x0.5 female
STOT-EL-16-40-TC-VIS-5D-M27	-500 to 333 mm -2 to 3 dpt	<0.25 / <0.5 λ	M27x0.5 male	M40.5x0.5 female
STOT-EL-16-40-TC-VIS-5D- M30.5	-500 to 333 mm -2 to 3 dpt	<0.25 / <0.5 λ	M30.5x0.5 male	M40.5x0.5 female
STOT-EL-16-40-TC-VIS-5D-C	-500 to 333 mm -2 to 3 dpt	<0.25 / <0.5 λ	C-mount male	C-mount female
STOT-EL-16-40-TC-VIS-5D-M42	-500 to 333 mm -2 to 3 dpt	<0.25 / <0.5 λ	M42x1 male	M42x1 female

* All models are available with a 6-pin FPC connector. The models with thread adapters come with a 6pin Hirose connector

** Wavefront error provided in λ RMS @525nm with optical axis vertical / horizontal

Applications

Applications for Our STOT-EL-16-40-TC are among others:

Machine vision

- Microscopy
- True 3D in augmented and virtual reality
- Refraction correction in ophthalmic devices

4. Manually Tunable Lens STOT-ML-20-37

The STOT-ML-20-37 adapts itself to your specific requirements. By manually rotating an adjustment ring, the lens changes its shape from convex to flat or to concave. This unique feature allows you to choose and finely tune the focal length of the lens within -40 to +40 mm range.

Our manually focus tunable lens is the ideal choice for applications in:

- LED illumination
- Optics R&D (e.g. beam expander)
- Education
- Ophtalmology
- System prototyping

Mechanical specifications

- Optical aperture:1 20mm
- External diameter: 37mm (39 including gears)
- Thickness: 13.2 mm
- Weight: 13.7g (without adapter) / 25.2 (with adapter)
- Max torque: 80 mNm (at gear teeth)
- Full tuning angle: 337 °

Optical specifications

Lens type: from plano-convex to plano-concave Optical power tuning range (BFL): -18 to +18 Dpt Focal tuning range (BFL): -55 to infinity to +55 mm Focus resolution: Depends on motorization Optical liquid (Refractive index) @20°C: 1.38 Optical liquid (Abbe number): V 65 Transmission spectrum: See Figure 2 Wavefront error (@525 nm, 5mm CA): 0.95λ RMS (across tuning range); 0.19λ RMS (at 0 dpt) Polarization preserving

Environmental specifications

Operating temperature: 10 to 40 °C Storage temperature: -20 to +75 °C Humidity: 30-50% R.H. (non-condensing) Lifetime (#random cycles): 5 mio #

Standard product number	Turning range	AR coating	C-mount adapter
STOT-ML-20-37-VIS-36D	-18 to +18dpt	400-700nm	no
STOT-ML-20-37-VIS-36D-C	-18 to +18dpt	400-700nm	yes

Mechanical mounting

Figure 1 shows the dimensions of the STOT-ML-20-37 lens. The back-focal range is measured from the mating surface of the housing of the OEM lens. This surface lies 5.4 mm behind the outermost surface of the C-mount adapter. The ring is used to set the focal range to the desired value.





Motorization

The STOT-ML-20-37 can be motorized using either a direct drive or a worm gear. The magnet can be used for calibration purposes.

Transmission

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 2 shows the transmission spectrum for the standard broad-band VIS coating.



Optical layout

Figure 3 contains the information needed to model the STOT-ML-20-37 lens for simulation. A precise ZEMAX model can be given upon request. As the cover glass is moved up and down, the membrane deflection changes continuously.



Mounting possibilities

As depicted there exists different mechanical mounting possibilities of the C-mount version. For mounting recommendations of the version without C-mount adapter, please contact us.



Figure 4: Mounting possibilities for the STOT-ML-20-37-C. (a) STOT-ML-20-37-VIS-LD-C shown with a standard 1/2" optical post mount with M4 screw. (b) STOT-ML-20-37-VIS-LD-C mounted to a 30 mm to 60 mm Cage Plate Adapter (LCP02/M) with the help of a C-mount to SM1 adapter ring (SM1A39)

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.



5. STOT-ECC-1C embedded lens controller

STOT-ECC-1C allows to control liquid lenses directly from camera or embedded systems, thus offering a compact and convenient solution for fast integration.

Main features:

- Connects directly to cameras and embedded systems
- Current control from -300 to +300 mA in 80 µA steps
- Communication interfaces:
 - UART and I2C (autodetect)
 - Analog input (0 10V)
 - > GPIO trigger
- Read-out of calibration data & temperature for compensation ("Focal Power Mode")
- Graphic user interface for control via UART, USB to UART cable available
- Software SDKs for Python and C# available
- RoHS, REACH and CE declaration of conformity

Mechanical specifications

Dimensions (L x W x H)	27 x 20 x 5	mm
Weight	5	g
Connector	Hirose HR10G-7R-6SB (73)	
Max. USB cable length extension ¹	5	m
Max. lens cable length (USB to UART) ²	1	m

Electrical specifications

Supply voltage range	5 / 9-24 (tolerance ± 5%) Two input	VDC
	voltage ranges (no operating window	
	in between)	
Absolute maximum supply voltage	26	VDC
Nominal control current ³	-300 to 300	mA
Current step	80	μA
Current repeatability	± 1	mA
Maximum power consumption (5V / 9-	1.5 / 2.5	W
24V)		
Analog voltage inputs level	0-10	V
Absolute maximum analog voltage input	11	V
Analog input resolution	12	Bits
Analog input impedance	>70	ΚΩ
Digital interfaces	GPIO, UART, I2C	
Digital signal logic level	3.3	V
UART Simple mode command latency ⁴	310	μs
I2C command latency ⁵	max. 100	μs

1.Maximum tested cable length in lab conditions, actual performance may depend on electromagnetic environment. Longer lengths are possible using active USB cables.

