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Dual-axis fast steering mirror with position feedback MR-15-30

Optotune's dual axis fast steering mirror series MR-15-30 is the ideal choice for applications that require large deflections in a compact form factor. The MR-15-30 has a mirror size of 15 mm and housing diameter of only 30 mm. It achieves up to ±25° mechanical tilt, corresponding to a 100° optical field of view (FOV). The mirror includes a position feedback system which allows it to be accurately controlled with a standard PID controller.

The actuator is based on proven technologies. In contrast to galvo mirror systems, the virtual rotation point is very close to the mirror surface. The mirror can be fabricated with various coatings such as protected gold or protected silver.

Advantages

- Large scan angle
- Compact
- Precise
- Reliable

Applications

- Automotive (LiDAR, dynamic headlights, ADAS)
- Vision (FOV expansion, zoom)
- Biometric (eye-tracking) and diagnostic equipment
- 3D printing

Mechanical specifications[1]

Actuator type	voice coil	
Mechanical tilt angle	X-axis: ±25 Y-axis: ±25	° circular FOV
Mirror diameter	15.0	mm
Center of rotation to mirror surface	1.3	mm
Housing diameter	30.0	mm
Height	14.5	mm
Weight	29.3	g
Mechanical clamping	4x M2 screws	
Magnetic shielding	yes	

Performance specifications

Zero drift (typical)	100	µrad/K RMS value over entire FOV
Sensor resolution (with 14-bit ADC)	22	µrad
Repeatability	40	µrad RMS value over entire FOV at room temperature

[1] All angle values refer to mechanical angles.

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Calibration accuracy	0.25 4.4	° mrad RMS value over entire FOV[2]
Static motor constant	3	rad/A linearized full range
Dynamic motor constant	$1.4 \cdot 10^4$	krad/(As^2) linearized full range
Resonance frequency	X-axis: 11-13 Y-axis: 15-18	Hz
Full-scale bandwidth (sine wave ± 25°)	20	Hz
Small-signal bandwidth (sine wave ± 0.1°)	350	Hz
Large angle step settling time (20° step)[3]	typ. 13	ms
Small angle step settling time (0.12° step)[3]	typ. 3	ms

Optical specifications

Surface finish	Protected gold, protected silver, dielectric VIS, custom	
Reflectivity Protected gold Protected silver Dielectric VIS	Average >95% (800 nm < λ < 2 µm) >96% (450 nm < λ < 2 µm) >97% (450 nm < λ < 650 nm)	 45° AOI 45° AOI 45° ± 25° AOI
Surface quality	5/ 5x0.4; L1x0.06; C3x0.25; E 0.25	60-40 scratch-dig (ISO 10110)
Mirror flatness	λ/2	P-V @549nm (ISO 10110)

Electrical specifications

Control interface	Analog interface for driver coils and for feedback readout	
Max. continuous current (RMS)	Single axis: 0.37 Both axes: 0.26	A, per coil
Peak current (10 ms duration)	2	A
Max. mean actuation power	1.5	W both coils together
Coil resistance (typical)	11	Ω
Coil inductivity (typical)	6	mH
Position sensor supply current (@1.5 V)	40	mA
Position sensor output current (typical)	0.1	mA
Temperature sensor	NXP LM75B or equivalent	I2C-address: 0x48 (+R/W bit)
EEPROM[4]	M24C08 or equivalent	I2C-addresses: 0x50 to 0x53 (+R/W bit)

Environmental specifications

Operating temperature[5]	-20 to +85	°C
Storage temperature[5]	-40 to +85	°C
Mechanical shock	105 *g*, 15 ms	ISO 9022-3-30-07-1
Vibration	2.6 *g*, 20-150 Hz	ISO 9022-3-37-02-0
Cycle life	$>2 \cdot 10^9$	cycles

[2] Evaluated from 50 calibration points. The factory calibration may degrade to 0.5° (typically 0.3°) long-term.

[3] Measured with the MR-E-2 Mirror Controller with 700 mA peak current.

[4] EEPROM content definition is available upon request.

[5] For larger temperature ranges, please contact Optotune.

