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6 Development of the cost-effective accelerometer for industrial applications

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Abstract

JAE has been offering a lineup of the quartz-type servo accelerometers that enable highly accurate measurements. There is a need for products that are cost-effective even in the market for servo accelero-meters, by the rise of MEMS accelerometer.

Based on our experience in product development, we have utilized simulations (magnetic analysis, stress analysis, etc.) to reduce the number of parts and simplify the shape of parts while maintaining product performance, resulting in a cost-effective accelerometer.

This paper introduces the outline of development of the cost-effective accelerometer JA-80GA.

1. Introduction

Servo-type accelerometers are used in a variety of applications, including vibration measurement for seismographic networks, vibration control in semiconductor manufacturing equipment, and tilt control in railway vehicles, and servo-type accelerometers from JAE are also employed in vibration measurement applications for semiconductor manufacturing equipment and seismographic networks. Up until now, JAE has featured ultra-high precision measurement (capable of detection of 1 μG of acceleration), but a strong demand has emerged for lower-cost sensors in the general industrial machinery market. We would like to provide an overview and introduce the features of the low-cost accelerometer JA-80GA, which we have developed for general industrial machinery, with the intention of reducing the number of component parts and simplifying their shapes while utilizing simulations and maintaining product performance with regard to resolution, noise, and the like.

Figure 1. External view of low-cost accelerometer JA-80GA for general industrial machinery

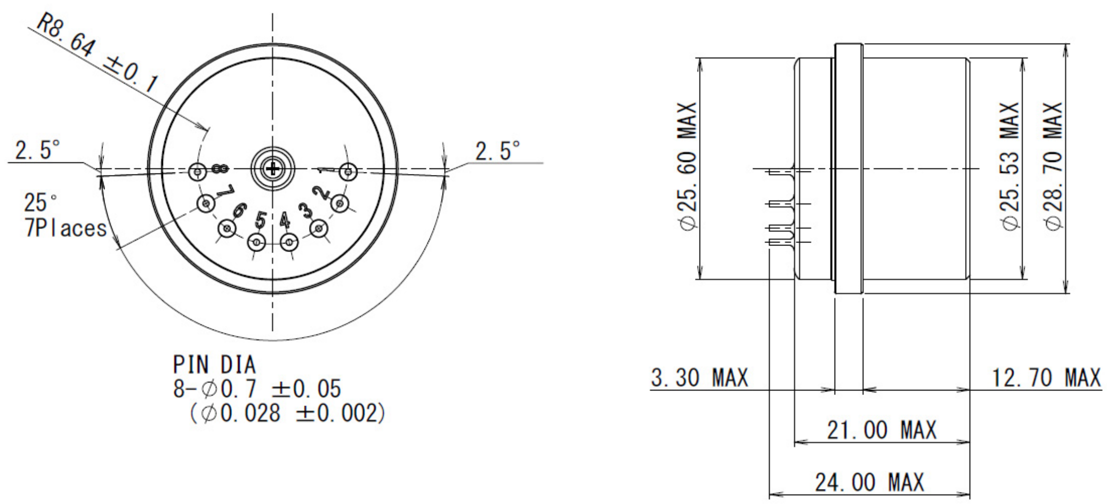
2. Product specifications

The basic specifications of the low-cost accelerometer JA-80GA for general industrial machinery we have developed are shown in Table 1.

Table 1. JA-80GA accelerometer specifications

Item		**Specification value**
Basic performance		
Measurement range		±30 G
Noise (@1–30 Hz)		0.7 μG/√Hz or less
Resolution		1 μG or less
Scale Factor	Nominal value (25°C)	1.33 mA/G ±10%
	Temperature coefficient (25°C)	Within ±180 ppm/°C
	One-year stability	Within ±1,200 ppm
Bias	Nominal value (25°C)	Within ±8.0 mG
	Temperature coefficient (25°C)	Within ±70 μG/°C
	One-year stability	Within ±1,200 μG
Environment		
Temperature range		−55°C to +96°C
Vibration resistance		25 G_{0-p}
Shock resistance		250 G
External dimensions		⌀28.70 × 24.00 mm
Mass		50 grams or less

External view



3. Product configuration

As shown in Figure 2, a servo-type accelerometer has three parts.

