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Conditioning and Transmission Module for Resistive Bridge Sensors

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Abstract **– This paper presents an enhanced conditioning and transmission unit aimed for interfacing resistive bridge sensors with remote data acquisition and control systems. The proposed module uses a simple but reliable communication technique based on a combination between frequency and pulse width modulations. This design, based on two transmission methods, ensures the multiplexing on a single carrier of the information regarding the temperature and the unbalance of a resistive bridge sensor. The circuit is practically implemented around a relaxation oscillator architecture, having a central frequency of operation of 8kHz. The polarization of the sensor is realized with a pair of constant current sources for alleviating the influences introduced by the parasitic resistance of the connection wires but also for reducing the influences of the electrical noise. The immunity against perturbations is also inherently increased by the robust transmission method which allows easy and accurate recovering of the measured signals using a proper receiver structure. Compared with existing solutions, the proposed circuit has an improved architecture which makes it compatible with the implementation in integrated circuits technology for improved linearity, stability and compactness.**

Keywords – conditioning; data transmission; bridge sensors; modulation.

I. INTRODUCTION

Remote transmission of the information regarding the real world physical quantities imposes a local processing of the analog signals generated by sensors. This local conditioning represents a necessity and also a challenge for proper interfacing with the digital measurement and processing systems. The difficulty of such implementations originates in the very low levels of the input signals that lead to higher sensitivity to the external and unwanted influences, especially in industrial environments. The resistive bridge sensors based on Wheatstone configuration represents a preferred solution for data acquisition and measurement systems because it ensures a higher accuracy compared with other types of sensors. The conversion of small resistance variation into a useful signal, as is the case of Wheatstone bridge, imposes very carefully consideration of the process linearity and the overall sensitivity. Also, the transfer over long distance of the voltage signal obtained at the output of the bridge can be realized in proper conditions only if a reliable communication technique is used. In this context, this paper contains the results regarding the implementation of an improved structure of resistance-to-frequency and resistance-to-duty-cycle converter. The module is designated for remotely interfacing digital measurement systems with Wheatstone based resistive bridge sensors, using a simple and feasible solution which does not allow accuracy degradation and ensures, in addition, an efficient compensation of the intrinsic resistance of the wires used for sensor connection [1], [2]. The paper is structured in six sections beginning with an introduction in the approached thematic and followed, in Section II, by the description of the general principle of operation for the resistance to frequency converters. In the third part is revealed the detailed structure of the module followed in the subsequent two sections by the presentation of simulation and experimental results.

II. THE PRINCIPLE OF THE RESISTANCE-TO-FREQUENCY CONVERTERS

The general principle of the resistance-to-frequency converter relies basically on the relaxation oscillator structure (Fig.1). The voltage generated by the imbalance of the sensing bridge is amplified and integrated. The feedback connection is realized through the comparator, by means of a current biasing source [3]. The classical relaxation oscillator has the advantage of simplicity but the frequency of its output signal is affected in a significant proportion by the imperfection of its internal components like voltage offsets and drifts of the operational amplifiers. Also the propagation delays represent another source if errors in relaxation oscillator based resistance-to-frequency converters. These unwanted influences can be alleviated by an internal compensation scheme and by using stabilized current sources for biasing the measurement bridge [4].

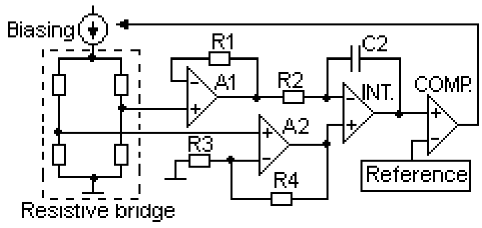

Figure 1. The principle of resistance-to-frequency converters.