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Overview of available standard products

Standard Product	Coating	Typical wavelength range
MR-15-30-G-25x25D	Protected gold	800 nm - 2 µm
MR-15-30-PS-25x25D	Protected silver[6]	400 nm - 2 µm (low humidity)
MR-15-30-DVIS-25x25D	Dielectric VIS	450 nm - 650 nm

Control

The MR-15-30 can be driven using Optotune's MR-E-2 Mirror Controller. For optimal performance, we recommend operating the mirror in closed loop. Optotune offers a development kit, consisting of a mirror head with an integrated heat sink, an MR-E-2 Mirror Controller, and the necessary accessories. The kit is well-suited for plug-and-play evaluation of the devices. The complete development kit is additionally offered in an OEM version without housing to facilitate integration into OEM equipment. For either development kit version, software is provided (Optotune Cockpit, C# SDK, Python SDK).

For details on the controller and development kits, please refer to our website.

[6] DISCLAIMER: Despite the protective coating layer, it is best to avoid exposing silver mirrors to high humidity environments due to the associated tarnishing risk. For applications in the visible spectrum, we strongly recommend the dielectric coating. Optotune declines the warranty due to humidity induced corrosion of the mirror coating.

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Mechanical layout

The mechanical layout of the MR-15-30 is shown in Figure 1. In terms of lateral alignment, we recommend using the outer diameter of the housing as an alignment feature rather than the M2 screw holes of the housing. When mounted, the mirror backside needs to be in firm contact with a heat sink.