- Mass section : Senses acceleration
- Detection section : Converts movement of the mass section into a detectable form
- Torquer section : Controls the mass section always be at the same position.

Once displacement of the mass section has been converted into an electrical signal by the detection section, a restoring force is generated by the torquer section using this signal, controlling the mass section to always be in the same position. The electrical signal used to generate the restoring force is proportional to the acceleration, so reading it allows acceleration to be sensed. Generally, a feedback mechanism for this kind of positional control of an object is called a servo mechanism, and an accelerometer that includes a servo mechanism is called a servo-type accelerometer. In the JA-80GA accelerometer, quartz is used in the mass section, which has a hinge section (fulcrum) that supports the pendulum using the spring-like characteristics of the material itself, referred to as a flexure hinge. In order to minimize error (zero-point unbalance), this hinge section must be processed to be extremely thin. We have been successful in utilizing electromagnetic simulations to adjust the restoring force of the torquer section, reducing the number of component parts and simplifying their shapes to lower costs while maintaining product performance.

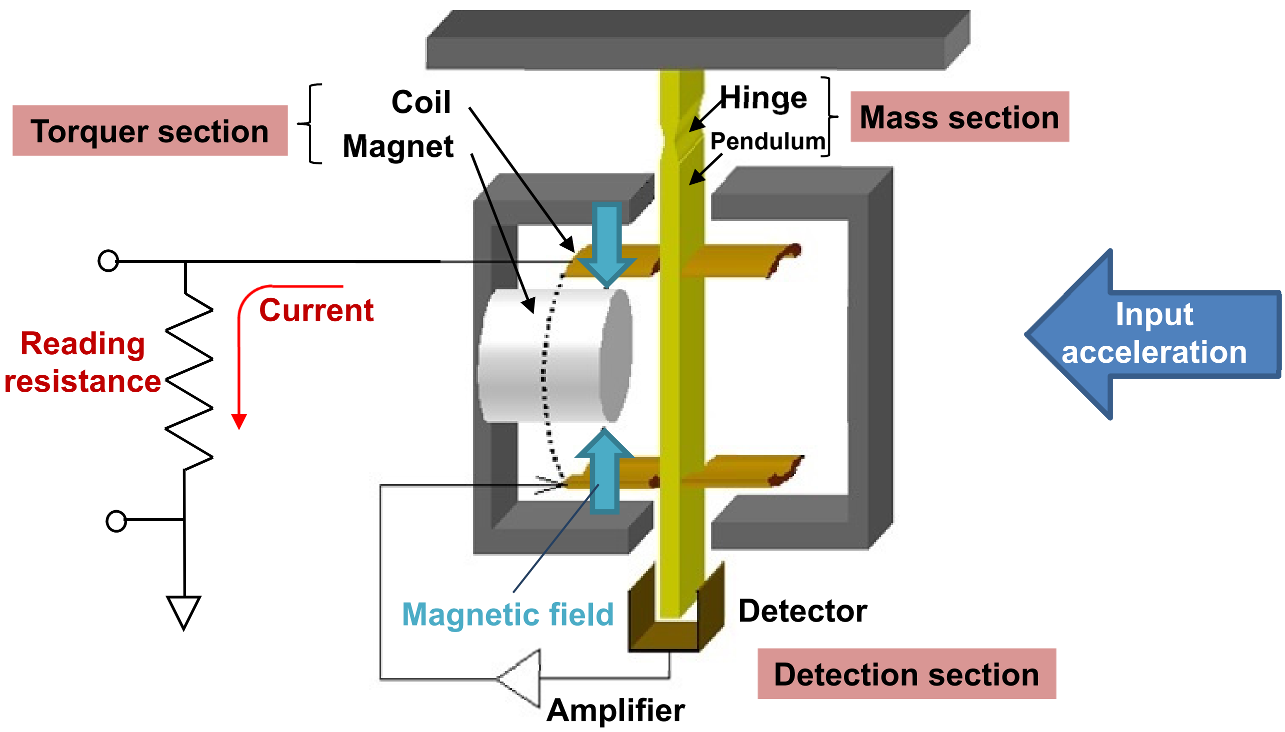


Figure 2. Servo accelerometer: Diagram of principles

4. Product performance