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III. THE STRUCTURE OF THE CONDITIONING AND TRANSMISSION MODULE

The general structure of the conditioning and transmission module for resistive bridge sensors is detailed in Fig. 2. The design is based on a symmetrical current source implemented with transistors Q_2 and Q_3. The polarization of these two transistors is realized with constant voltage generated by the operational amplifier U1A which is connected in a negative feedback configuration for better stabilization of the output currents. A reference resistor, R_{19}, is supplied by the constant current from the previously described source. On this way is generated a voltage drop at the terminals of R_{19}, this signal been used for detection of the overall resistance variation of the sensing bridge. This arrangement was necessary for eliminating an additional temperature sensor that otherwise would be necessary for thermal compensation of the resistive bridge. The information regarding the temperature of the bridge is integrated into the output signal of the module. The duty-cycle of the square wave output signal is modulated by the information regarding the temperature of the bridge sensor. The voltage read from the arms of the bridge is periodically switched before to be supplied to the differential amplifier implemented around the U1B circuit. This switching action is performed for alleviating the cable capacitance and resistance influence on to the transmitted signal. The connection cable influence on the sensor's operation represents a very important aspect in the case of remote measurement and acquisition systems. Another approach for solving this problem is based on the polarity switching of the current sources that bias the bridge but this solution is more difficult to implement and is not so efficient for remote sensing. The commutation blocks used in the design of the conditioning module was based on CD4066 quad bilateral switch that achieves a relatively low resistance of approximately 150Ω in ON state. This low specific attenuation on the signal path correlated with other features like the maximum switching speed of 1MHz and the large transfer bandwidth of 40MHz made it suitable for the proposed application. All the differential amplifiers and also the comparators were based exclusively on the TL082 operational amplifier. This circuit is characterized by a high slew rate of 13V/µs, which is an important parameter for the configurations that are specific to this project. The small input bias currents and also reduced offset voltage variation with temperature in conjunction with the relatively high bandwidth of 3MHz that characterize the TL082 operational amplifier represented important arguments for selecting it as main block in the realized module. The entire operation of the switching blocks and the logic circuits is controlled by the clock signal whose frequency is fixed by the integrator's passive components, C_1 and R_{11}. The amplitude of the ramp waveform generated by the integrator develops only between the voltage levels fixed by the window comparator realized with U6b and U7B. The thresholds of this comparator are fixed with the corresponding voltage divider composed of three equal resistors. The integration time is also influenced by the current generated through R_{29} potentiometer by the amplified imbalance voltage. The resistive bridge sensor can be used for measuring the air flow into a vent but also for tire pressure monitoring. The CD 4043 represents a quad RS latch based on NOR gates and is used for driving the switches in the schematic [5].

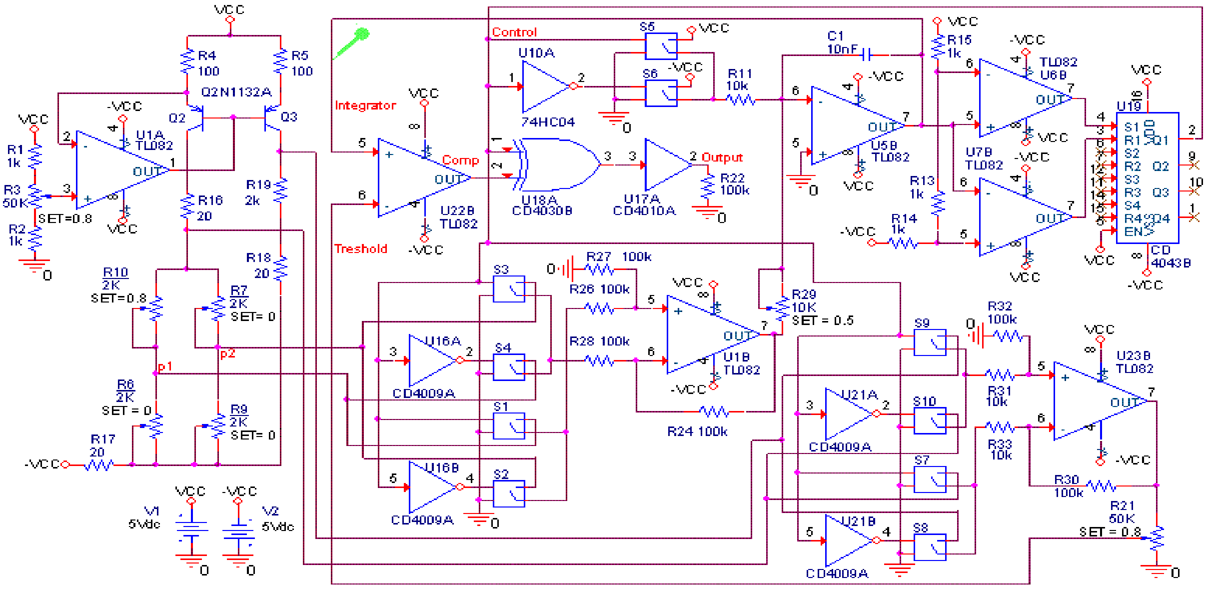

Figure 2. The electronic schematic of the module used for conditioning and transmission of signals from resistive bridge sensors.

