Teaching and Design on Integrating Interpolation Electronics for Nanometer Measurement and Positioning

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ABSTRACT

This paper presents a method, to teach the senior students how to integrate the multi-domain knowledge of electronics, optics, control as well as precision measurement, and proposing a high resolution subdividing electronics module to the sinusoidal encoder output of positioning motor, such that the module can not only be used as a counter for linear and/or angular measurements, but also subdivide the periods of the sinusoidal encoder signals up to 1600 times.

Firstly, the most important role on the interpolation electronics design is portrayed, including complex programmable logic device (CPLD), digital noise filter, digital frequency multiplier and the whole interpolation circuit. Lots of logic devices are housed in one CPLD. Those connections can be specified using the development program. The function of the CPLD device can be made by using the development language (VHDL, Verilog, ABEL) or by the way of graphic editing. CPLD is convenient that it is possible

to rewrite many times, because the contents of the circuit are recorded to the flash memory. CPLD with In-System Programmability (ISP) can help accelerate development time, facilitate in-field upgrades, simplify the manufacturing flow, lower inventory costs, and improve printed circuit board (PCB) testing capabilities.

For digital noise filter, digital frequency multiplier and counter, we use M4A5-64/32 CPLD, which manufactured by Lattice®. For interpolation main function, we use EP1K30 CPLD, which is been categorized to Field Programmable Gate Arrays (FPGA) by Altera®.

For counting the signals in quadrature with 90 degrees of phase difference, normally, the requirement is that the two waves have the same amplitude as well as DC offset. So, they can be represented as signals of cosine and sine. Using these two signals we can get the arctangent (ATAN) value, the corresponding phase angle will also be obtained when we interpolate the waves within a single period. Finally, we can convert the phase angle into displacement.

But for the variation of actual signals in quadrature, they are not always satisfy these required terms. Such as quadrature laser interferometer, amplitude and DC offset voltage of output signal will be influenced by laser intensity and measuring distance. With the result, the amplitude and DC offset voltage will be variable. Also the phase difference of these two signals will be changed by the variance of laser polarization, and not always be 90 degrees. All of

these parameters will affect the accuracy of displacement measurement.

Secondly we briefly describe the mechanism for test, including stepping motor and its driver module, Linear Variable Differential Transformer (LVDT) and its signal processing module, optical encoder, as well as the digital circuit with high speed 8051 microprocessor. In which the sinusoidal encoder and laser interferometer are frequently used for nanometer position control. At last, the purpose of laser interferometer and its operation principle are illustrated.

From the results of experiment test it can be seen that the whole module is suitable for those applications requiring high-resolution encoder, nanometer measurement as well as fast data acquisition with phase tolerance of ± 45 degrees.

Keywords: Subdividing, Interpolation, Angle Encoder with Sinusoidal Voltage Output, Linear Scale, Quadrature Phase Interferometer, Precise Positioning