4.1. Measurement range, temperature characteristics of scale factor, and noise characteristics

We have successfully reduced the number of component parts of the magnetic circuit while simplifying their shapes through magnetic circuit simulations, as shown in Figures 3 and 4, while maintaining product performance. The most important perspective in a simulation is how small the deviations can be made between the parameters used by the simulator and the actual product, and this can determine whether the simulation succeeds or fails. By incorporating the experience and know-how we have cultivated through long years of accelerometer development when designing the parameters of this simulation to improve simulation accuracy, we were able to produce an accelerometer that met all the product performance requirements, as shown in Figures 5–7, with a single initial prototype that required no revision.

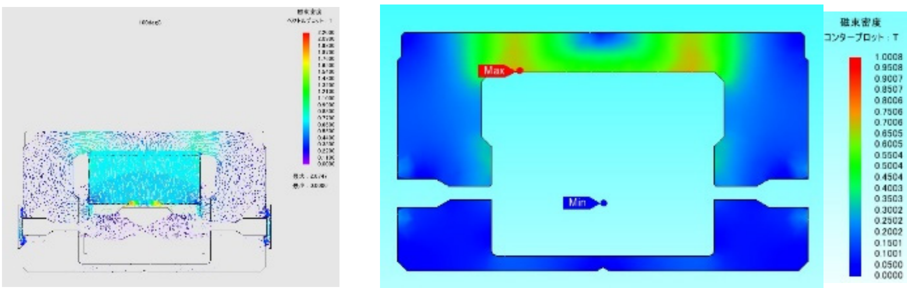


Figure 3. Example of magnetic simulation analysis of magnetic circuit (at room temperature)

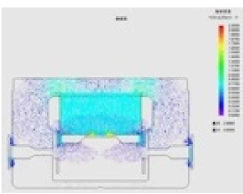
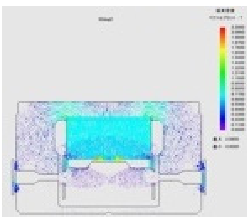
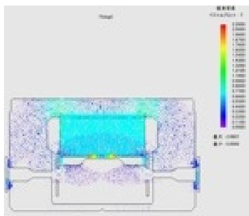
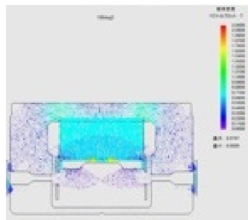
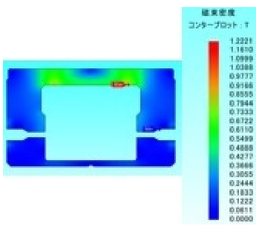
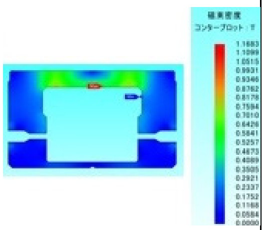
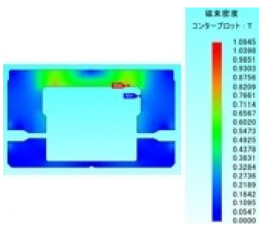
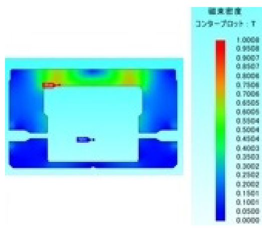
	25°C	50°C	75°C	100°C
Magnetic flux distribution Vector diagram				
Magnetic flux density distribution Contour diagram				

