Low Power Magnetic Levitation

Sponsor

This is a joint academic project based on research from Prof. Forrest Brewer and Prof. Joao Hespanha. Prof. Brewer has 30+ years experience in real-time software and related signal processing. Prof. Hespanha has decades experience in formal controls and control modeling.

Background

Pragmatic magnetic levitation comes in many forms from suspended objects via solenoid to maglev based trains. Conventional levitation makes use of a coil and variable drive current to suspend objects with a control system to create a stable system. In this project, the goal is to design a levitation scheme based on a permanent magnet to produce the suspension field and a smaller, low power solenoid and control system to stabilize the object at the usual unstable point where magnetic attraction is exactly balanced by gravitational acceleration. In theory, such a levitation could be done at nearly zero power. Such solutions are of interest in magnetic bearings and related applications.

Conventionally, high efficiency drives are based on digital switching a PWM signal into an H-Bridge driving the solenoid winding, thus avoiding linear amplifier losses. There are a wide variety of bridge style driver circuits based on BJT, DMOS, IGBT or wide bandgap (SiC or GaN) switches. In this project, the goal is to minimize the controller and drive power, so a strategy of FPGA based digital design using sigma-delta bit-stream based controllers is used. This allows for a very low power, but high performance controller with very low latency. Although non-traditional, the use of such filters could enable re-implementation of the design in ultra-low power/cost fpga platforms such as Lattice ICE40. This would enable long runtime for battery operation.

Problem Statement

In this project, the students need to design a demonstration platform consisting of a mid-size permanent magnet surrounded by a wound solenoid used to make small modifications to the field and thus the attraction force on a ferro-magnetic test sample. A suitable means of accurately measuring the physical separation of the magnet an the sample must be designed and built, typically this is done with an LED and a large area photo sensor such as a CdS cell to provide proportional photoresistivity that can be used to drive a suitable ADC measuring the position. Prototyping of the design should be done with a PYNQ Z1 or Z2 fpga card that provides real-time logging of data and control algorithm acceleration for conventional or PDM based controller. The use of PYNQ allows for real-time experimentation on the controller algorithm and settings with real-time logging of design state. PYNQ python based analysis simplifies testing and control debugging.

The initial goal is stable operation of levitation at power levels at least 10x smaller than direct levitation. This design can be built using a suitable high-speed H-bridge card to drive the solenoid. A secondary goal is the mapping of the controller into a PDM version running on an ICE40 test card which would enable practical battery operation.

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Deliverables

Development of an optimal control scheme is well beyond the scope of a team capstone project. Instead, the group needs to construct a prototype and suitable web-based display software to debug the design as well as provide demonstration of operation.

Student Qualifications

- 1-2 students with interest in control algorithms and fixed-point controllers.
- 1-2 students with python and gui development interests.
- 1-2 students fabricating the prototype and building the driver and A/D interfaces.

Resources

- **PYNQ** (http://www.pynq.io/) boards will be available
- H-BRIDGE EVALPWD13F60 (e.g.)