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Field Tuning of Linear Resonant Actuators Using Motion Sensor Feedback

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ABSTRACT

Linear resonant actuators (LRAs) create tactile feedback in consumer devices by generating vibrations. LRA characteristics can change with time due to environmental conditions, thereby degrading the performance of the LRA. Variations in LRA performance can be compensated during operation by using techniques of parameter detection, measurement, and correction, which themselves rely on accurate back EMF measurement. A back EMF test is accurate so long as the LRA is stationary, the device is lying on a flat, vibration-free surface, and is free of external movement. This disclosure describes techniques that ensure accurate measurement of LRA parameters by performing back EMF measurements when onboard motion sensors indicate zero or low device motion.

KEYWORDS

- Linear resonant actuator (LRA)
- Motion sensor
- Field tuning
- Tactile feedback

BACKGROUND

Linear resonant actuators (LRAs) are widely used in consumer devices, e.g., cellular phones, trackpads, gaming consoles, etc., to provide tactile feedback by generating vibrations. The performance and effectiveness of LRAs can be quantified by the amount of acceleration they generate for a given mass. Acceleration generated by LRAs depends on their internal structure, which usually includes coils, magnets, moving masses, etc.

During operation, the characteristics of the internal structures of the LRAs can change with time due to environmental conditions such as temperature, humidity, accidental dropping of the device, etc. Such change in internal structures can degrade the overall performance of the LRA. Variations in LRA performance can be compensated by using certain techniques of parameter detection, measurement, and correction.

The parameters of the LRA that are measured to correct for performance include its resonant frequency (F0), resistance (ReDC), Q-factor, acceleration, etc. These parameters can be extracted by measuring and analyzing the back electromotive force (EMF) generated by the LRA. The back EMF measurement or self-test can be done in the field, e.g., upon internal triggering by the control systems of LRA. While performing a back EMF test, the LRA is to be stationary, lying on a flat, vibration-free surface, and free of external movement. If these conditions are not satisfied, the back EMF measurement becomes inaccurate.

In some devices, Hall effect sensors monitor the field performance of an LRA and apply appropriate corrections. However, this technique uses additional sensors and circuitry that increase the cost of the device.

DESCRIPTION

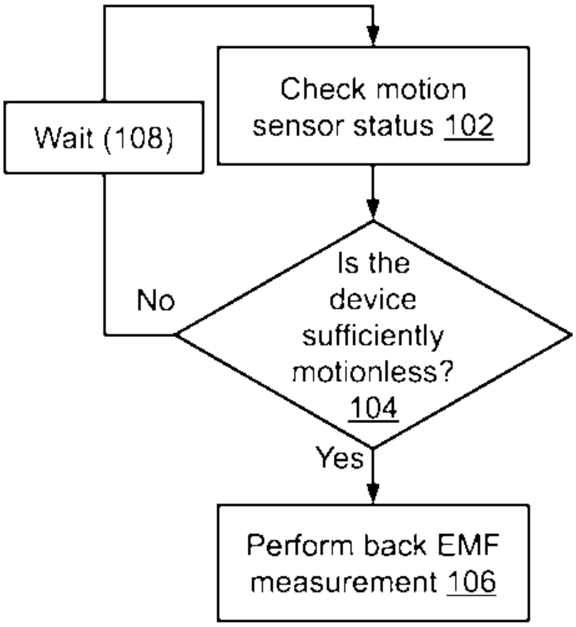

Fig. 1: Field tuning of linear resonant actuators using motion-sensor feedback

Fig. 1 illustrates field tuning of linear resonant actuators using motion sensor feedback, per techniques of this disclosure. In various consumer devices, there are typically motion sensors, e.g., accelerometers, gyroscopes, magnetometers, inertial measurement units, etc., that can detect six degrees of freedom motion, where each of three degrees of freedom represent displacement and rotation of the device body along the X, Y, and Z axes.

When the LRA is scheduled to conduct a back EMF self-test, the motion sensor status is checked (102), e.g., by a controller or CPU of the device. If the motion sensor readings indicate that the device is sufficiently motionless (104), e.g., the device is not moving or vibrating, or its motion is within a small, acceptable range, the back EMF measurement is performed (106). If the motion sensor readings indicate that the device is insufficiently motionless, the back EMF self-test is not immediately performed. Rather, after a suitable wait period (108), the motion sensors are checked again. In this manner, the techniques enable a reliable back EMF measurement made in a motion-free environment, from which LRA parameters can be accurately extracted.

CONCLUSION

This disclosure describes techniques that ensure accurate measurement of the parameters of linear resonant actuators by performing back EMF measurements when onboard motion sensors indicate zero or low device motion.