

MFG-100/MFG-100-i

MagnebotiX tabletop magnetic field and gradient control systems

The MagnebotiX MFG-100/100-i systems comprise a tabletop magnetic field generation unit, power electronics, and a control software user interface (MBX Pro). The system is capable of generating arbitrarily oriented magnetic fields and field gradients within a spherical workspace having a diameter of approximately 10 mm. The fields are unrestrained in both translational and rotational degrees-of-freedom (DOF), and thus the system can levitate and control magnetic objects in viscous liquids with 5 degrees of freedom (3-DOF position, 2-DOF orientation). By applying time-varying signals, rotational or stepping-based actuation of magnetic objects is accomplished. With our MBX Control software and its plugin-based architecture, multiple control strategies are possible ranging from manual open-loop control to custom solutions for fully automated servoing of magnetic objects along predefined paths. The MagnebotiX MFG-100-i is adapted for use in an inverted configuration, such as on an inverted microscope.



Field Generation and Control Modes

- *Field control*: generate an arbitrarily oriented field vector within the workspace for magnetizing ferromagnetic objects. Magnetic objects that can move freely will align with the external magnetic field.
- *Gradient control*: exert a force on magnetized objects to pull mobile objects in arbitrary directions along the field gradient or levitate objects in liquids
- *Rotational control*: controllably change the magnetic field orientation to exert a torque on a magnetized object, causing it to reorient if deflectable and rotate freely with the external field if mobile
- *User-specific control*: define fields and gradients as a function of time using standard mathematical notation: square wave, sawtooth, precessing field vector, exponentially decreasing – if you can define it mathematically you can generate with our new software.

Suggested Areas of Application

- Studies of magnetic microactuation strategies through the influence of magnetic forces and torques acting on small magnetic objects in air or liquids
- Selective isolation and extraction of naturally magnetic or magnetically tagged biological and non-biological objects from viscous liquids
- Mechanical manipulation and extraction of non-magnetic objects in liquids with the help of an untethered magnetic end-effector
- Studies on the mechanical properties of small objects through their interaction with an untethered magnetic end-effector
- Mechanobiology studies at the single cell or engineered tissue level, such as direct mechanical interaction with microorganisms and cells, and studies of their behavioral response with an untethered magnetic end-effector
- In vivo studies at the small animal level such as zebrafish

System Components

MagnebotiX MFG-100 / 100-i magnetic field and gradient generation unit

- Maximum working volume diameter: 1 cm
- Max. magnetic field strength (center): 20 mT in any direction
- Max. magnetic field gradient (center): 2 T/m
- Max. magnetic field frequency: 300 Hz at 2 mT, 80Hz at 10 mT
- Max. slew rate per coil at 20 A step input: 20 T/s
- Dimensions (W x D x H): 250 mm x 275 mm x 110 mm
- Weight: 4.5 kg



MagnebotiX ECB820 power unit

- Number of channels: 8
- Max. current per channel: 20 A
- Max. voltage per channel: 48 V
- Max. power consumption: 1008 W
- External power requirements: 110 - 240 VAC / 50 - 60 Hz
- Dimensions (W x D x H): 440 mm x 325 mm x 130 mm
- Weight: 10 kg
- Connection to control computer: Ethernet



System safety features: over-temperature and over-current monitoring of all coils; controller shutdown upon loss of communication with coil unit; external emergency shutdown switch.

MagnebotiX HID100 human input devices

- Input devices: Keyboard, mouse, SpaceNavigator (3DCONNEXION), PlayStation3 controller

Microscope, cameras and lenses not included

- Microscope or lenses are determined by the user according to experiments to be performed. Basler USB3 cameras are compatible with our MBX Pro software (plug-and-play (e.g., Basler USB3 ACE or Pulse series).
- Tested products : Stereo (dissecting) microscope with a suitable stand to accommodate the MFG-100 (Olympus, Leitz, etc.)
 - : Edmund VZM 200i 2x zoom lens (WD: 90mm, DOF: 1.5mm) optics.
 - : inverted fluorescence microscope models: Olympus IX 71, 73, 81 and 83; Nikon Eclipse TE2000/Ti-S/Ti2

The principle of the magnetic field generating technology is protected by patents WO 2011029592 A1 and WO 2013127516 A1 to ETH Zurich and sub-licensed to MagnebotiX AG. For more details on the MFG100 / MFG100-I systems see S. Schuerle, S. Erni, M. Flink, B. E. Kratochvil, B. J. Nelson, "Three-Dimensional Magnetic Manipulation of Micro- and Nanostructures for Applications in Life Sciences", *IEEE Transactions on Magnetics*, Vol. 49, No. 1, January 2013, pp. 321-330.

The MBX Control software was originally developed ("daedalus") in the Institute of Robotics and Intelligent Systems, Multiscale Robotics Lab, ETH Zürich.

All specifications are subject to change without notice.