IV. THE SIMULATION OF THE MODULE

The operation of the conditioning and transmission module was initially verified and optimized using PSPICE simulation. The electronic schematic was edited in ORCAD 16 designing environment, as can be observed in Fig. 2. The entire module was extensively evaluated through various types of simulations, including transient time domain analyses and parametric analyses. Both categories of analyses were performed considering a simulation interval of 300µs with a time step of 1µs for accurately plotting the visualized waveforms but without increasing the simulation time to unpractical values [6].

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In Fig. 3 can be remarked the results of the parametric simulation of the circuit, considering the R_{10} from the bridge sensor as the input variable for analyses. From the respective table it results that the duty-cycle of the output signal maintains constant over all range of input values while the center frequency of the generated waveform is in function of the bridge unbalance, which is according with the expectations. Also in Fig. 4 are presented few sample results showing the time domain analysis results. In this picture are illustrated successively and in a correlated manner some waveforms captured in the most significant points of the schematic [7].

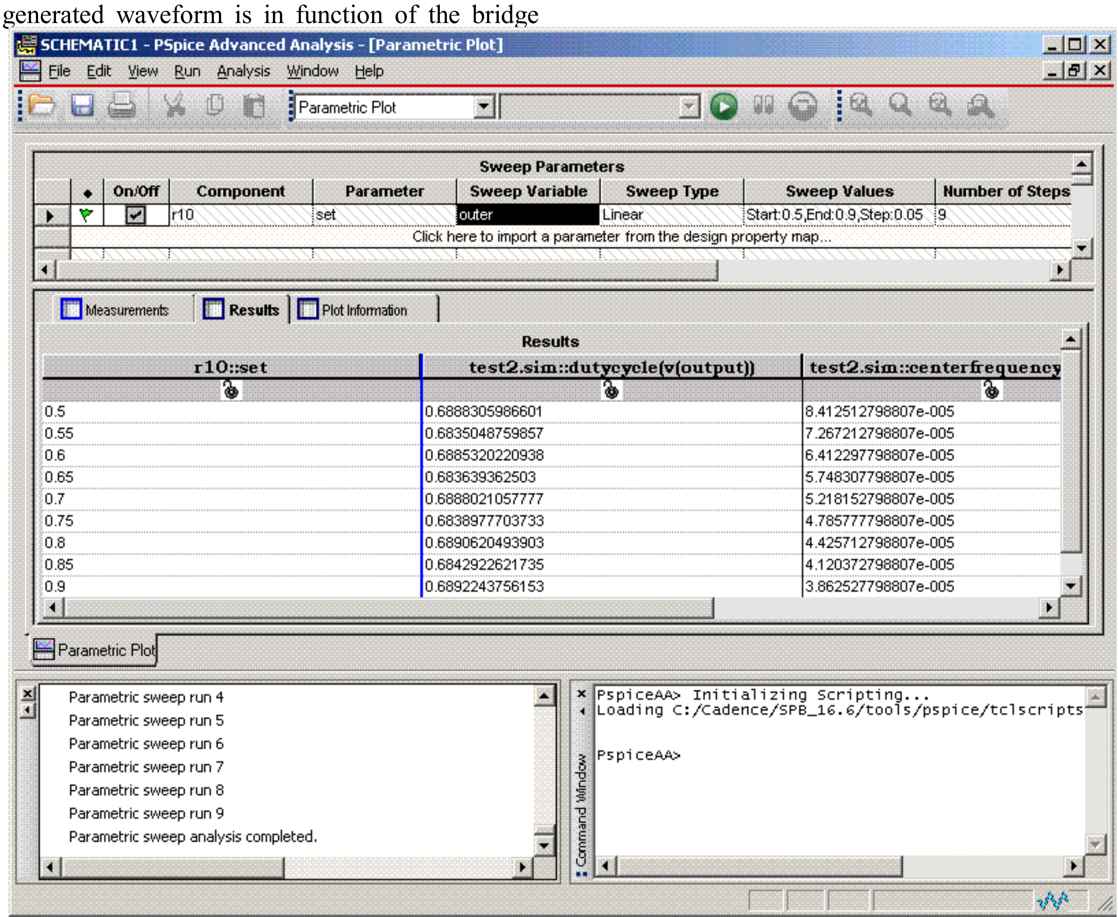

Figure 3. The parametric simulation results showing the values for the duty cycle and the frequency of the output signal generated by the module, considering the measuring bridge imbalanced due to a variations caused by resistor R10.