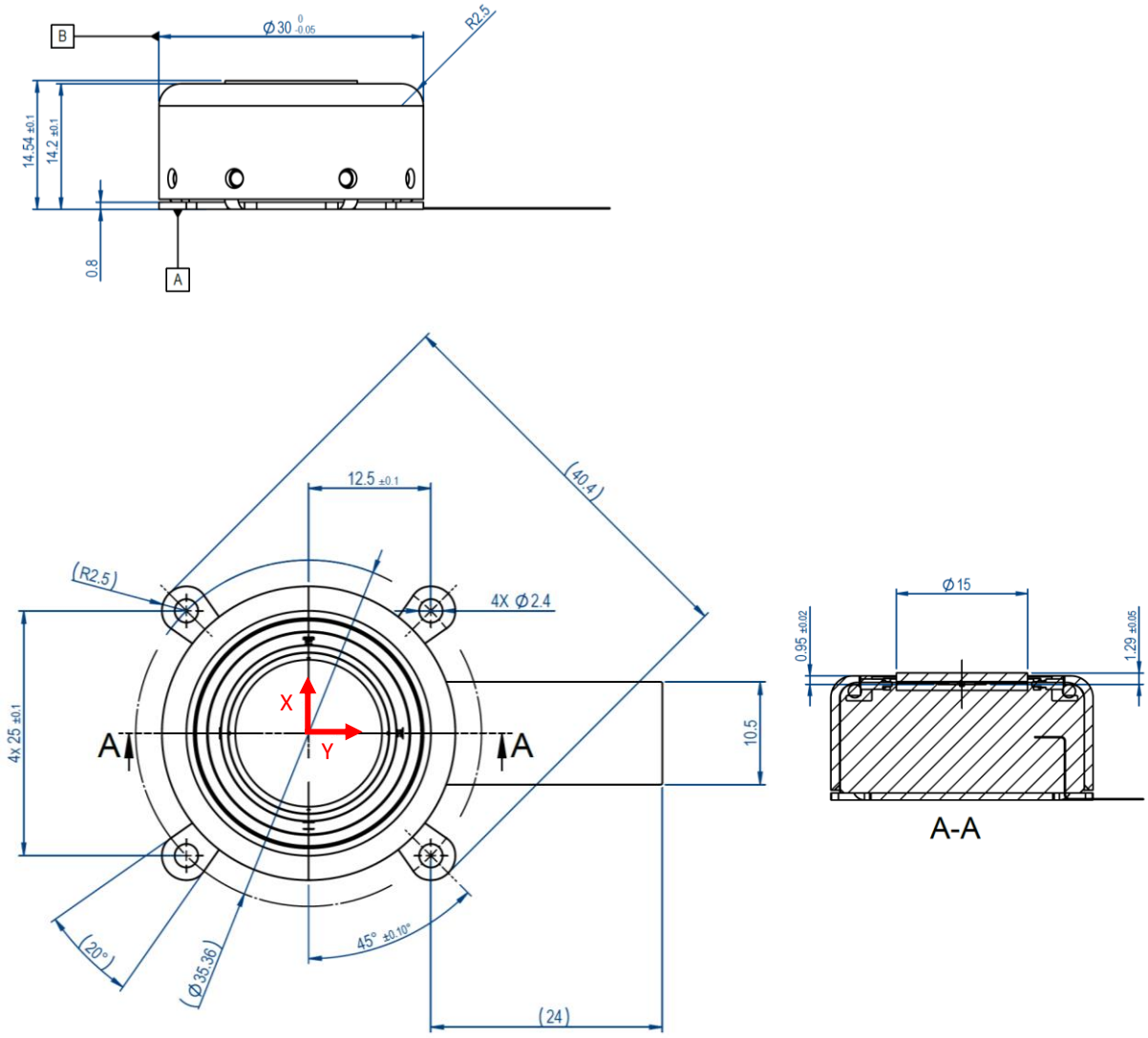

Figure 1: Mechanical drawing of the MR-15-30 (unit: mm). The red arrows show the definition of the mirror axes.

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Beam clipping

Beam clipping may occur depending on the beam diameter, beam incident angle, and deflection of the mirror. See Figure 2. For a beam incident at 0°, beam diameters of up to 10 mm can be used without clipping across the full FOV achievable with the mirror. An Excel-based calculation tool to evaluate beam clipping can be provided upon request.

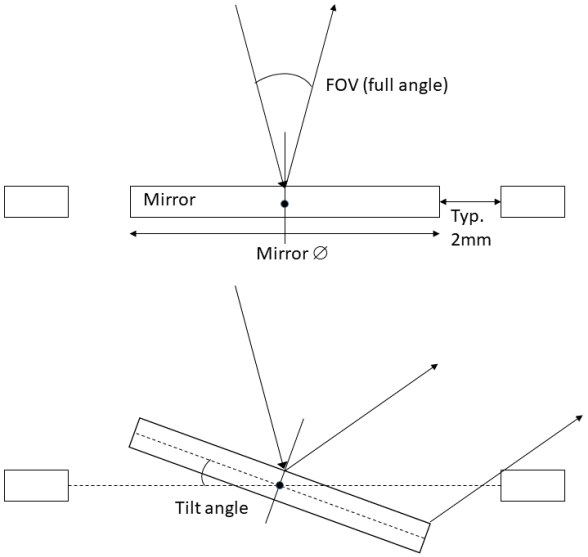

Figure 2: The maximum allowed beam diameter that can be used with the MR-15-30 without clipping the beam depends on incident angle of the beam and the mirror tilt angle.

Custom products

Optotune offers customization of mirror substrates and coatings upon request. The standard substrate is 1 mm thick and 15 mm in diameter (Figure 3). Thicker substrates need to have a smaller diameter to maintain the full FOV of the mirror. For a substrate diameter of 12.7 mm, the thickness can be as large as 3.5 mm. Note that a custom mirror substrate might lead to a change in inertia and influence the mirror dynamics.

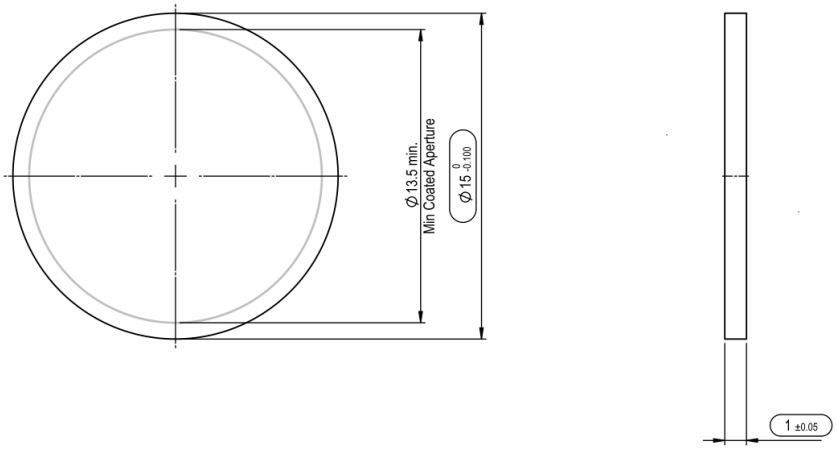

Figure 3: MR-15-30 mirror substrate dimensions.

