Electronics Control and Interface Architectures for MEMS Sensors and Actuators

ELECTRONICS CONTROL AND INTERFACE ARCHITECTURES FOR MEMS SENSORS AND ACTUATORS

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Abstract: Quality and performance of the MEMS systems are determined in good measure by the quality of electronic control and the interface due to specific problems of coupling between different technologies with different specific parameters. Possible solutions will be presented in the following analysis of the actuators control electronics architectures. Will be analyzed several variants of actuators, particularly magnetic actuators.

Keywords: Electronic control, MEMS, sensors, actuators.

1. Introduction

MEMS field is one of the most competitive in the world, the impact of these systems being already present in the reality of daily technique, announcing a significant change in the near future of technical systems. This impact will be felt especially with large scale production of MEMS and development of techniques for networking and communication, integration in networks, etc. MEMS elements require a rigorous monitoring and control of many parameters. Electronic control systems must be accurate, fast, reliable and cheap. Of a special importance is the interface between the conventional command and control electronic systems and the MEMS sensors and actuators. The signals generated by a MEMS sensor need to be routed to an electronic control unit before they become useful to the host system. But MEMS devices are produced in a fundamentally different technology from that of solid-state electronic integrated circuits such as microcontrollers or applications processors, and there is a wide mismatch between the characteristics of each.

This means there is a requirement for an interface which can bridge the two worlds, an interface which is optimized for the high bias-voltage, small-signal world of MEMS, but which can also supply a clean, stable output which is usable in the world of digital electronics.

2. Analyze

MEMS applications use a large variety of devices from accelerometers, actuators, switches, relays, to sensors for liquid, gas, biological agents. Most of these devices and systems that integrate them require precise control and specific drivers. Figure 1 shows a general representation of a MEMS system with input and output devices. A wide range of MEMS produce inputs in the system (the left side of Figure 1, MEMS like sensors, transmitters for interacting with the physical world) The other end of the MEMS system can be used as output devices to control, move, displace in order to produce results (right side of Figure 1).

Figure 1: Input and output functions of a MEMS System

Actuators, gears and motors are controlled by the output signals of electronic devices. Actuators and motors allow movement of mirrors in scanning systems.
Block diagrams of command are illustrated in Fig 2 and include DAC converters and final amplifier stages.

![Figure 2: The block diagram of 2 axis actuation](image)

One microprocessor can drive several axis. Through the microprocessor can be generated different waveforms. Due to the accelerated evolution of the industry more and more external circuits are integrated on the same chip with MEMS. However, it is not always practical or convenient, in terms of the cost to integrate each circuit with MEMS. External actuating circuits remain convenient to optimize and speed up development of MEMS prototyping. Complex wave forms can be generated through DAC but also with the help of specialized circuits of high performance for digital signal processing type (DSSP)

**Actuator classification**
A brief classification can be:
- electrostatic-motion due to attraction between conductors with opposite electric charges
- thermal - displacement due to thermal expansion
- piezoelectric - displacement due to strains induced by an electric field
- magnetic - displacement due to the interaction of different magnetic elements: permanent magnets, external magnetic fields, magnetic materials and electrical circuits.
- other types – based on different physical phenomena

**Magnetic actuators**
- Versions of electromagnetic actuators
  - permanent magnets interacting with an external field
  - permanent magnets interacting with the current coil
  - conductors / current coil that interacts with an external field
  - variable reluctance devices
- An important feature: result a large force
- Less good characteristics
  - high power dissipation compared with other
  - the complex manufacture and important issues related to material

Also for MEMS there is the requirement to use advanced command and control techniques for getting of certain performance and control targets.

These techniques should be appropriate to the features of the model and take into account a number of factors ignored on the macro level but playing an important role on micro scale.

Moreover, the nonlinearity of the model forces the designers to linearize as much as possible the model used before applying control techniques instead of relying on the design of nonlinear controllers, which are very complicated to implement.

Microdevices MEMS are generally operated using simple input signals in open loop. These signals (eg, magnetic, piezoelectric, electrostatic, thermal, etc.) are used to operate the device in a desired static configuration or to continuous excite the device to get a certain dynamic behavior (eg, micro-resonators, micro-scanners, filters, etc.)

For a fast and efficient reaction, a microdevice must reach the desired state with the best possible transient dynamic features. To accomplish this, microdevices are often redesigned. However, the redesign approach can be expensive, time-consuming and have often resulted in complex devices. Therefore, it is advisable to use different methodologies focused on changing control signals for the desired response.

Drive signals can be controlled using a control technique either in closed loop or in open loop. A controller in closed loop well designed is generally more robust to errors in estimates of parameters, it needs a model not very precise of the system, is less sensitive to external perturbations, thereby achieving a better response and more stable than open loop controllers.

However, their application to micro-scale systems is usually very cumbersome and expensive. Measurements of reaction to the micro scale are difficult to perform and requires very precise detection techniques, especially for very low signal-noise ratio.

Even if the application of current detection techniques in the laboratory is difficult, but not impossible, their actual implementation in real systems for large-scale production is very expensive and sometimes impossible using available technologies.

For these reasons, a carefully designed open-loop control algorithm can be the best alternative.
3. Electronic control scheme:

Making a control system in which the drive function is to be performed by electromagnetic actuators and the control to be based on a dedicated protocol if the computing implementation is desired, must aim at specific functional requirements. To drive an actuator or two actuators for 2D scanning, the implementation of the following functional blocks is necessary:

- Signal generator (pulse signal, ramp shaper, sinusoidal, PWM generator, etc.)
- Amplifier block (amplification of the signal in order to obtain the desired amplitude)
- Current generator (generating voltage or current conversion in order to ensure that the supply current of the actuator electromagnetic is proportional with the command voltage)
- Power supply (supply voltage of the circuit diagram including reference voltages)

Implementing these functions / blocks may start with wired logic (discrete components), through microprocessors, controllers, FPGA and reaching PC type computers (equipped with specialized boards or interfaced with specialized modules).

Electronic control processes reference signals (programmed manually or automatically) or reaction signals (supplied by transducers) introduced as inputs in order to obtain as output of electric commands for actuators/ electromagnetic actuators.

A microprogrammed version to control two electromagnetic actuators ensure the implementation of the above functions. The drive of electromagnetic actuators can be made in open loop or closed loop. Closed loop version involves reading information from transducers, which can be independent or in the case of electromagnetic actuators these transducers can be even those actuators coils.

The microsystem based on microprocessor performs the following functions:

- Processes the received position information via an A / D inductive transducer on loop reaction
- Performs the function of PID regulator
- Acts as ramps forming based on scheduled commands
- Provides the interface I / O and D / A converters command signals of the two current generators that supply the two electromagnetic actuators.

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5. References

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