Figure 4. Example of magnetic simulation analysis of magnetic circuit (at applied temperatures)

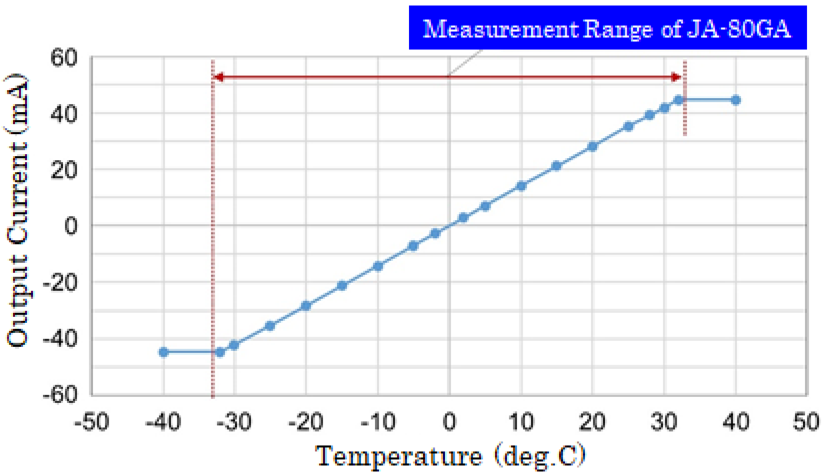


Figure 5. Measurement range (representative example of actual measurement data for initial prototype)

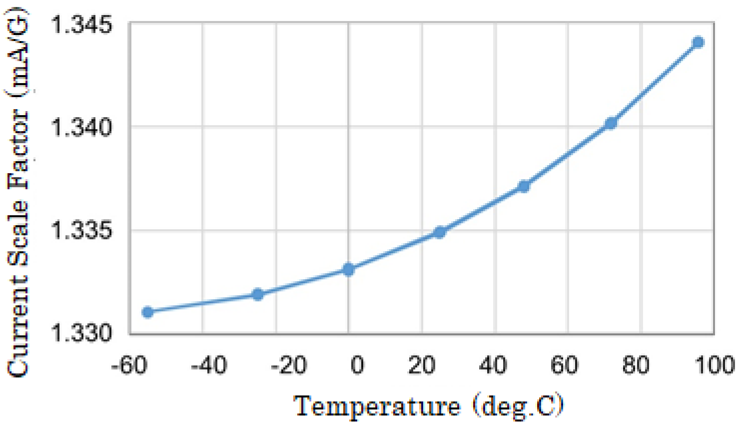


Figure 6. Temperature characteristics of scale factor (representative example of actual measurement data for initial prototype)

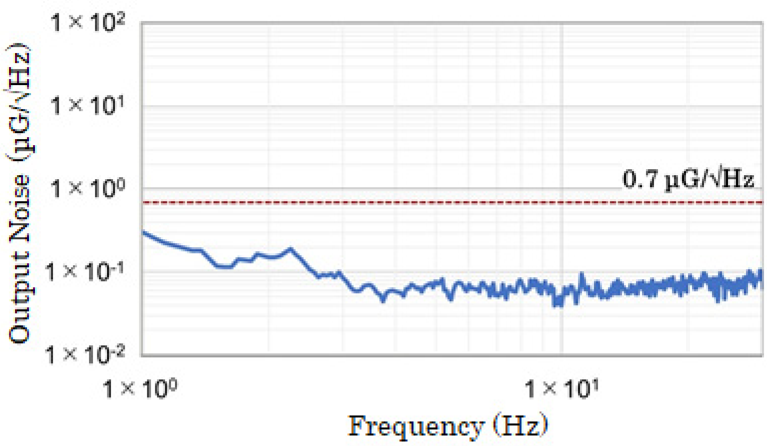


Figure 7. Output noise (representative example of actual measurement data for initial prototype)

