Shadow DEX-EE Series Specifications

DEX-EE

DEX-EE CHIRAL

1. Introduction

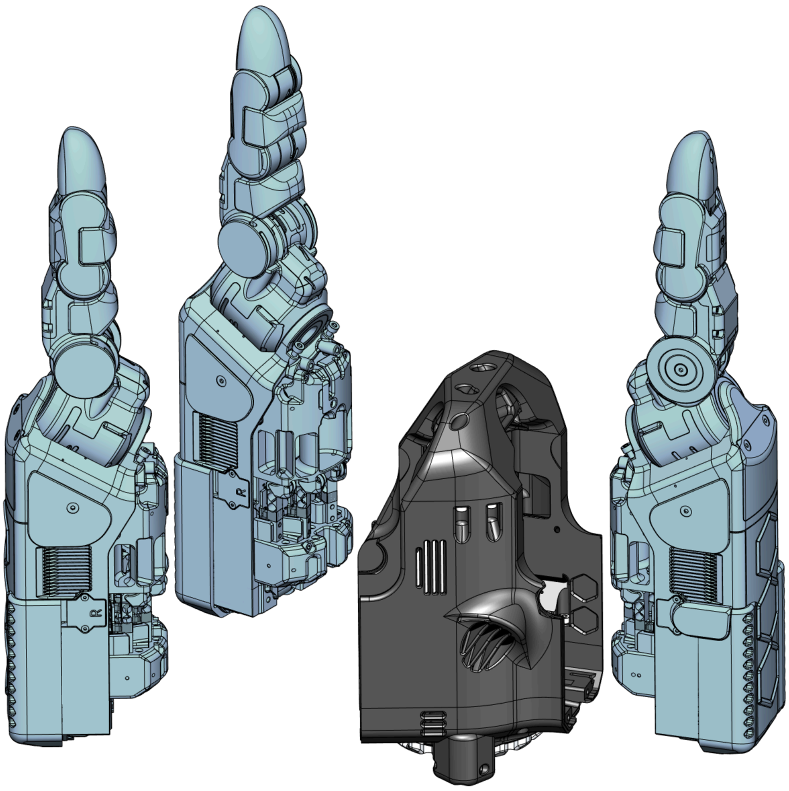
DEX-EE (available in two configurations, DEX-EE and DEX-EE Chiral) is a premier dexterous robotic hand engineered specifically for high-cycle machine learning research and autonomous manipulation. Designed to survive the "trial and error" phase of AI training, the hardware is resilient against aggressive force demands, high-frequency impacts, and surface abrasion. This physical durability, paired with **active compliance**, ensures the hand remains operational even when subjected to the unpredictable or high-torque outputs of an untrained neural network.

Key Specifications & Capabilities

- **Maximum Experimental Uptime:** Engineered for continuous operation in deep RL environments.
- **Industrial Reliability:** High Mean Time Between Failure (MTBF) and a design optimised for a Short Mean Time To Repair (MTTR).
- **Comprehensive Tactile Feedback:** High-density sensor coverage for nuanced object manipulation.
- **Advanced Control:** High-accuracy, stable joint control with native **ROS integration**.
- **Unrivalled Modularity:** The architecture supports rapid reconfiguration to suit diverse research goals:
    - **Symmetric:** A versatile 3-finger layout for balanced grasping.
    - **Chiral:** A new, human-like anthropomorphic configuration designed for complex tool use and human-centric environments.