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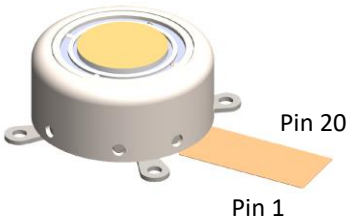
Electrical layout

The electrical connection of the MR-15-30 is a 0.5 mm pitch, 20-pin FPC cable. The pinout is shown in Figure 4.



Pinout: MR-15-30		
Position	**Function**	**Value**
1	LED cathode supply	40 mA, 1.5 V
2	LED anode supply	
3	Y coil +	±1 A, ±15 V
4	Y coil +	
5	Y coil -	
6	Y coil -	
7	X coil +	
8	X coil +	
9	X coil -	
10	X coil -	
11	VDD	3.3 V
12	SCL	digital 3.3 V
13	SDA	digital 3.3 V
14	GND	-
15	Position feedback anode	analog 0-200 µA
16	Position feedback Y2 cathode	
17	Position feedback Y1 cathode	
18	Position feedback X2 cathode	
19	Position feedback X1 cathode	
20	Position feedback anode	

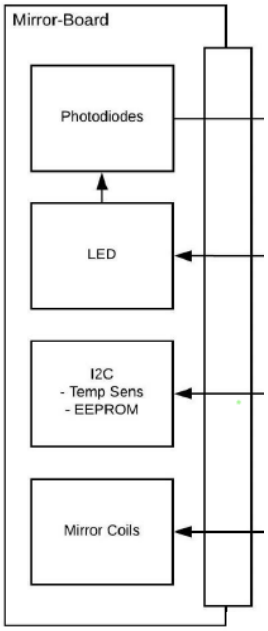


Figure 4: Pin assignment and block diagram of the MR-15-30.

Thermal management

- Heat is generated as a function of actuation current and conducted away through the backside of the MR-15-30. The mirror needs to be firmly mounted on a metallic (copper or aluminium) heat-conductive plate.
- The maximum dissipated power at the maximum static deflection is 0.25 W/channel (0.5 W total).
- For fast oscillations with high duty cycle, the total dissipated power for both axes is 4-5 W.
- A safety interlock interrupts the mirror operation when it reaches its maximal operating temperature of 85°C.

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Reflectivity

The reflectivity of the MR-15-30 standard coatings for an angle of incidence (AOI) of 45° is shown in Figure 5.

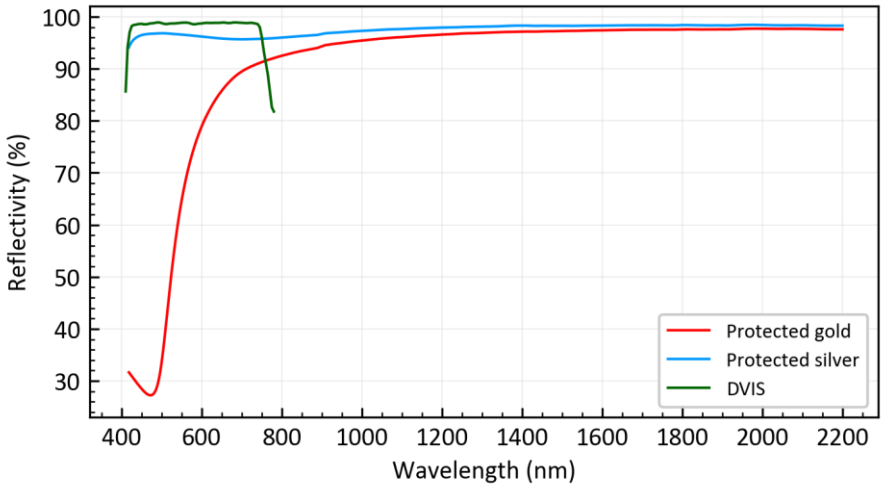

Figure 5: Reflectivity of the MR-15-30 standard coatings.

Maximum frequency

The maximum recommended RMS current per coil on the MR-15-30 when actuating one axis is 0.37 A (corresponding to 0.52 A peak current for a sine wave). Higher currents can be used, but only for short durations before overheating the mirror.

