Development of Compact Auto Focus Actuator for Camera Phone by Applying New Electromagnetic Configuration

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In this paper, auto focus actuator, which is used to move a lens module in the mobile phone having a camera module, is developed. Camera module containing auto focus actuator requires to minimize total size because of characteristics of the application area such as mobile phone, digital camera, and personal digital assistant. There are stepping motor, voice coil motor, and piezoelectric motor as auto focus actuator. In this paper, voice coil motor having new electromagnetic configuration is proposed. And actuator using proposed voice coil motor is developed by optimal design method using magnetic circuit analysis. The sectional area of the developed actuator is reduced to 32.4% compared with actuator using general electromagnetic configuration. From the performance test, the developed actuator has moving stroke of 0.64 mm for 2.1 volt, hysteresis of 40 μm, full stroke current of 54 mA, and unit step motion of 3 μm.

Key Words: Auto Focus Actuator, Camera Phone, Camera Module, Magnetic Circuit Analysis, Optimal Design

Nomenclature

\[ b_{arm} : \] Arm width of the plate spring  
\[ B_g : \] Magnetic flux density at the air gap  
\[ B_r : \] Remanence flux density of the magnet  
\[ d_{coil} : \] Diameter of the coil  
\[ E : \] Young’s modulus of the plate spring  
\[ F_{emag} : \] Electromagnetic force  
\[ F_{min} : \] Minimum electromagnetic force  
\[ g : \] Air gap  
\[ h_{coil} : \] Coil winding thickness  
\[ h_{mag} : \] Thickness of the magnet  
\[ i : \] Current flow  
\[ i_{max} : \] Maximum current  
\[ k : \] Spring constant of the plate spring  
\[ k_{mi} : \] Magnet leakage factor  
\[ L_{arm} : \] Arm length of the plate spring  
\[ l_e : \] Effective length of the coil facing with magnet  
\[ n : \] Coil winding number  
\[ R : \] Resistance of the coil  
\[ r_b : \] Inner diameter of the barrel  
\[ t : \] Thickness of the plate spring  
\[ t_b : \] Thickness of the barrel  
\[ T_c : \] Temperature of the coil  
\[ t_{yoke} : \] Thickness of the yoke  
\[ V : \] Applied voltage  
\[ w_{coil} : \] Coil winding width  
\[ a_m : \] Magnet fraction  
\[ \delta : \] Moving stroke  
\[ \mu_r : \] Recoil permeability of the magnet  
\[ \rho : \] Resistivity of the coil

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1. Introduction

The mobile phone having a camera module is
called camera phone. Camera module consists of image sensor, lens module, infra red (IR) filter, housing, printed circuit board (PCB), flexible PCB (FPCB), and connector as showed in the Fig. 1 (Lee, 2004).

Recently, in the market of the camera phone, number of pixels in the image sensor has been increased for acquisition of the market share. Camera phone using high pixel image sensor having above 2.0 mega pixel required to have an additional function such as optical zoom and auto focus. Because these functions need the actuator for moving lens module, camera phone becomes bulky. Camera module containing auto focus actuator requires to minimize total size because it is inserted in the mobile phone. Therefore, study for minimization of the actuator using for optical zoom and auto focus has been conducted by the many researchers (Kim, 2001; Choi, 1999).

In this work, auto focus actuator, which is used to move a lens module in the mobile phone having a camera module, is developed. There are stepping motor, voice coil motor, and piezoelectric motor as auto focus actuator. A voice coil motor having new electromagnetic configuration is proposed. And actuator using proposed voice coil motor is developed by optimal design method using magnetic circuit analysis. Camera module having the developed actuator, image sensor, and electric circuit is attached to the image processing system. Performance test is conducted to verify the developed actuator.

2. Comparison of Electromagnetic Configuration

The driving methods such as stepping motor, voice coil motor, and piezoelectric motor are used usually as an auto focus actuator in the camera phone. Among these driving methods, stepping motor has disadvantage of large size and piezoelectric motor has disadvantage of low repeatability (Kim, 2005). On the other hand, voice coil motor has advantage of small size and high repeatability, so selected as the actuator for camera phone. Table 1 lists the advantages and disadvantages of the each driving method (Chung, 2005).

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Stepping motor</th>
<th>Piezoelectric motor</th>
<th>Voice coil motor</th>
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<tbody>
<tr>
<td>Shock stability</td>
<td>Power loss</td>
<td>Size</td>
<td></td>
</tr>
<tr>
<td>Disadvantage</td>
<td></td>
<td>Repeatability</td>
<td>Power loss</td>
</tr>
</tbody>
</table>

2.1 Electromagnetic configuration

In general, voice coil motor for auto focus actuator has electromagnetic configuration as shown in Fig. 2(a); winding coil is fixed in the barrel having lens module, and magnet attached at the yoke is faced with the each winding coil. Whereas proposed electromagnetic configuration is that winding coil is wound in the barrel with different winding direction. And magnet fixed at the yoke has different magnetization direction to face with winding coil as shown in Fig. 2(b).

2.2 Comparison of magnetic flux density

Finite element analysis (FEA) is used to cal-