Design of An Integrated Gap Sensor for Urban Maglev Train

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ABSTRACT: This paper proposes the design of an integrated levitation gap sensor for urban maglev train. Three eddy current sensors have been integrated to solve the problem when passing through guide way gap. A pair of flat PCB detection coils has been integrated for self-diagnosis. Also the circuit is integrated by a single FPGA chip for linearization, frequency compound, AD interface and IO interface. EMI method is proposed in the end. Compared with the traditional ones, the proposed levitation gap sensor is much more digitalized and integrated.

1 INTRODUCTION

In recent years, urban maglev train has been well developed in China and other countries. Since it levitates at a constant gap during all the working time, it is very important to realize a kind of non-contact gap measurement device with less sensitivity to dust or grease. As a kind of suitable device, eddy current displacement sensor's theory is showed in figure 1. When detection coils excited by high frequency currents are closing to the conductor, equivalent mutual impedance is changed for eddy currents and static magnetic. Applied some signal processing circuits, the gap distance is reflected as changes of equivalent output voltage. Calibrating the relation between gap and output, the gap distance information can be easily measured[1-2].

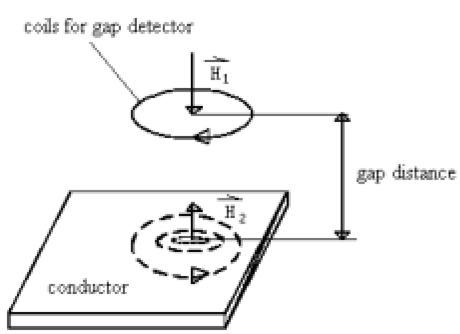

Figure 1. Theory of gap sensor

Since it is very important for levitation control system to keep stable, it is necessary to make research on some specialties about levitation gap sensors in urban maglev train. This paper proposes a novel design considering stability, reliability and maintainability of gap sensors. The subsequent experiments will be carried out in the future.

2 DESIGN FOR PASSING THROUGH GUIDE WAY GAP

In the urban maglev transportation system, long tracks are composed with a number of segments that exist many guide way gaps between each segment showed in figure 2. Some gaps are wider and some are narrower. Since the widest may reach about 30mm, it should pay attention to solve the problem of passing through guide way gaps because output of eddy current sensor may be affected by these gaps.

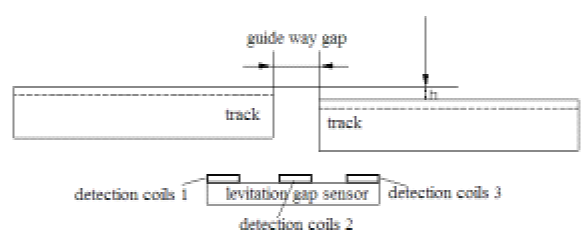

Figure 2. Scheme of position between tracks and sensor

As showed in figure 2, the sensor should include three coils which cover width of guide way gap to pass through the guide way gap smoothly. Because these coils are stimulated by a certain kind of AM and FM oscillating circuit, they have to be placed in a row with a larger distance to avoid detection electromagnetic field disturbance by each other. This may cause a larger structure of sensor which is the traditional type. To solve the problem, also three detection coils which are integrated in each oscillating circuit are placed one by one according to the largest guide way gap. It is showed in figure 3. The width of each coil must be lager than the largest width of guide way gap. Since these coils are each designed as a flat rectangle one stimulated by AM oscillating circuit with different specific frequency separately, detection electromagnetic field induced by each circuit do not disturb each other. As a result, distance between detection coils can be smaller than traditional ones and the proposed sensor can be compact.

When the sensor is passing through the guide way gap, levitation controller can choose the right two signals easily by comparison because output of the one below the guide way gap is affected clearly.

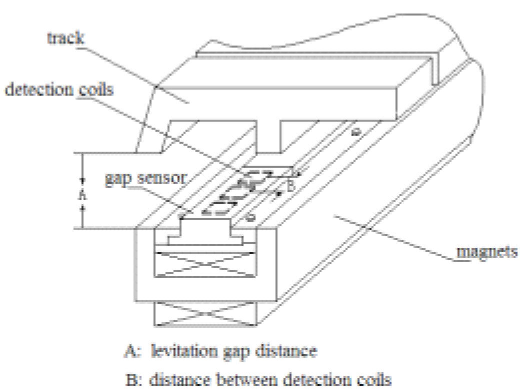

Figure 3. Gap sensor and track

3 DESIGN FOR SELF-DIAGNOSIS

As mentioned above, the proposed sensor composes three circuits which measure gap distance separately to pass through guide way gap smoothly. In the traditional sensor, the spiral coils cannot be integrated together to sense the same levitation gap not only for the AM and FM oscillating circuit but also for the structure of coils. Since it is very important to keep levitation control system reliable, gap sensors are one of key devices which are distributed in the train. The proposed sensor should be realized self-diagnosis which is much harder for traditional one[3].

Because detection coils are designed as PCB circuits, each can be designed as a pair one composed with two coils which located at the same place in different layers of board. It is showed in figure 4. Since each coil inspired by the same frequency in the pair detects the same gap distance, outputs should be the same value if sensor does not fail. Based on the rule, each output in the pairs can be compared to judge if sensor is in failure. As a result, the sensor can realize self-diagnosis by calculations showed in figure 5.