The maximum achievable oscillation frequency of the MR-15-30 as a function of deflection angle is shown in Figure 6. Note that data for actuation of a single axis is shown. When operating both axes simultaneously, the RMS limit is 0.26 A (0.37 peak for a sine wave). The maximum mean actuation power should not exceed 1.5 W.

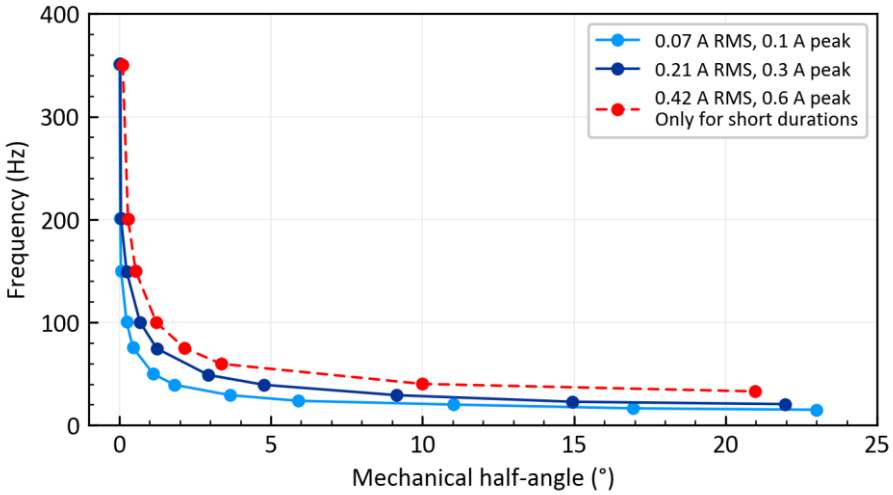

Figure 6: Maximum oscillation speed (sinusoidal) of the X axis as a function of the mechanical half-angle and driving current. RMS currents above 0.37 A can only be used for short durations.

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Static response

The static deflection of the MR-15-30 as a function of applied current and power is shown in Figure 7. Note that because of hysteresis arising due to friction and magnetic remanence, the deflection of the mirror will depend on its previous positions. In closed-loop operation, the hysteresis is compensated for via the mirror calibration.

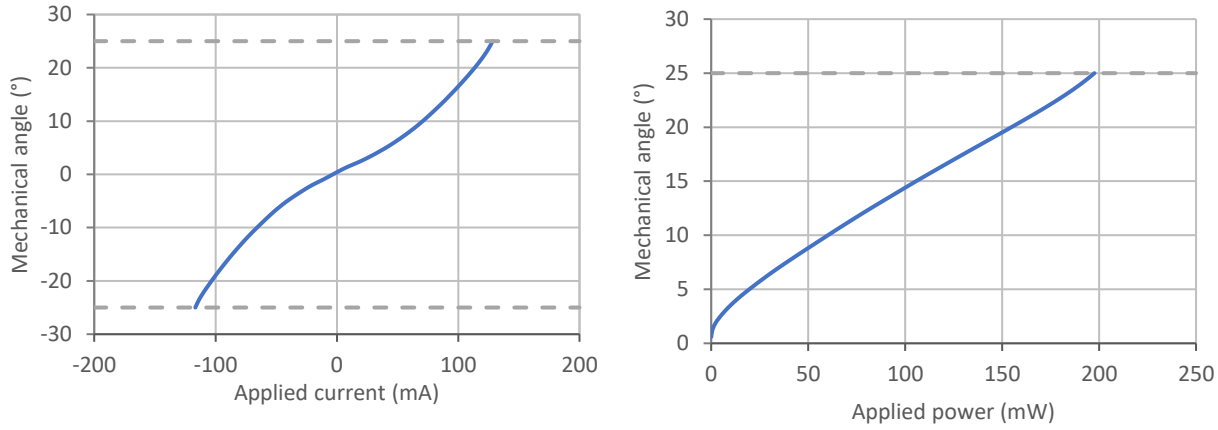

Figure 7: (Left) Mechanical angle versus applied current for a single axis.
(Right) Mechanical angle versus applied power. The slope corresponds to ~8.6 mW/°.

