Frequency Response Modeling of Inductive Position Sensor with Finite Element Tools

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Abstract

Introduction: Position sensors find several applications in the automotive sector. Some of the common examples include automatic gear shifter module, seat position adjustment and accelerator-pedal position modules etc. Because of extreme weather condition, such as dust, humidity and moisture and fluctuation of temperature and wide operating temperature range (-40°C to +90°C) confronted by automotive electronics position sensing based on resistive or capacitive principles may not be suitable in many occasions. Instead, a non-contact type of inductive position sensor has several advantages in such applications.
The paper presents here a frequency response modeling of a planar spiral inductive coils printed directly on the PCB and can be used as a non-contact inductive position sensor. Due to the space restriction on the PCB often such coils have small size and 8-9 turns. Therefore, small size of the coil results in a small inductance value which may be insufficient for reliable position sensing. Therefore, inductive position sensing uses the multi-layer plannar coils with a sliding metal plate (copper [1]) over the planar coils, wherein the transducer generates a coil inductance/signal changing along with moving distance or angle under the function of eddy current damping at MHz frequecies. Plannar coils are fabricated directly on the PCB as flat coils and the inductance of three coils are influenced by the eddy current damping effect (see Figure-1).

Figure-1: Planar coils with copper activator/attenuator element

Use of COMSOL Multiphysics:
Higher the operating frequency is, larger is the eddy currents effect in the moving metal piece of sensor. Therefore, in the paper a multilayer (see Figure-2) planar coil operating at 12 MHz has been modeled wherein, each layer of coil is series connected and maintains a narrow vertical gap (100 µm) between two consecutive layers to produce a larger inductance value from the corresponding planar coil. The flat coil's inductance is damped or reduced due to the generation of eddy currents effect at higher frequencies by a thin Hexagonal or Rhombus shape sliding copper activator element (non-contact type).
The change of coil inductance values with sliding activator's distance over the planar coil form the basis of presented inductive sensor, which has been modeled and simulated with Comsol multiphysics tool.

Fig.-2: Modeling of planar coil with Comsol

Results: Figure shows the simulation results obtained from Comsol multiphysics

Figure-3: Comsol simulation results from planar coil
Figure-3 shows that frequency response modeling (with batch sweep) at 12 MHz frequency of two layer planar coil with Rhombus shape activator brings the coil inductance value from 750 nH down to L=338.4 nH. Inductance values change in the 1D plot group will be shown in the final paper. However inductance curve looks like inverted Gaussian function (like blue curve-thin line) as shown in MATLAB plot of corresponding voltage (Figure-4).

Figure-4: Equivalent voltage (mV) corresponding to planar coils' inductance change due eddy current damping effect. Coil inductance at 12 MHz was simulated with Comsol multiphysics.

The model has been utilized in the development of an automatic gear shifter module of a leading German car.

Reference

References:
[1] ZF-Friedrichshafen AG Patent-document: CN000101424508B