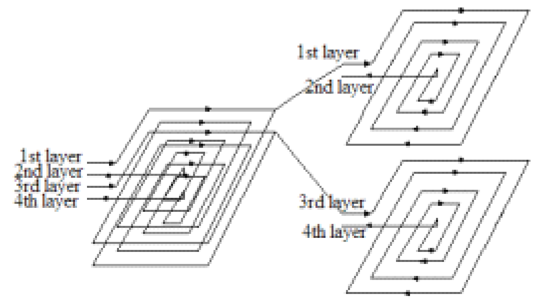

Figure 4. The proposed detection coils

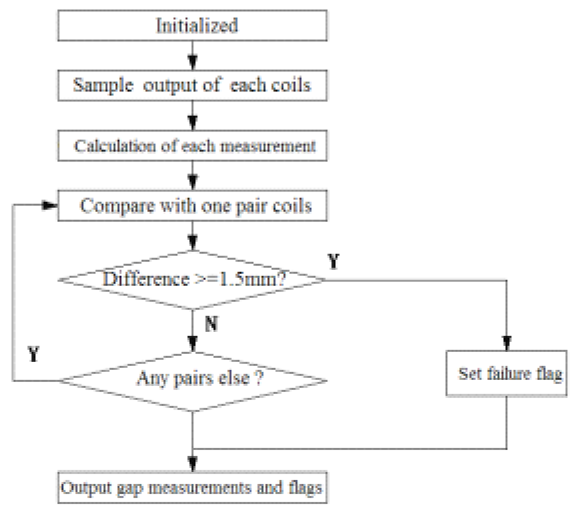

Figure 5. Self-diagnosis calculation

4 DESIGN FOR INTEGRATION BY FPGA

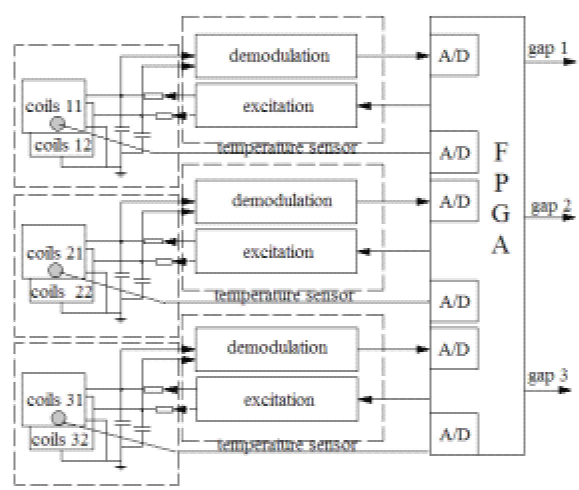

Figure 6. Scheme of proposed gap sensor

Because three eddy current sensor circuits have to be integrated into one gap sensor, integration should be considered greatly. Otherwise it may be too complex to be reliable. Figure 6 is the scheme of proposed gap sensor. In the scheme, there are oscillating circuits, excitation circuit, demodulation circuit, AD sample circuit and FPGA circuit. In the proposal, except the analog circuit all the rest digital circuits are designed by FPGA which include linearization, frequency compound, AD interface and IO interface to levitation controller.

To realize frequency compound, FPGA divides the frequency from one crystal oscillator and yield each specific frequency for excitation circuit by a little complex calculation. Also to realize linearization, FPGA can look up a table which is founded between the circuit outputs and gap distance involving the consideration of temperature drift. Furthermore it is easy to realize a specific communication rules between gap sensor and levitation controller. Since all the mentioned can be programmed by VHDL language with a single FPGA chip, the real circuit of gap sensor becomes integrate and flexible.

5 DESIGN FOR EMC

Because gap sensor is mounted between the magnets and tracks, the electromagnetic field environment is complex. It is important to consider the EMC method.

To avoid electrostatic discharge immunity and radiated electromagnetic field immunity, all the circuits of gap sensor are wrapped up in the cage proposed in figure 7. This cage is casted wholly and precisely with aluminum alloy.

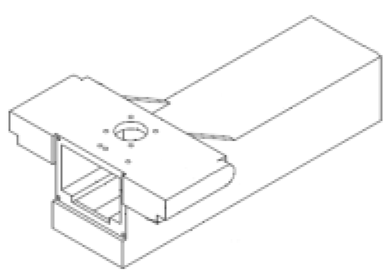

Figure 7. Cage of proposed gap sensor

To avoid electrical fast transient/burst immunity and immunity induced by radio-frequency fields, some proposals have realized in the supply powers. Figure 8 shows that two stage filters have been designed to endure some EMC tests, such as electrical fast transient or burst immunity test and surge immunity test[4]. When input passes through the first filter, the common mode disturbance has been eliminated. And the second filter can eliminated the differential mode disturbance.

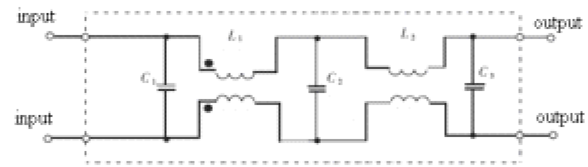

Figure 8. EMI filter circuit

6 CONCLUSION

A levitation gap sensor for urban maglev train has been proposed to realize a digitalized one for stability, reliability and maintainability.

By integrating three pairs of coils into a flat PCB board, the proposed gap sensor can provide two effective gap measurements when passing through guide way.

By comparing outputs of two coils located at the same place, the proposed gap sensor can realize self-diagnosis which is much more important in the urban maglev train.

By integrating the circuit with a single FPGA chip, the proposed gap sensor can realize a flexible and compact structure.

By using whole cage casted aluminum alloy and EMI filter circuit, the proposed gap sensor can realize reliable and stable gap measurement to levitation control systems.

The subsequent experiments will be carried out in the future.

7 REFERENCES

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