6-Axis Miniature Hexapod

COMPACT AND HIGHLY PRECISE

EtherCAT® Option

EtherCAT® is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

H-811

- Smallest Hexapod with vacuum option
- Travel ranges to 34 mm / 42°
- Load capacity to 5 kg
- Actuator resolution 40 nm
- Min. incremental motion to 0.2 µm
- Repeatability to ±0.1 µm
- Includes integrated scan algorithms for fiber optic alignment

making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction. Vacuum-compatible version to 10^{-6} hPa available

Direct drive with brushless DC motors (BLDC) and long-life ball screws

High precision, velocity and lifetime

Powerful digital controller, open software architecture

User-defined, stable pivot point, software-selectable. Positions commanded in Cartesian coordinates. Macro programming. Open source LabVIEW driver set. Work space simulation software. Virtual Hexapod machine software. Optional: Collision avoidance software (external obstacles).

H-811.xx1 includes C-887.11, 6D vector motion controller plus 2 additional servo axes. Options:

- Analog interfaces/photometer cards for visible light (F-206.VVU) or the infrared light range (F-206.iiU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

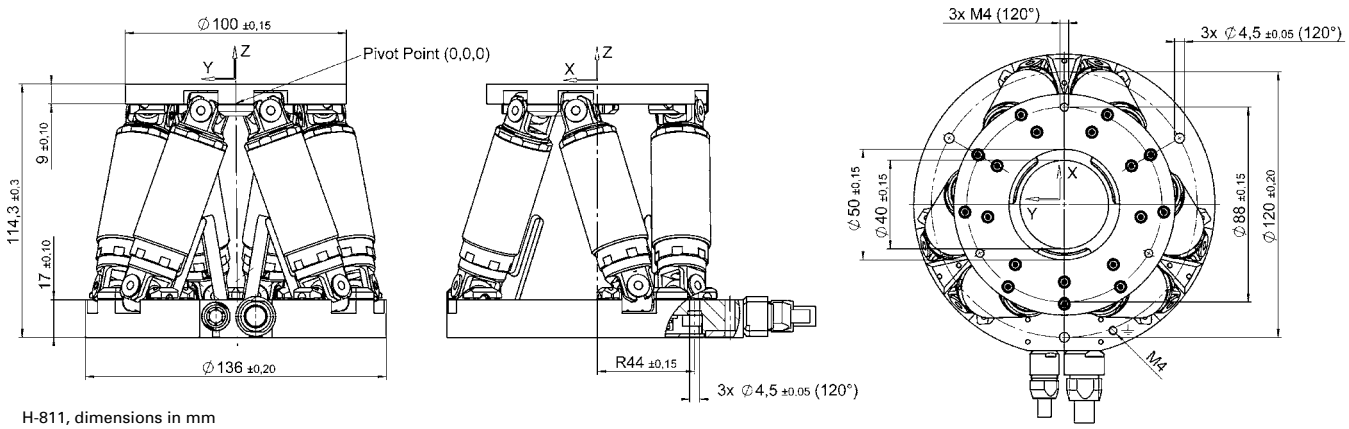
H-811.xx2 includes C-887.21 compact 6D vector motion controller

Fields of application

Research and industry, standard and vacuum environments. For micromanipulation, laser and optics alignment, biotechnology, tool control

	H-811.D1x	Unit	Tolerance
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Motion and positioning			
Travel range* X, Y, Z	±17, ±16, ±6.5	mm	
Travel range* θ_X, θ_Y, θ_Z	±10, ±10, ±21	°	
Single-actuator design resolution	40	nm	
Min. incremental motion X, Y	0.5	µm	typ.
Min. incremental motion Z	0.2	µm	typ.
Min. incremental motion θ_X, θ_Y, θ_Z	3.5	µrad	typ.
Backlash X, Y	1	µm	typ.
Backlash Z	0.2	µm	typ.
Backlash θ_X, θ_Y	10	µrad	typ.
Backlash θ_Z	15	µrad	typ.
Repeatability X, Y	±0.3	µm	typ.
Repeatability Z	±0.1	µm	typ.
Repeatability θ_X, θ_Y	±4	µrad	typ.
Repeatability θ_Z	±8	µrad	typ.
Max. velocity X, Y, Z	10	mm/s	
Max. velocity θ_X, θ_Y, θ_Z	250	mrad/s	
Typ. velocity X, Y, Z	5	mm/s	
Typ. velocity θ_X, θ_Y, θ_Z	120	mrad/s	
Mechanical properties			
Stiffness X, Y	0.2	N/µm	
Stiffness Z	3.6	N/µm	
Load (base plate horizontal / any orientation)	5 / 2.5	kg	max.
Holding force, de-energized (base plate horizontal / any orientation)	15 / 2.5	N	max.
Motor type	Brushless DC motor		
Miscellaneous			
Operating temperature range	0 to 50	°C	
Material	Stainless steel, aluminum		
Mass	2.2	kg	±5%
Cable length	2	m	±10 mm