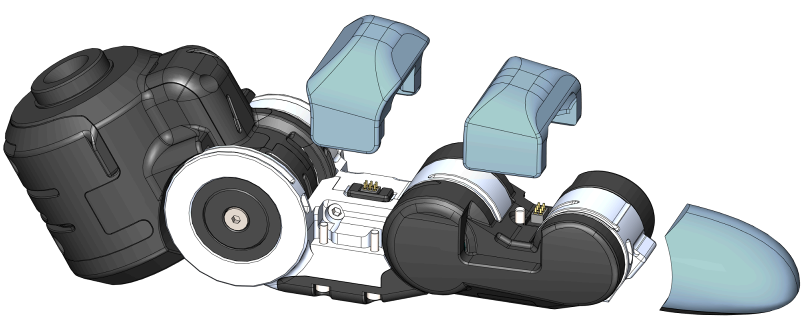
2. Modularity

DEX-EE is a modular robot. Each finger is a self-contained unit that is user-replaceable for quick repair. Should one finger be damaged, it can quickly be replaced while the damaged module is repaired.



Alternative hand base configurations, with different finger numbers or orientations, can be commissioned.

The tactile sensors are also modular and can be removed or replaced. The communication network inside the finger will detect the presence or absence of tactile sensors, determine their type and inform the host PC. Sensors with different numbers of taxels or employing different technologies can be designed and installed.



3. Available Configurations

The DEX-EE system is designed with a modular base architecture, allowing for different finger arrangements depending on the specific research or operational requirements.

DEX-EE

The standard DEX-EE configuration features three fingers arranged in a symmetric distribution around the centre of the hand base. This configuration is specifically engineered for high-uptime machine learning experiments where balanced, multi-directional grasping is required.

Best for: Autonomous grasping research, reinforcement learning, and high-repetition machine learning tasks.
Key Advantage: Balanced force distribution and a simplified kinematic model for non-anthropomorphic manipulation.

DEX-EE **Chiral**

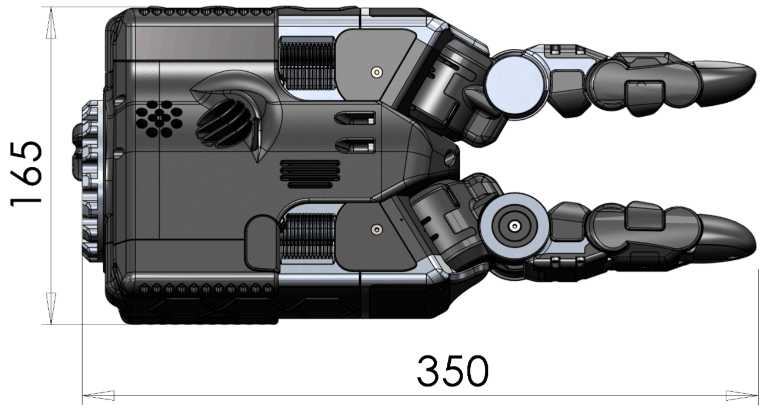
The DEX-EE Chiral configuration is designed for applications requiring human-like kinematics. By repositioning the third finger down and to the side, it creates an offset analogous to the human thumb. This modification enables more natural interaction with tools and environments designed for humans.

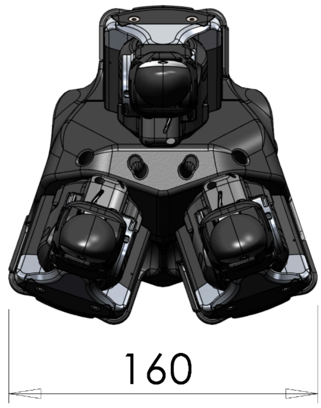
Best for: Human teleoperation, imitation learning, and complex bi-manual manipulation styles.
Key Advantage: Closely matches human hand geometry, which simplifies the mapping of human motions to the robot and facilitates the copying of human-style bi-manual tasks.
Options:

