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Magnetically Levitated Systems and Microactuators

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Abstract:
The article describes the two main types of magnetically levitated systems on general and detailed characteristic basis. A comparison between the AC and DC power supplies for these systems, including the pros and cons of each type, is also provided in the paper. Further, the constructed magnetically levitated planar actuator with moving magnets, the translator and stator design are explained.

TYPES OF PLANAR ACTUATORS

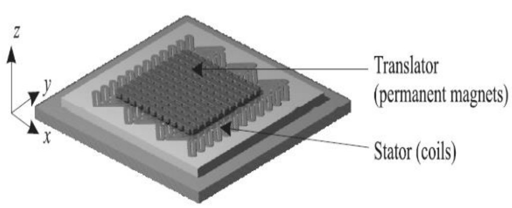
The next-generation of lithography requires a high precision stage, which is compatible with a high vacuum condition and for this, a magnetic levitation stage with two or more degrees-of-freedom is considered state-of-the-art technology. Nowdays the size of wafer is moving up to 12 inch in order to enhance the efficiency of a batch process. Therefore, a high resolution process and a large operating range concurrently with the application into a super-clean environment are the requirements for the related micro-actuators. The noncontact characteristic of magnetic levitation technology enables high precision positioning as well as no particle generation. The manufacturing process of a recent semiconductor IC, imposes very severe constraints on not only the processing accuracy but also the working environment. However, the heat is inevitably generated, while using electromagnetic actuators for levitation, which deforms the structures and degrades accuracy of the stage, and though a gravity compensator is required [1].

Different types of conventional transportation systems such for example: belt-type conveyors or articulated robots generate dusts and pollution due to the mechanical friction or lubrication, and are inadequate and inappropriate to satisfy the environmental demands. The magnetic levitated carrier system for the transportation systems has the advantages of being contact free, can eliminate the mechanical components e.g., gears, guide etc., reduce the mechanical alignment and maintenance cost, hence it satisfies the environmental demands. Therefore, research on contact-free type transportation system and actuator has been actively performed by worldwide researchers. There exist two types of planar actuators, referred as either with moving coils or moving magnets. The following Figure 1 shows an example of these planar actuators.

The actuator from the first type consists of moving air-core coils and stationary magnets. The main advantage of such system is the usage of a small number of coils and their amplifiers, as the stroke force can be easily increased by adding a few more magnets in the magnet array. Moreover, the simpler design of these actuators allows control of the torque on the translator part by using different coil topologies. A big disadvantage for this class is that there should be a cable to connect the translator and the stator part, as the coils require power and cooling [3].

The second type of actuators with magnetic levitation consists of moving magnets and stationary air-core coils. In contrary with the previous class of actuators, it doesn't require a cable for connecting the translator with the stator part, which is really a big advantage from the design point of view. Coils are located and powered in the stator platform, which means smaller amount of disturbances to the translator. But, the torque decoupling as a function of position is more complex than in the moving-coils planar actuators. In manufacturing processes, working environment affects the quality of the precision products [3] [4].

a)



b)

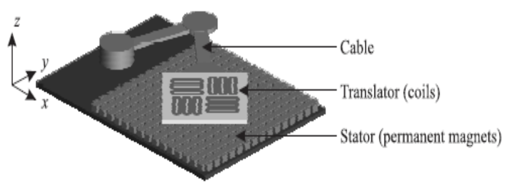


Figure. 1. Planar actuators: a) moving magnets, b) moving coils

MAGLEV SUPPLY SOURCE TYPES

There exist two approaches for designing a controlled force magnetic levitation system: one uses attractive forces interacting between an electromagnet and a soft magnetic flux closure, and the other is based on repulsive forces between electromagnets and appropriately magnetized permanent magnets.

Electromagnetic levitation technology, where the attractive forces are used, there is either an AC or DC source to drive the electromagnets. Although there have been built and tested several experimental systems which use as the supply the AC sources, this method of stabilization is appropriate for applications where mass of the levitated object, translator, is relatively small. The losses caused by the effect of the eddy currents and the complex circuit design and control of the power modulation, makes the AC method of stabilization inappropriate for heavy payloads.