2. Maximum tested cable length in lab conditions. Maximum cable length may depend on electromagnetic environment. Higher cable lengths should comprehend lower baud rates.

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3.Input voltages and thermal limitations apply, see Figure 4, 5, 6 and 7.

4.Average delay between end of command on UART RX line and output change using simple mode commands in Terminal app. Generally, the whole configuration time varies with command length, speed of communication and its mode, infrastructure, control host, operating system, programing language etc. This delay time variation also applies for protocol mode commands.

5. Analogically defined delay but using I2C communication bus. It corresponds also to latency of GPIO input trigger by both rising and falling edge.

Thermal specifications

Operating temperature	0 to 65	C
Storage temperature	-40 to 85	C



The STOT-ECC-1C can be part of STOT-EL-16-40 lenses or ELMs (electrical lens modules) or ordered separately.

Currently two cable options are provided.

Part number	Description
150-347-00	Hirose adapter kit with STOT-ECC-1C
150-349-00	USB to UART cable, Hirose connector, 1m
152-219-00	CAB-6-100-M-OE (Hirose to open-ended wire cable, 1m)
149-740-01	STOT-EL-16-40-TC-VIS-5D-C-E (Typical STOT-EL-16-40 lens with STOT-
	ECC-1C integrated)

6. STOT-ICC-1C Industrial Current Controller -1 Channel

Main features:

- Industrial current controller with robust casing and a DIN rail adapter
- 1 channel output for driving tunable lens (current up to +/-500 mÅ)
- High output current stability in the whole temperature range
- Communication and other interfaces:
- Power supply options:
 - > USB, I2C, UART, Ethernet with PoE+ capability
 - ➢ Analog input (0 − 10 V)
 - Trigger Input/Output signals
 - > 2x Status LEDs (Red/Green/Orange)
 - Power supply options:
 - Barrel connector
 - PoE (RJ-45 connector)
 - USB-C Power Delivery
- Graphical user interface for control via USB, UART¹ or Ethernet
- Software SDKs for Python and C# are available
- RoHS, REACH and CE certified

Mechanical specifications

Dimensions (L x W x H)	64 x 105 x 28.7	mm
Weight	240	g
USB Connector	USB-C	-
Max. USB cable length ²	2	m
Max. lens cable length (Hirose) ³	5	m
Accepted DC Barrel Plug	2.1 I.D. x 5.5 O.D. x 10.0	mm
Output connector	Hirose HR10G-7R-6SB (73)	
Auxiliary output connector	Standard rectangular header, 100"	10 pins
	(2.54mm) pitch	
I/O connector	Standard rectangular header, 100"	14 pins
	(2.54mm) pitch	
Mounting	T-slots for standard M4 nut	

Thermal specifications

Operating temperature	0 to 45 (+/- 500 mA)	°C
	0 to 65 (+/- 300 mA)	
Storage temperature	-40 to 85	C°

Electrical specifications

Supply voltage range typical	5 to 48	VDC
Supply voltage range absolute limits	4.75 to 57	VDC
PoE specification	PoE (802.3af or higher)	
USB-C power delivery requirement	15	W
(min)		
Total power consumption (max)	15	W



1. The software supports UART which is available on the I/O connector. A compatible CP210X USB to UART Bridge must be used.

2. Maximum tested cable length in lab conditions, actual performance may depend on electromagnetic environment. Longer lengths are possible using active USB cables.

3. Maximum tested cable length in lab conditions. Maximum cable length may depend on electromagnetic environment.

Driver outputs

Maximum output current	±500	mA
Minimum output current step	65	μA
Resolution	14	bits
Output current thermal stability	0.5	mA
Front-end voltage ⁴ (configurable)	6 – 15 (factory default = 12	V
Output voltage limit	6 – 15	V
Output stage topology	Full bridge, filtered PWM (load not grounded)	
Digital communication with lens	Dedicated I2C bus, 400kHz max	
I2C logic level (pullups implemented)	3.3	V
Power supply for I2C (output channel)	3.3	V
Power for logics, max. current	typ. 100	mA
Status LED (main + output channel)	Red, Green, Orange LED	

4 The front-end voltage supplies the output stage. The output voltage is slightly lower than the front-end voltage.

Driver inputs

Analog input leve	0 – 10	V
Analog input resolution	16	Bits
Analog input BW	10	kHz
Digital inputs	GPIO, I2C, UART	
Digital inputs logic level	3.3 (NOT 5 V tolerant)	V

Ordering Information

Part number	Description
STOT-ICC-1C	STOT-ICC-1C Controller with a DIN rail adapter
STOT-ICC-1C Controller Kit	The Controller Kit contains:
	STOT-ICC-1C
	DIN rail adapter
	 STOT-ICC-1C Extension Board for lenses with FPC flex
	cable
	 AC/DC Power supply to 24V/1A
	 USB-A to USB-C cable, 1 m
STOT-ICC-1C PCBA Controller	STOT-ICC-1C PCB only (OEM) version