Vacuum versions to 10^{-6} hPa are available under the following ordering number: H-811.DVx. Specifications for vacuum versions can differ.
Technical data specified at 20±3°C.
Ask about custom designs!
* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.



H-811, dimensions in mm

Hexapod Control with EtherCAT

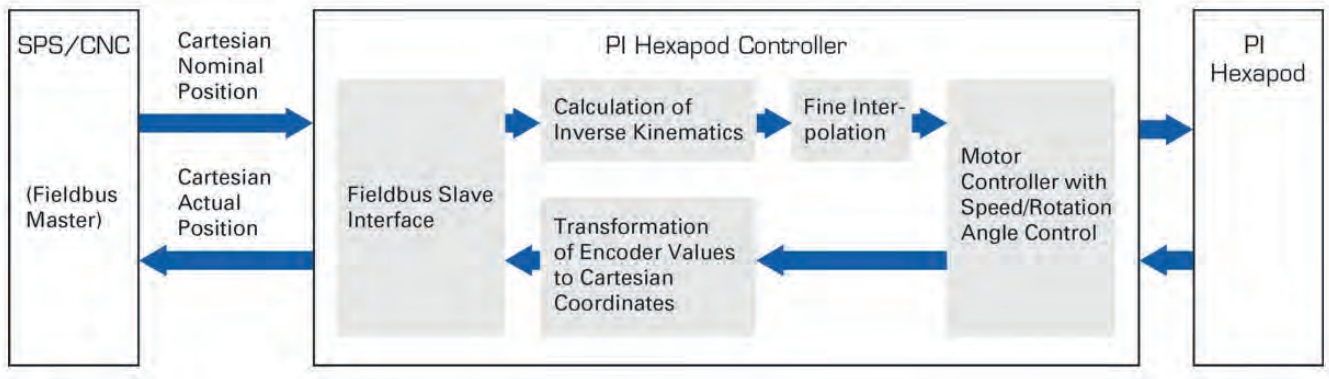
MOTION CONTROLLER WITH AUTOMATION INTERFACE FOR SIX-AXIS POSITIONING SYSTEMS

The positioning system consists of the C-887.311 controller with EtherCAT interface and a Hexapod, in this case H-811. For commanding with PLC, the system acts like an intelligent six-axis drive

C-887.311

- Synchronous clock for entire automation line
- Synchronous motion in six axes
- Cycle time 3 ms

EtherCAT®



Digital controller with EtherCAT fieldbus interface

Real-time system. Master PLC control for commanding positions and feedback in Cartesian coordinates. Coordinate transformation. Integrated amplifiers for six axes with DC motors

Supported operating modes

Reference move of the Hexapod to the mid-position of all six axes. Absolute positioning in six Cartesian axes. Cyclic position commanding via PLC for synchronization with further automation components. Stand-alone operation possible with PI GCS commands

Fields of application

Integration of Hexapod six-axis positioning systems in automated processes. On request: Control via additional interfaces, i.e. Profinet, Profibus, CANopen, SERCOS III

Stand-alone operation

All functions for commanding with PI GCS are integrated in the digital controller: Vectorized motions. Stable, virtual pivot point can be defined freely in the work space. Data recorder for recording operating parameters such as motor control, velocity, position or position errors. Macro command language. Stand-alone operation possible with Autostart macro, connection of keyboard and monitor, or optionally via manual Hexapod control unit

Scope of delivery

The six-axis Hexapod system from PI contains the Hexapod mechanics, the digital controller with EtherCAT interface and all connecting cables. Power source (24 V / 5 A) for axes and controller (DC ATX 150W, 10-30 V DC) provided by customer

	C-887.311
Fieldbus protocol	EtherCAT (CoE = CANopen over EtherCAT)
Drive profile	CiA402 Drive Profile (IEC 61800-7-201)
Number of axes/device type	Multiple axis device with 6 Cartesian individual axes
Cycle time	3 ms
Supported modes of operation	Homing mode, profile position mode with linear interpolation in the drive, cyclic synchronous position mode via PLC
Supported modes of synchronization	Distributed Clock (DC) mode SyncManager (SM) mode
Bus connector	RJ45 socket
Dimensions	182 mm × 248 mm × 185 mm

All information preliminary.

