Abstract

Angle sensors are quite useful in many fields, such as automotive, aerospace, process and manufacturing industries, etc. Tunneling Magneto-Resistance (TMR) technology provides compact, high-sensitivity sensing solution at low price and power consumption, and is now becoming a popular choice for angle sensing. These sensors possess analog sine-cosine natured transfer characteristic that can depend on some non-ideal parameters. Simple and efficient electronic front-ends are necessary for these sensors. Such front-ends should provide features like linearization and digitization, high accuracy, wide range, and minimal dependence on non-idealities. This thesis reports the design, analysis, and performance evaluation of a number of front-ends, with afore-mentioned features for TMR angle sensors.

The thesis, first describes a simple direct-digital front-end that performs modulation of the TMR sensor outputs using a quadrature-shifted sine waves, followed by a phase-to-digital conversion. This scheme gives linear output with-respect to angle over full-circle range. Next, the thesis proposes an innovative methodology which can minimize the adverse effect of two major non-idealities, namely, phase-error of the oscillator and parasitic capacitances of the TMR elements. Two linearizing digitizers are proffered to implement this method. The first digitizer uses an advanced circuit to render a low-conversion time, while the second circuit uses architecture of low-component count. The thesis, then, describes a novel linear digital front-end that employs an improved sinusoidal-to-time-period conversion logic on a DC-excited TMR sensor. This scheme is also suited for continuously rotating targets.

The thesis, in its latter half, focuses on the ratiometric measurement techniques, suitable for TMR angle sensors. The proposed techniques are realized using an oscillator-less direct-digital front-end, employing a voltage-to-frequency converter. This approach eliminates the errors associated with the sine wave oscillators of the previous works. Further, the thesis discusses improved front-ends, based on dual-slope technique, for TMR angle sensors. Finally, the feasibility of using resistance-to-digital converters for TMR half-bridges is also explored.

Extensive error analysis is carried out to quantify the effect of non-idealities of the developed front-ends. Detailed performance evaluation is conducted using simulation, emulation, and experimentation with a commercial TMR angle sensor. The findings from these studies are described in the thesis.

Keywords: Angle sensors, Direct-digital measurement, Error analysis, Linearization, Misalignment studies, Ratiometric operation, Static and dynamic response, Tunneling Magneto-Resistance.