4.2. Vibration resistance performance

We have also checked the vibration resistance performance of the JA-80GA through vibration testing in order to confirm that it can be installed in applications that require vibration resistance performance. Using a vibration tester (Figure 8), random vibration patterns (Figure 9) were applied, and Bias trends (Figure 10) were checked before and after vibration was applied.

Figure 8. Vibration tester

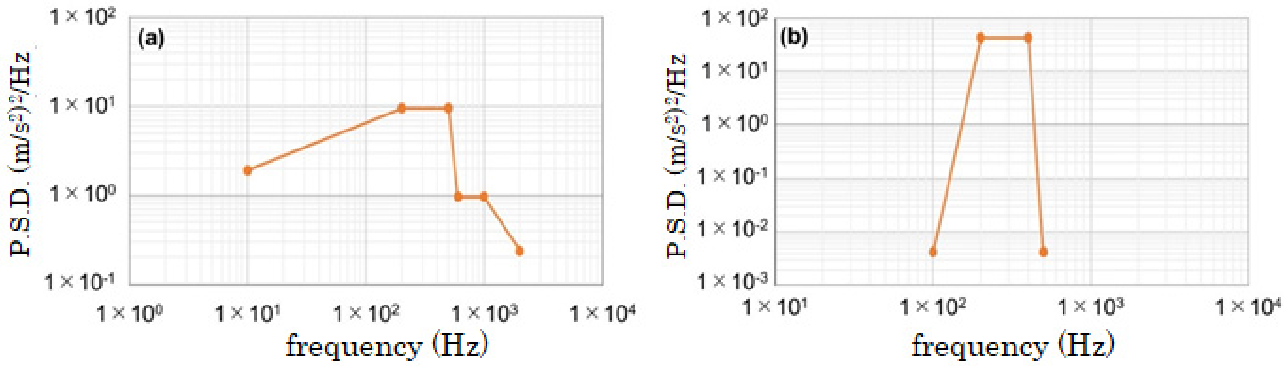


Figure 9. Random vibration patterns

(a) FT-Vib, (b) HEFT-Vib

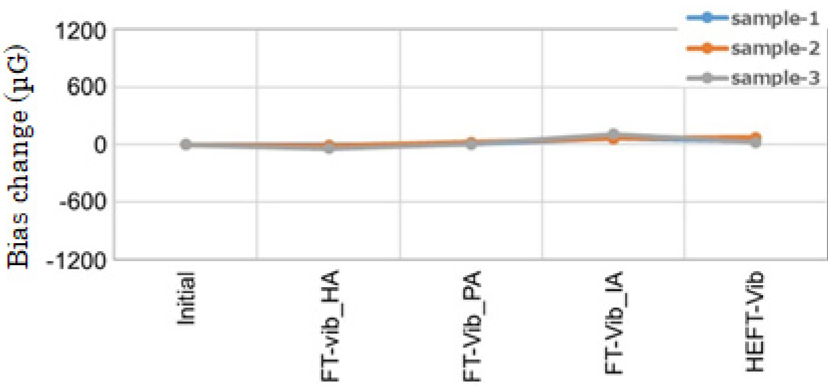


Figure 10. Bias trends by applying vibration

5. Summary

By reducing the number of component parts and simplifying their shapes while maintaining product performance, we have developed a low-cost accelerometer for general industrial machinery.

We would like to make use of our strengths as a sensor manufacturer that has begun to manufacture and supply accelerometers for general industrial machinery, which are key sensors for vibration control, while responding to a wide range of market demands and producing even lower-cost servo accelerometers.

