Response-Time Performance Evaluation of Liquid Cristal Lens Cell based on Effective Voltage Feedback Control

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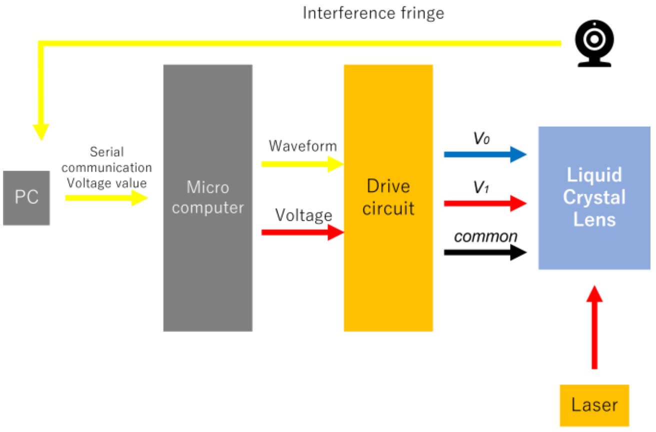
In recent years, digital camera technology has been used in a variety of situations ranging from single-lens reflex cameras to smartphones, small cameras such as security cameras, and medical cameras. Particularly in an automotive industry, it is broadly used as one of core sensors required to recognize a distance to traffic signs, road surfaces, and obstacles. Camera systems that capture enlarged or reduced images are essential for this application. Currently, optical zoom systems and digital zoom systems are the mainstream. The optical zoom system is a zoom system similar to that used in single-lens reflex cameras. Although it can take high-resolution and high-quality pictures, it requires more space and electric power to drive itself. The mechanical optical zoom system must be continuously moved along the optical axis according to a mechanical mechanism using piezoelectric elements and stepping motors to move each lens in the unit to its appropriate position. In contrast, the digital zoom method used in smartphones and other devices is compact because it uses an image processing technique to enlarge or reduce the image by software, but the image quality is degraded.

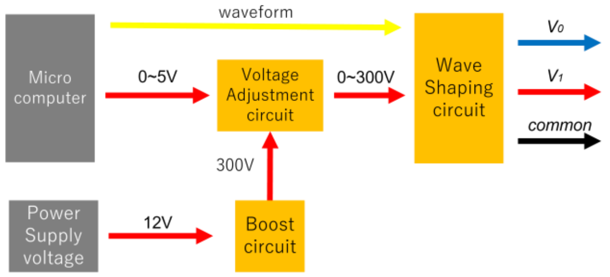
Our research on liquid crystal lenses is exactly one of the research projects aiming at solving the above-mentioned problems. A liquid crystal lens cell is a lens that can generate the lens effect by applying alternative voltages to its transparent electrodes and can change its focal length in a non-mechanical manner. By using a pair of the liquid crystal lens cells, the optical zoom system used in conventional camera systems can perform without any mechanical part. However, the most severe problem of the liquid crystal lens is that its response is too slow to achieve a required focal length. To address this issue, previous studies achieved a more quick response by using unique control methods and driving circuits.

Based on other issues raised in the previous studies, a configuration of our proposed liquid crystal lens visual feedback system is shown in Fig. 1. In this study, an interference optical system is combined with a driving system of the liquid crystal lens. First, a value of an effective voltage is commanded from a PC to an embedded microcontroller. Next, the microcontroller sends voltage reference values and waveform commands to the driving circuit to generate our required waveform. Then, the amplified voltages are applied to the liquid crystal lens to drive it, as changing according to a sampling time of 0.5ms.

By irradiating a planar wave expanded from a laser beam to the driving liquid crystal lens, interference fringes are generated. The interference fringes are observed by a CMOS camera and input into an image processing PC to estimate the focal length of the driving liquid crystal lens at a time of observation. Then, the estimated focal length is used for visual feedback control of the liquid crystal lens.



(a) System architecture



(b) Drive circuit
Fig 1. Feedback System