Frequency response

The frequency response of the MR-15-30 under sinusoidal excitation with 15 mA peak current is shown in Figure 8. The resonance frequency of the X-axis typically lies between 11 and 13 Hz; the resonance frequency of the Y-axis between 15 and 18 Hz.

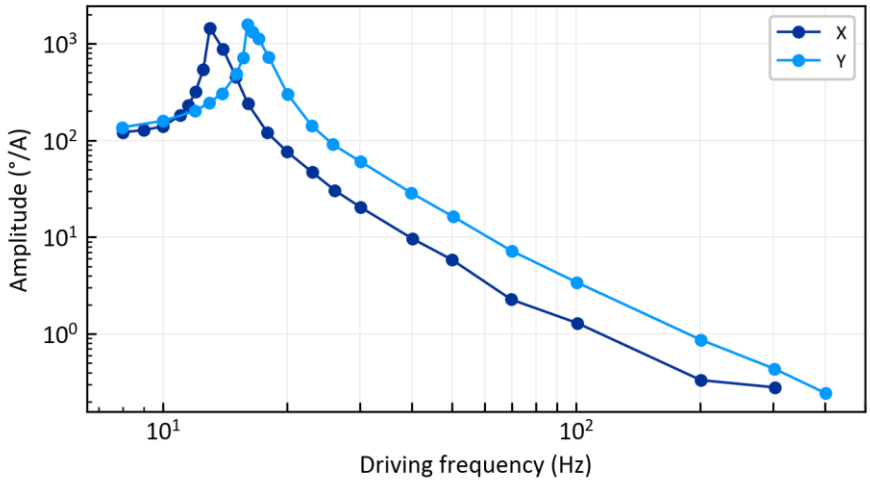

Figure 8: Magnitude response of the two axes of the MR-15-30 with sinusoidal excitation, 15 mA peak current.

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Step response

A small (0.12°) and large (20°) step response for the MR-15-30 when operated with the MR-E-2 Mirror Controller is shown in Figure 9 and Figure 10, respectively. All angles refer to mechanical angles.

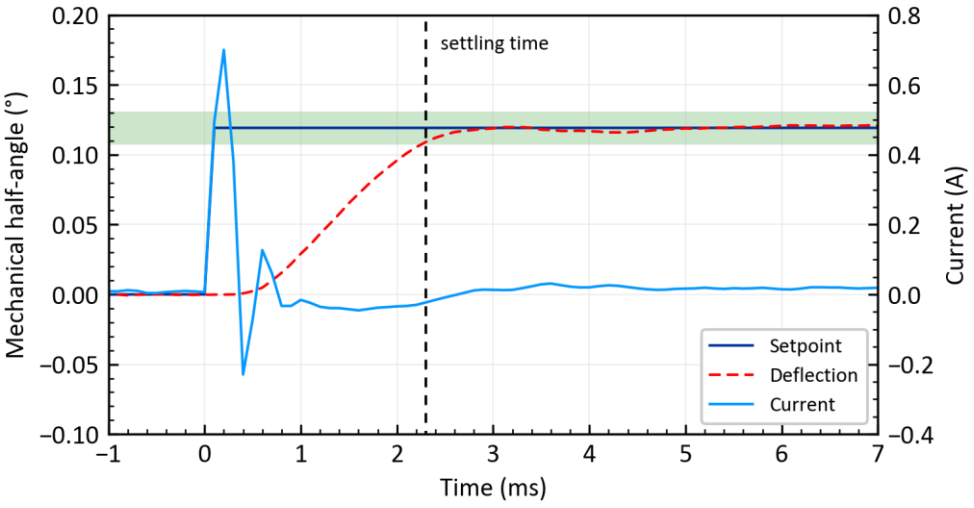

Figure 9: Small step settling of the X axis for a 0.12° step. The settling time to within ±5% of the step (green shaded area) is 2.3 ms.

