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Front-end design of high precision displacement sensor based on linear array CCD

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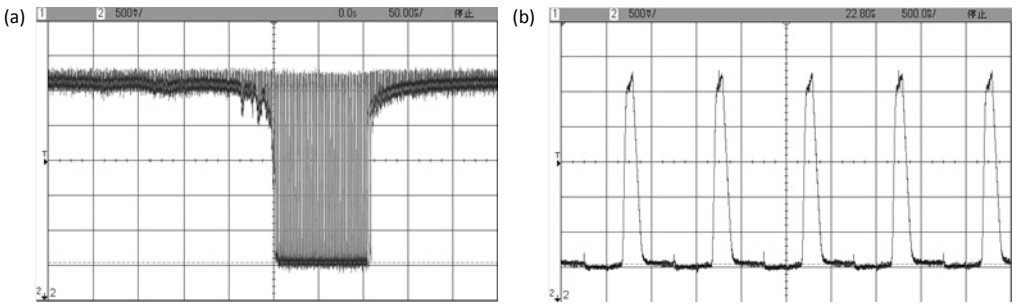

Output signal waveform of OS. (a) The OS output waveform of one scan cycle.
(b) The signal waveform of pixels which spot illuminates.

Abstract: The laser displacement measurement system has great demand in the field of measurement in China, but the domestic measurement of displacement equipment are different from foreign products in the miniaturization and performance, existing large volume, low accuracy, limit of application environment and other issues. Moreover, the research on displacement measurement system based on CCD still remains in the laboratory stage and cannot be manufactured. In order to achieve the high-precision non-contact measurement for tiny displacement, a high-precision displacement sensor front-end module is designed based on linear array CCD. The laser is used as a displacement signal transmission medium. The principles of laser triangulation and "Scheimpflug" theorem are used to design an optical lens. The light spot reflected by the measured surface is focused on the photoelectric sensor. According to the structure of linear array CCD and drive timing analyses, the system uses the FPGA to generate the drive pulse timing required for the linear array CCD, and the inverter to improve the driving ability to drive linear array CCD normally. The CCD pixel outputs the one-dimensional video signal and compensation signal after the spot is illuminated. Differential amplifier circuit and low-pass filter circuit are applied to eliminate the reset pulse crosstalk and high frequency noise interference, and a stable analog signal is output, which is available for digital circuits for high frequency sampling to obtain digital signals. Thereby the size and position of the spot center are obtained through the image processing algorithm. When the measured surface moves, the position of the spot center on the CCD also moves. According to the laser triangulation principle, we can calculate the displacement of the measured surface in the direction of the optical axis. The system has the characteristics of simple structure and small volume. The design of integrated circuit meets the measurement requirements, such as stable output signal, high resolution and high precision. Moreover, the designed optical structure meets the requirements, and linear array CCD driving circuit is simple and applicable, aiming at the front-end acquisition and amplification. Experimental tests show that the sensor front-end module outputs are stable with small interference analog signal after calculation. The maximum range is ±15 mm, and the accuracy can reach 20 μm after image processing. The system can be widely used in the precise measurement of tiny displacement, and has a strong practicality and guidance for engineering design. In the future, the system should be further designed and improved in terms of analog signal acquisition, A/D conversion, digital signal processing and image processing. So that it can make a complete and accurate measurement of the displacement and be suitable for practical applications and the need for production.

Keywords: displacement sensor; linear array CCD; laser triangulation; drive timing; signal processing

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