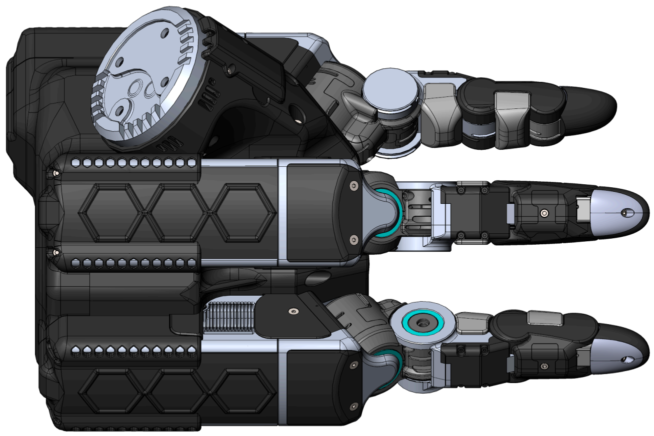
- Left/Right: Specific orientations to mirror human hand dexterity.
- Bi-Manual Pair: A matched set of left and right hands for dual-arm robotic platforms.

4. Dimensions and kinematics

DEX-EE is larger than a human hand, measuring 350mm in length, and 165mm x 160mm in width and height.

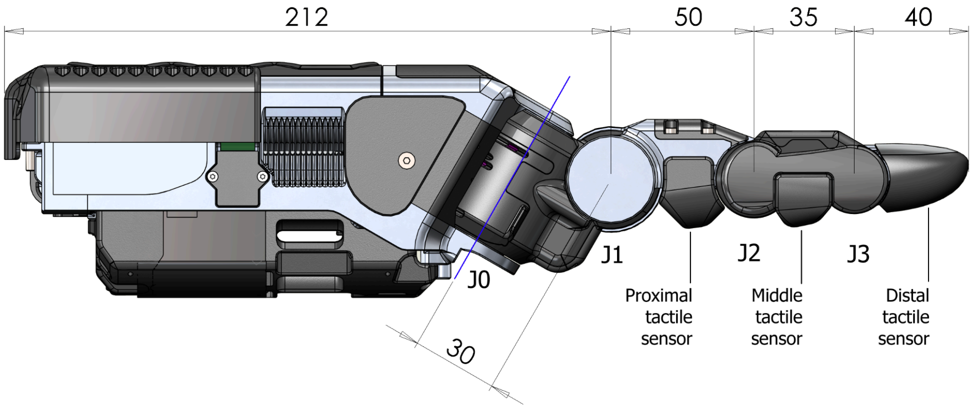






Speed	Up to 180 °/s per joint
Force	At least 8 N force at the finger tip
Weight of a single finger	1.2 kg
Weight of a 3-fingered hand	4.1 kg

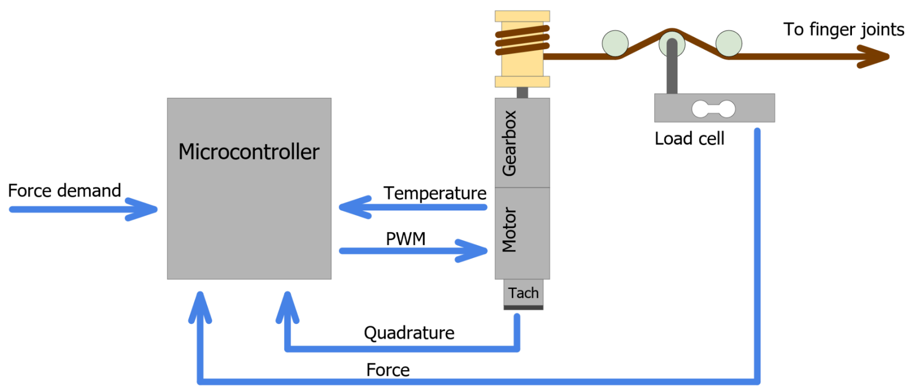
The kinematics of each finger are similar to a human finger, with an abduction-adduction joint at the base, and three flex/extend joints along its length.



	Range -ve	Range +ve	Range Total
J0 (Base Joint)	-50º	50º	100º
J1 (Proximal Joint)	-80º	45º	125º
J2 (Middle Joint)	0º	80º	80º
J3 (Distal Joint)	-30º	85º	115º

5. Actuation and control

The four joints of each finger are driven by five motors in an N+1 configuration. The motors are housed in the base of the finger and are connected to the joints via tendons. Each motor unit executes a 10kHz force control loop, giving active compliance to the finger.