6-Axis Motion Hexapod

HIGH DYNAMICS APPLICATIONS

H-811.S11

- Travel ranges to 34 mm / 42°
- Velocity to 25 mm/s
- Dynamics to 25 Hz over 0.1° travel range
- Integrated wave generator
- Developed for test stations for image stabilization

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction. Vacuum-compatible version to 10^{-6} hPa available

Direct drive with brushless DC motors (BLDC) and long-life ball screws

High precision, velocity and lifetime

H-811.S11 incl. 6D controller for Hexapods, plus two additional servo axes

- Digital I/O interfaces for trigger signal emission
- Precise running of predefined motion profiles with high path accuracy

Powerful digital controller, open software architecture

User-defined, stable pivot point, software-selectable. Positions commanded in Cartesian coordinates. Macro programming. Open source LabVIEW driver set. Work space simulation software. Virtual Hexapod machine software. Optional: Collision avoidance software (external obstacles).

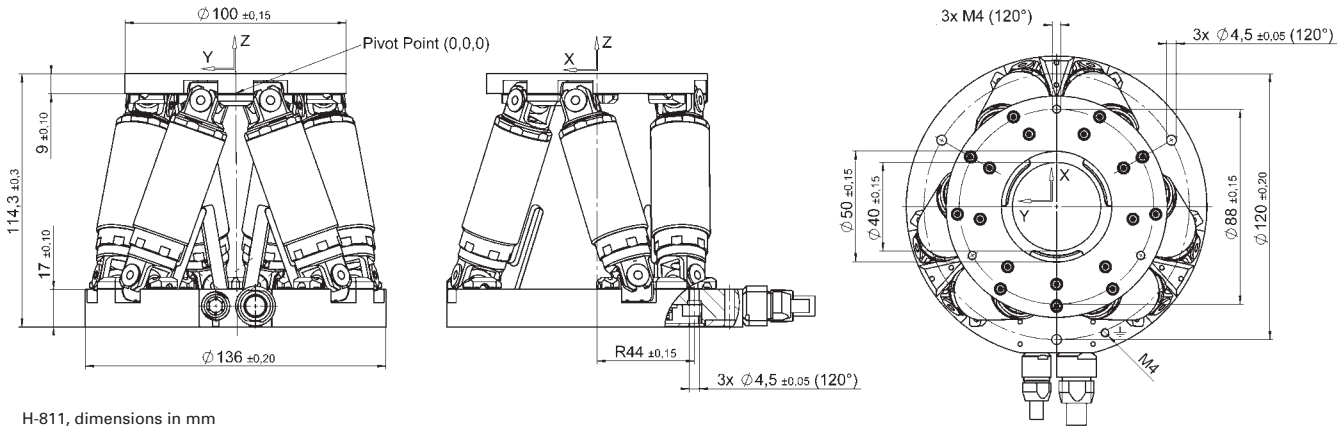
Fields of application

Research and industry, test systems, e.g. for image stabilization in cameras and mobile devices

Preliminary data	H-811.S11	Unit	Tolerance
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Motion and positioning			
Travel range* X, Y, Z	±17, ±16, ±6.5	mm	
Travel range* θ_X, θ_Y, θ_Z	±10, ±10, ±21	°	
Single-actuator design resolution	80	nm	
Min. incremental motion X, Y	2	µm	typ.
Min. incremental motion Z	1	µm	typ.
Min. incremental motion θ_X, θ_Y, θ_Z	12	µrad	typ.
Repeatability X, Y	±0.5	µm	typ.
Repeatability Z	±0.2	µm	typ.
Repeatability θ_X,θ_Y	±8	µrad	typ.
Repeatability θ_Z	±15	µrad	typ.
Velocity X, Y, Z	25	mm/s	max.
Velocity θ_X, θ_Y, θ_Z	325	mrad/s	max.
Velocity X, Y, Z	10	mm/s	typ.
Velocity θ_X, θ_Y, θ_Z	250	mrad/s	typ.
Mechanical properties			
Stiffness X, Y	0.2	N/µm	
Stiffness Z	3.6	N/µm	
Load (base plate horizontal / any orientation)	1.5 / 0.3	kg	max.
Holding force, de-energized (base plate horizontal / any orientation)	15 / 2.5	N	max.
Motor type	Brushless DC Motor		
Miscellaneous			
Operating temperature range	0 to 50	°C	
Material	Stainless steel, aluminum		
Mass	2.2	kg	±5 %
Cable length	2	m	±10 mm