In contrast with the above AC method, the explicit DC method, generally known also as the electromagnetic levitation system (EMLS), is characterized by simpler circuitry configuration and favourable power requirement. In the circuits using the DC EMLS, a switched mode power amplifier is mainly part of the design and used to control and utilize the current as well as the attraction force of the electromagnets. A simple electromagnetic levitation system consists of four main components: (i) Actuator and Rail, (ii) Position Sensor, (iii) Controller, (iv) Power amplifier [5].

The electrodynamic system uses the repulsive forces to levitate the object. In contrast with the first system, the electromagnetic system, produces levitation of the object based on the attractive forces between electromagnets and the levitated ferromagnetic objects. As part of this system, a position transducer is used to sense and measure and the gap between the magnet pole-face and the ferromagnetic object. Then the output signal from the transducer is fed back to a comparator. The process continues with output signal of the comparator being applied to a position controller, giving in this way the reference current for the current loop. The actual current supplying the coil is sensed and compared with the reference current by the current sensor. A very important element in this process is also the power amplifier, which produces necessary currents in the actuator coils after receiving a command from the current controller. Prior to this, the current error process task is completed in the current controller. The currents from the power amplifier going through coils generate requisite magnetic forces which are the key for levitating the translator [5].

DESIGNED MICROACTUATOR WITH MOVING MAGNETS

The moving coil principle in silicon microstructures requires powering and cooling of the coils. Also, adding here the guidance of the current lines on the thin etched silicon beams. The springs which are driven by the Lorentz force, are moving in the magnetic field of an external magnet. Strong currents are necessary in order to produce large deflections and this can cause thermally induced bending or buckling of the thin microstructures. Therefore, the principle with a moving magnet is more effective, including simpler circuit design.

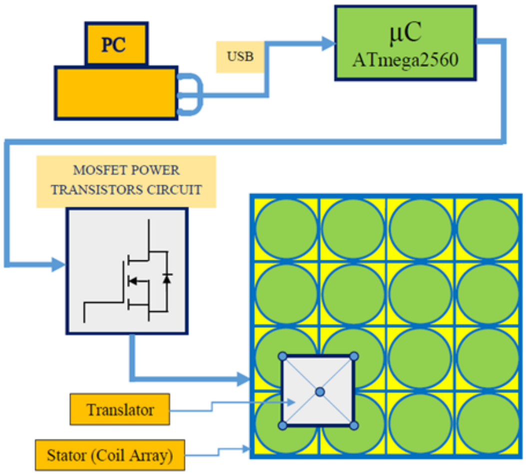


Fig. 2 Block diagram of the planar actuator with moving magnets

The translator consists of several permanent magnets and mainly its stabilization is required. This can be done by constructing such a uniform shaped object with the center of mass coincident with the center of geometry. In numerical analysis the levitation distance between the levitated magnet and the cylindrical solenoid underneath is strongly related with the magnetic flux in between. If such a distance is very small, then the magnetic flux approaches a constant value. The aim of the stator design is the arrangement of the cylindrical solenoids and their floating currents in such a way, so together would form a uniform magnetic field over a planar surface slightly above the coil array. To be able to achieve a high-precision positioning performance, it is needed to set up properly the control and the altitude of the carrier. The supply of the coils is done from an external power supply connected to the supply pins of the circuits with the MOSFET power transistors. For full control of floating current of the coils, four such circuits are needed.

Concerning the type of planar actuator described here, the translator is represented by a uniform shaped object with specific characteristics. This is embedded with one stabilizing permanent magnet on every corner so that it can provide sufficient control force against the lateral forces, and with one permanent magnet on the bottom of the carrier to counteract the weight of the carrier. In the stator platform there are 16 identical coils, forming together a 4x4 array. The current flowing through a relevant coil in the stator is controlled from the output PWM signal of one of the pins of the board Arduino Mega 2560. With a limited output current from the pins and able to create very weak magnetic field around the coil, 4 external circuits with power MOSFET transistors were constructed [6].

LITERATURA

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