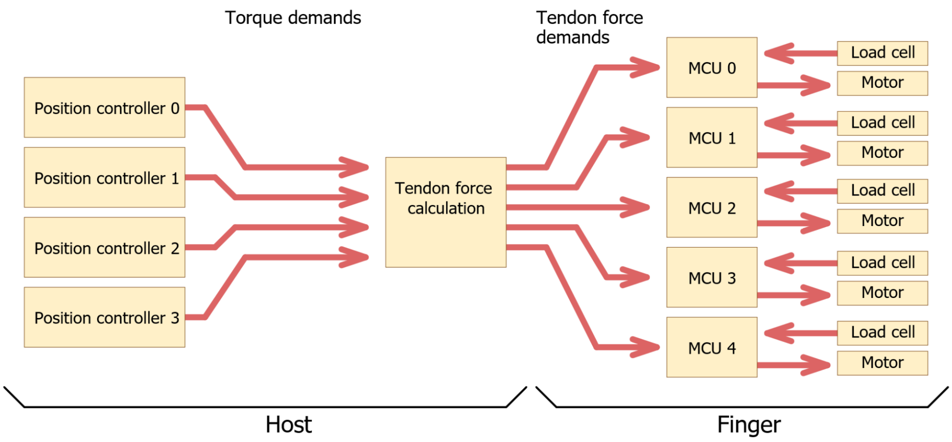


Several control modes are available at the host:

- Joint position PID running at 1 kHz. Outputs joint torque commands.
- Joint torque, mapped via N+1 calculator to tendon force at 1kHz.
- Tendon force (PID running at 10 kHz on each motor unit). Output is motor PWM.

- Motor PWM is applied to each motor directly at 40kHz (however, this is not recommended as it bypasses many of the safety features of the finger).

In position control mode, controllers run on the host at 1kHz, creating joint torque demands, which are translated into tendon force commands, which run inside the finger at 10kHz.



6. Sensing

Each finger contains 155 individual sensor channels, plus video from the distal tactile sensor.

Sensors per finger			
Sensor	**Quantity**	**Rate (Hz)**	**Resolution**
Joint	4	1000	0.022°
Acceleration (3 DOF)	3	1000	0.061 mg [1]
Angular rate (3 DOF)	3	1000	4.375 mdps [2]
Tendon Force	5	1000	4 mN
Motor velocity, current, temperature, clutch slip detection	5	1000	
Middle tactile 3-DOF displacement + temperature	14	100	
Proximal tactile 3-DOF displacement + temperature	22	100	
Distal tactile sensor video	1	50	

1. mg = milli-g
2. mdps = millidegrees per second

Motor temperature and current are used for health monitoring of the motors. When the temperature of the motors exceeds a safe threshold, motor power is increasingly restricted until the temperature returns to a safe level. Motor power does not suddenly cut out due to over-temperature.

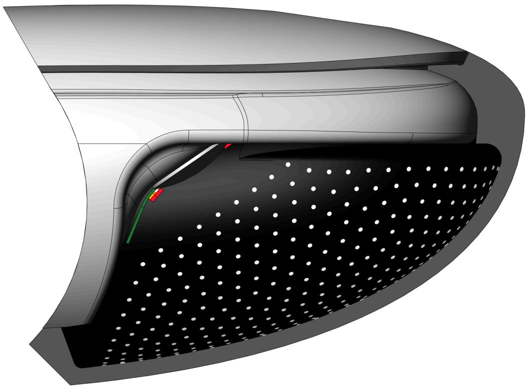
Tendon odometry is recorded to estimate the amount of work done by each tendon. This can help to predict tendon failure, allowing users to replace tendons before failure. Odometry can be reset through a ROS service when a tendon is replaced.