Technical data specified at 20 ±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.



H-811, dimensions in mm

Controller for Hexapod Positioning Systems

6-D VECTOR MOTION CONTROL, COMPREHENSIVE FUNCTIONALITY

C-887

- Sophisticated controller using vector algorithms
- Freely programmable, virtual pivot point
- Data recorder
- Macro program functionality
- Stand-alone operation possible and control through TCP/IP and RS-232 interfaces
- Extensive software support

Digital controller for 6-axis-parallel kinematics

Included in the delivery of all PI standard Hexapod systems

- C-887.11, 19" controller, comprises the control for two additional single axes with servo motors, the functionality can be enhanced with many additional options
- C-887.21 compact bench-top controller for a lower system price

Extensive software support

Functions

Real-time system. Position control using Cartesian coordinates, vectorized motion. Stable, virtual pivot point can be defined freely in the working space. Data recorder for recording operating parameters such as motor control, velocity, position or position error. Macro command language. Stand-alone operation possible with Autostart macro or connection of keyboard and monitor. Optional: Manual control unit

Custom designs

Custom designs are available for use at high altitudes, e.g. for astronomical telescope applications. Processing of absolute sensors. Control of motor brakes. Processing of additional (redundant) position sensors for increased safety requirements, e.g. in medical technology

Software

PIMikroMove user software. Common command set for all PI positioning systems. Shared libraries for Windows and Linux. Complete set of LabVIEW VI's. Graphical user interfaces, configuration software and graphically displayed scan routine.
Optional: PIVeriMove software for checking a restricted operating space

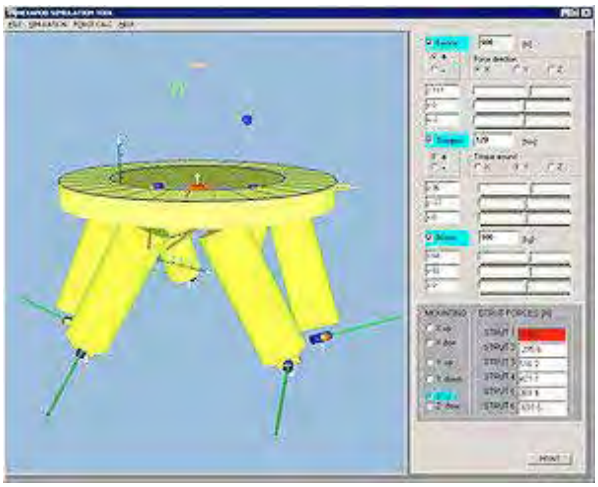
Interfaces

TCP/IP Ethernet can also be used for remote control and service, RS-232. Monitor, mouse and keyboard interface. On request: RS-422 for up to 1.4 km cable length

Possible enhancements for C-887.11

- Analog interfaces/photometer cards for visible light (F-206.VVU) or the infrared light range (F-206.iiU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

	C-887.11	C-887.21
Function	6-D controller for Hexapods, 19“, incl. control of two additional single axes, can be enhanced with many options	6-D controller for Hexapods, compact bench-top for a lower system price
Drive type	Servo motors (Hexapod and additional axes) Optional: Piezo drives	Servo motors
Motion and control		
Servo characteristics	32-bit PID filter	
Trajectory profile modes	Trapezoid, linear interpolation	
Processor	CPU: 1.8 GHz, motion control chip with 2.5 kHz servo update rate	
Encoder input	AB (quadrature) differential TTL signal, 5 MHz	
Stall detection	Servo off, triggered by position error	
Reference point switch	TTL signal	
Electrical properties		
Max. output power per channel	10-bit output for PWM drivers, 24 kHz	
Max. output voltage per channel	TTL in PWM operation for SIGN and MAGN	
Interface and operation		
Communication interfaces	TCP/IP, RS-232 VGA (monitor), USB (keyboard, mouse, manual control unit)	
Hexapod connection	MDR, 68-pin for data transmission M12 4-pin. for power supply	
Connection for additional single axes	15-pin sub-D	–
I/O ports	Optional: Analog inputs (photometer cards)	–
Command set	PI General Command Set (GCS)	
User software	PIMikroMove	
Software drivers	LabVIEW driver, shared libraries for Windows and Linux	
Manual control	Optional: C-887.MC control unit for Hexapods	
Miscellaneous		
Operating voltage	100 to 240 VAC, 50 / 60 Hz	
Operating temperature range	5 to 40°C	
Mass	11 kg	5 kg
Dimensions	395 × 483 × 185 mm	255 × 226 × 185 mm



