Efficient Digitizing Interface Circuits for Various Resistive Sensor Configurations with Considerations on Wide-span and Remote Measurements

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by

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Abstract

Resistive sensors are widely employed for several applications in automobile, aerospace, chemical, and other process industries. They are routinely used for the measurement of physical variables such as temperature, displacement, magnetic field, and force. The properties (such as simplicity in construction, durability, good dynamic range, and low cost) of resistive sensors make them an excellent choice for the above measurement scenarios. There are different variants and configurations (e. g., single element, differential sensor, and bridge-based versions) of resistive sensors. Several other measurement challenges (including remote measurements, wide-operational span, non-linear transfer characteristics, and presence of secondary sensing elements) are associated with industrial resistive sensors.

Efficient interfacing electronics are required to process the resistive sensors and realize automated instrumentation systems. This thesis proposes the design and development of simple and efficient digitizing interface circuits for broad classes of resistive sensors. Initially, this thesis focuses on the design and development of a dual-slope-based digitizer suited for different resistive sensor configurations. This digitizer enables constant current excitation and can be used to control self-heating errors. Moreover, the circuit uses only a single reference voltage. Next, an alternate technique based on the relaxation oscillator principle is proposed. This scheme provides many meritorious features such as simple architecture, low output error, adaptability with various resistive sensor configurations, independence from many circuit nonidealities, etc. Further, this scheme is enhanced to adapt with wide-span sensors. This scheme implements a novel multiregiming technique, based on geometric series principles, and provides low conversion time for the entire measurement range.

Further, digitizing schemes for remotely-located resistive sensors are also proposed. The proposed digitizers with inbuilt wire resistance compensation show excellent immunity against the connecting leads. These circuits are suitable for a broad class of resistive sensors including bridge configurations. The proposed universal

digitizer for bridge-based sensors shows independence from the mismatch of wire resistances and parasitic elements of sensors.

The thesis later focuses on the design of a simple microcontroller-based scheme for remotely-located resistive sensors. This scheme can be easily modified to adapt with the various class of resistive sensors. This technique has the advantage of independence from microcontroller threshold voltages, low power consumption, wide range measurement, etc. Later, this technique has been enhanced for the interface of RC impedance sensors. Here, this enhanced method is useful to measure the resistance as well as the capacitance of RC sensors. Finally, a digitizing circuit for another special type of resistive sensor (e. g., thermistor) is also proposed. This method proposes a novel linearization approach to linearize the output of the thermistor. In addition, this technique is independent of connecting wire resistances.

The methodology of the proposed digitizers was mathematically brought out and their performance was verified using simulation studies. Detailed error analysis was carried out to determine the influence of various parameters on the digitizers' output. Hardware prototypes of the digitizing interfaces were built and tested with various commercial resistive sensors. Details of the developed methodologies, simulation and error analysis performed, hardware setup, and evaluation results achieved are presented in this thesis.