7. Tactile sensing

The finger contains two types of tactile sensors.

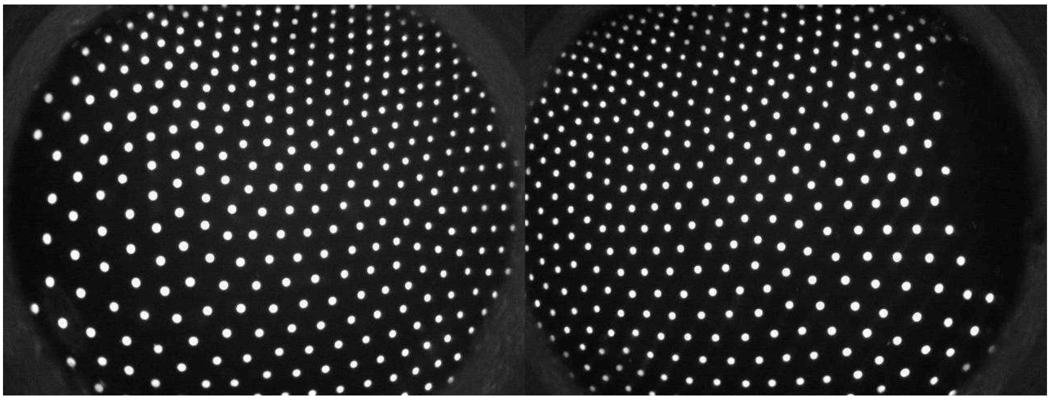
Distal tactile sensors

The distal sensor is a wide dynamic range, high-resolution tactile sensor.



Cutaway view of the sensor, showing particles inside and one camera

The sensor consists of a stereo camera pair viewing the inside surface of the silicone skin. White markers on the inside surface of the skin provide information about its deformation, and therefore the forces acting on it and the shape of the surface in contact.



View through the stereo cameras, showing the 525 particle distribution

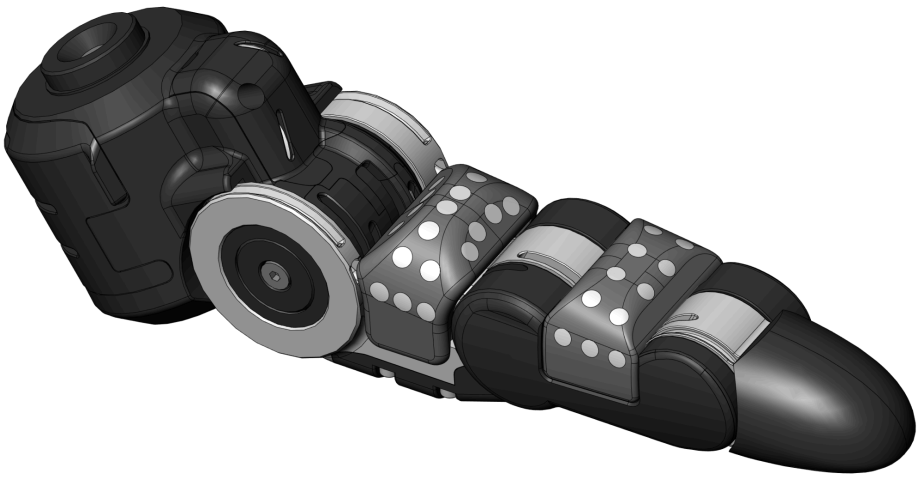
Very small forces on the skin result in noticeable movement of the particles, but the particles continue to move even with forces up to several tens of Newtons, giving the sensor a high dynamic range. Video output from all three sensors in the hand is available over a single USB 3.0 connection, each with a resolution of 1280x480 at 50 FPS.

Even distribution, clusters and Ulam spiral patterns

Different patterns of particles can be chosen at manufacturing time, including high or low density, clusters, and Ulam spiral. Custom patterns are possible. These patterns contain approximately 500 particles, but the maximum number of particles is 2180.