All PI Hexapod systems are delivered with an extensive software package. Included are simulation programs that calculate the working space of the Hexapod and the individual loads on each actuator depending on the Hexapod orientation in space

Highly advanced digital controllers are also available for Hexapods with piezo stepping drives which are suitable for operation in strong magnetic fields or UHV environments

Hexapod-Specific Software

Due to their parallel kinematic structure, Hexapods necessitate a particularly complex control system. The position coordinates, for example, are given in virtual Cartesian axes which are then converted into positioning commands for the individual actuators by the controller. PI supplies special software that allow the 6-axes positioners to be more convenient in operation and easier to integrate.

Determining the work space

The limits of the work space vary depending on the current position of the Hexapod (translation and rotation coordinates) and the current coordinates of the pivot point. A special software tool included with each PI Hexapod calculates these limits and displays them graphically.

Checking the permissible load

As with any multiaxis positioning system, the load limit of the Hexapod varies as a function of a number of factors such as orientation of the Hexapod, size and position of the payload, current position (translation and rotation coordinates) of the Hexapod platform, and forces and moments acting on the platform.

The Hexapod software package includes a PI simulation tool that calculates all forces and moments and compares them individually against the specified load limits of the corresponding Hexapod mechanics.

Preventing collisions with PIVeriMove

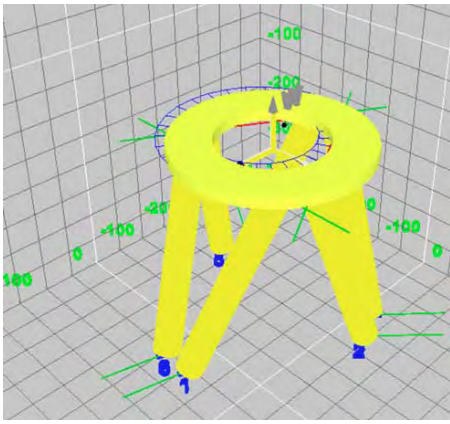
Another proprietary PI simulation software tool enables offline graphical configuration and simulation of the Hexapod motion in the application environment. CAD data of objects can be imported or approximated with simple shapes such as cylinders and cuboids. PIVeriMove then checks restrictions in the work space. Implemented in the controller firmware or the application software, this prevents the Hexapod from approaching positions where the platform, struts, or the mounted load would collide with the surroundings.

Emulation: The Hexapod system as a virtual machine

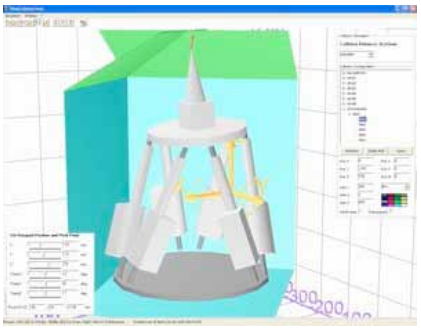
A virtual machine that can be installed on the customer's host PC is available to emulate a complete Hexapod systems (mechanics, controller and even peripherals). Application programs can then be developed and pre-tested, different load scenarios can be simulated and the work space can be determined before the system arrives, saving significant cost and development time.

HexaApp: PI Hexapod control via iPhone, iPad or iPod

The Hexapod system can also be controlled wirelessly from mobile Apple iOS devices. A corresponding app enables command control of touchscreen, motion sensors or via a command input window.