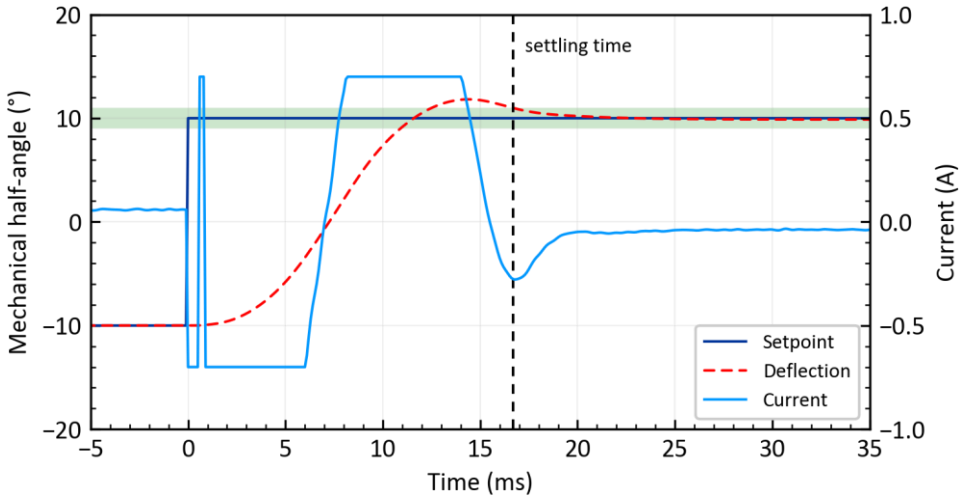

Figure 10: Large step settling time of the X axis for a 20° step. The settling time to within ±5% of the step (green shaded area) is 16.7 ms.

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Environmental testing

The MR-15-30 has passed the following reliability tests:

Test	Test procedure	Remark
Mechanical cycling	5-point star pattern, 5 Hz, room temperature, controlled by MR-E-2	2 billion cycles reached with no signs of fatigue
Accelerated gimbal test	8000 rpm	800 million full rotations reached without significant degradation
Temperature cycling	-40°C to 70°C, 1 K/min, 50 hours	ISO 9022-2-14-06-1
Temperature shock	-40 to 55 °C, 2.5 h/cycle, <20 s transition time, 5 cycles	ISO 9022-15-03-1
Dry heat	85°C, 45% relative humidity, 1 week	ISO 9022-2-11-06-1
Mechanical shock	15 ms deceleration, 9 shocks per axis, up to 105 g	ISO 9022-3-30-07-1
Free fall in blister package	1 m, 3 axes, 2 drops per axis	ISO 9022-3-33-6-0
Vibration (sine)	10-150 Hz sweep, 1 oct/min, 2 h per orientation	ISO 9022-3-33-6-0
Vibration (random)	20-150 Hz, 2.6 g rms, 10 min per orientation	ISO 9022-3-37-02-0

Packaging

Single MR-15-30 units ship in cardboard boxes. Larger volumes ship in ESD-safe and stackable PET trays of 25 MR-15-30 units each (Figure 11), sealed in a vacuum bag.

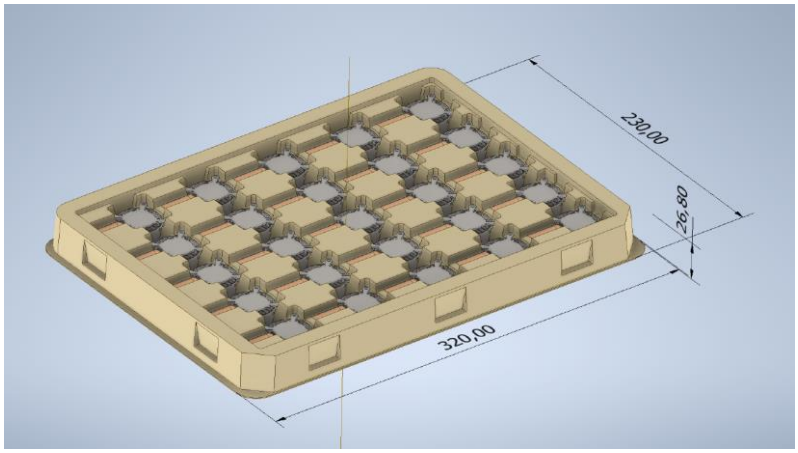

Figure 11: MR-15-30 tray design.

Safety and compliance

The product fulfills the RoHS, REACH, CE and flammability UV94 V-0 compliance standards. The customer is solely responsible for complying with all relevant safety regulations for integration and operation, including EMC compliance.

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

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