Middle and proximal tactile sensors

Optional Modular tactile sensing regions are available on the middle and proximal phalanges of each finger.



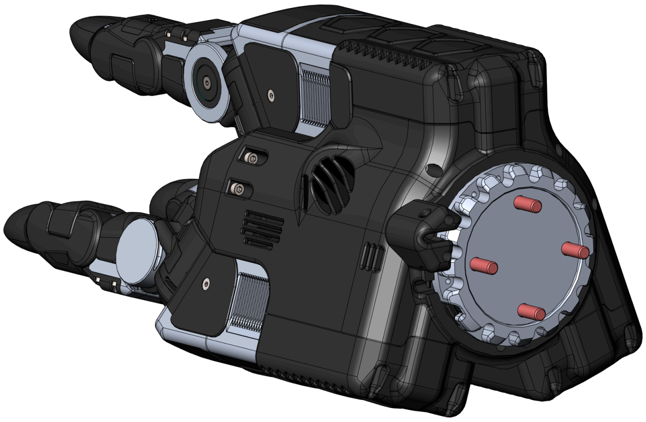
Proximal and middle taxels marked as white spots

The tactile sensors consist of user-replaceable modules with 22 (proximal phalanx) or 14 (middle phalanx) sensing cells. Each cell consists of a magnet and an accompanying 3-axis Hall effect sensor. The cells are distributed across the silicone surface of the sensor. The cells give raw magnetic field strength in the normal (x) and shear (y, z) axes and cell temperature with a resolution of 12 bits. Magnetic field strengths for x, y and z axes and temperatures for each sensing cell update at 100 Hz.

8. Hand base

The Hand Base houses three Finger Units to form a whole hand. Each Finger Unit can be mounted (or unmounted) by a trained user using six screws to attach the Finger and its cover, and a single connector for data and power.

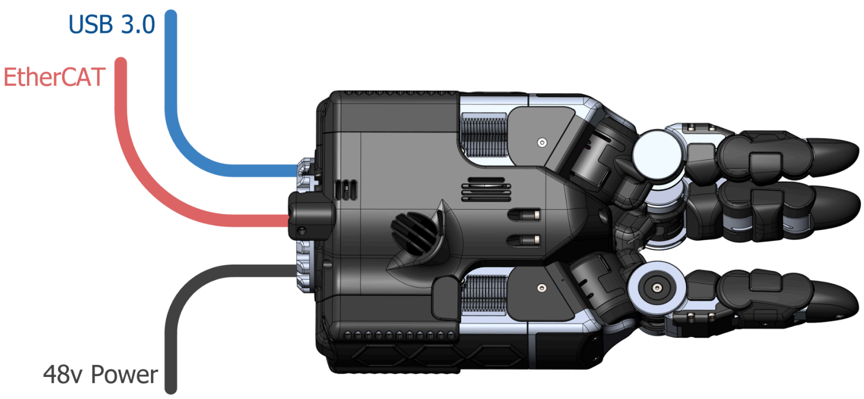
The base connects to an arm using 4 x M6 screws in a 50mm PCD pattern (compatible with ISO 9409-1-50-4-M6). Three incoming cables provide power, EtherCAT Data and USB for the Distal Sensors.



Communications

The hand has two external communication interfaces and one internal network.

- EtherCAT from the hand to the host: This is a 100 Mbps Ethernet-based communications field-bus, and is fully integrated into ROS (Robot Operating System).
- USB 3.0 distal tactile sensor feed.
- Dual FAN bus within the finger: The FAN bus (Finger Area Network) is a flexible 3 Mbps bus architecture developed by Shadow for modular robot systems.



Power

The hand requires a 48V 200W power supply. The actual power consumption depends on the torque demanded at the joints.

9. Sales and company information

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Revision	Issue date	Description of change
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