The simulation software graphically displays the position and the available work space of the Hexapod model



The M-811 was replaced by the H-811, see above

M-811 Vacuum-Compatible Miniature Hexapod 6-Axis Positioner

High Precision and Very Versatile

The M-811.STV vacuum-compatible Hexapod comes complete with software and a highly specialized Hexapod controller. It combines small size with high-load capacity and high accuracy.

- **Vacuum-Compatible Miniature Hexapod**
- **Complete with Specialized Hexapod Controller and Software**
- **Travel Ranges 34 x 32 x 13 mm, Rotation to 42 Degrees**
- **Load Capacity to 5 kg**
- **Actuator Resolution 40 nm**
- **Min. Incremental Motion to 200 nm**
- **Repeatability up to ±0.2 µm**
- **Velocity to 10 mm/s**

The M-811.STV is PI's smallest standard vacuum-compatible Hexapod. Despite its size it can handle loads up to 5 kg (2.5 kg in any orientation) and achieves velocities up to 10 mm/sec. With a diameter of only 130 mm and a height of 115 mm it provides travel ranges up to 35 mm in the XY-plane and up to 13 mm in the Z-direction. In combination with the large tilting angles of 20° around the X and Y axis and up to 40° around the vertical axis it allows for complex motion profiles with particularly flexible placement of the load – a great advantage in restricted areas (such as beam lines) and small vacuum chambers.

Each individual strut has a positioning resolution of 40 nm; multi-axis motion can be accomplished with sub-micron repeatability. In addition to controlling all axes in Cartesian coordinates, a software command allows the user to select the center of rotation (pivot point) freely anywhere inside or outside the system envelope.

Application Examples

- Biotechnology
- Semiconductor technology
- Micromachining
- Micromanipulation
- X-ray diffraction measurements
- Tool control

Hexapod vs. Serial Kinematics Systems

The Hexapod is driven by six high-resolution actuators all connected directly to the same moving platform. This design provides a high system stiffness and a large clear aperture. Because of the low mass of the moving platform, positioning operations can be performed with far lower settling times than with conventional, stacked multi-axis systems. In such systems, runout, guiding errors, and the friction and inertia of moving cables all accumulate to limit accuracy and repeatability—problems which do not affect parallel kinematic systems like the Hexapod.

Fixed Virtual Pivot Point

For optics and other alignment tasks, it is important to be able to define a fixed pivot point. The sophisticated Hexapod controller allows choosing any point in space as the pivot point for the rotation axes by software command. The pivot point remains fixed relative to the platform.

Ordering Information

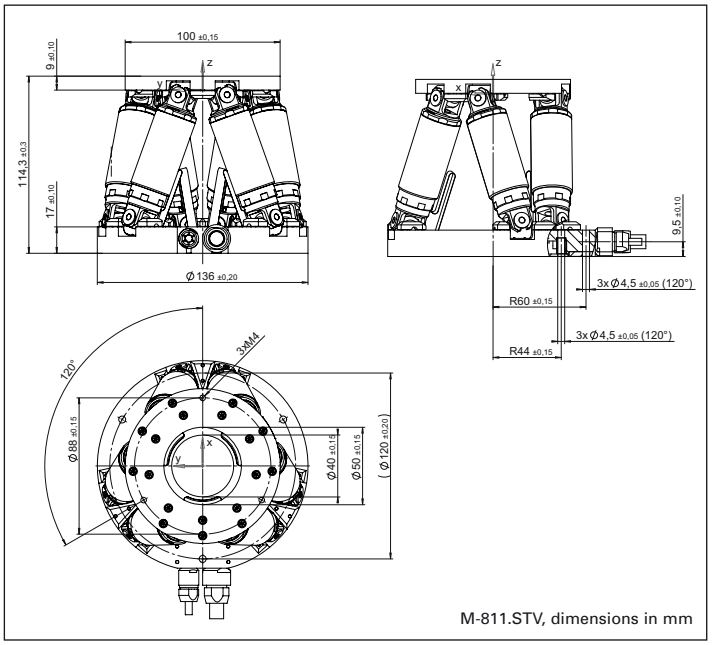
M-811.STV
Miniature Hexapod Microrobot with Controller, Direct Drive, 5 kg Load, Vacuum Compatible to 10^{-6} hPa

Ask about custom designs!

Target positions in 6-space are entered in user-friendly coordinates and reached by smooth vectorized motion.

Open Architecture

Control of the Hexapod is facilitated by the controller's open interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.



M-811.STV, dimensions in mm