In the first part of the picture (Fig. 4) are presented the output signals from the integrator and the differential amplifier that is responsible with the threshold level calculation. These waveforms have the same frequency and are correlated in time. The signal containing the comparison result between the above mentioned waveforms is presented in the bottom part of the Fig. 4. The result is phase-shifted with respect to the signal that controls the switching blocks and by using the XOR function it results the output modulated waveform having only half of initial frequencies for reducing the overall nonlinearities of the circuit [8].

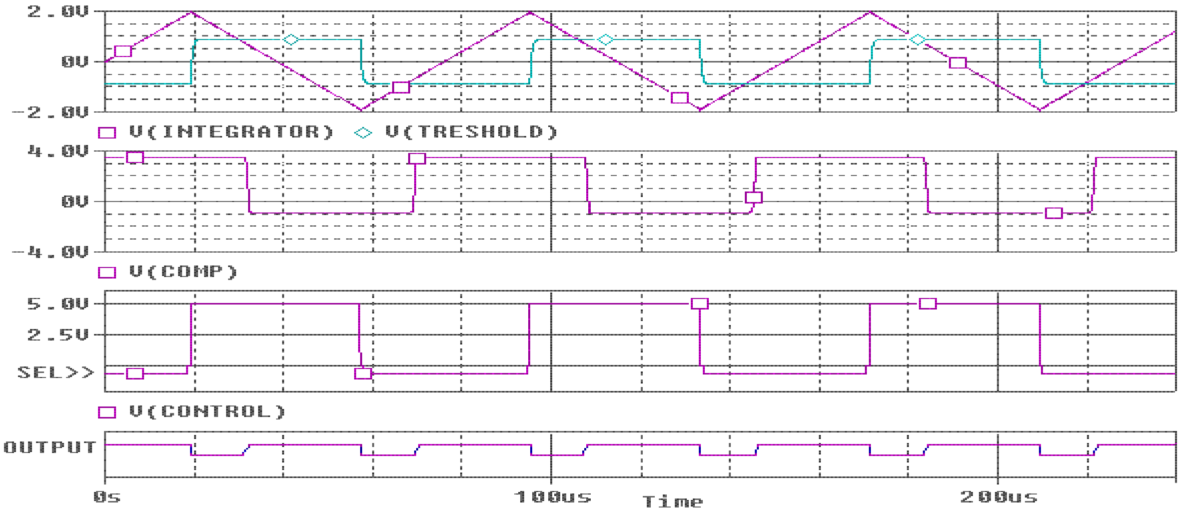

Figure 4. Sample waveforms obtained as a result of time domain simulation of the proposed module.

V. Implementation and Results

The prototype board used for practical evaluation of the correct operation of the conditioning and transmission module for resistive bridge sensors is presented in Fig. 5. The user can adjust some of the values of the potentiometers for better tuning of the module. The implementation allowed an in depth comparison between the simulated and practical results. From these experiments resulted a good correlation and a convergence amongst every important parameters such central frequency, sensibility and errors. The structure provided a remote transmission from a 2kΩ resistive bridge sensor over a 10m cable ensuring a maximum of 5% relative errors, but the module can be further improved by using a more compact design or even an integrated implementation using silicon based technology. Regarding the immunity against perturbations, the measurements performed with HM5014-2 spectrum analyzer and its dedicated probes revealed that the demodulation of transmitted pulses, carrying the information from resistive bridge sensor, is possible only if signal-to-noise ratio is maintained above 7 dB. This limit is also in accordance with the simulation results and was found that is strongly influenced by the sensitivity of the receiver which can be significantly improved using low-noise components and synchronous demodulation architecture.

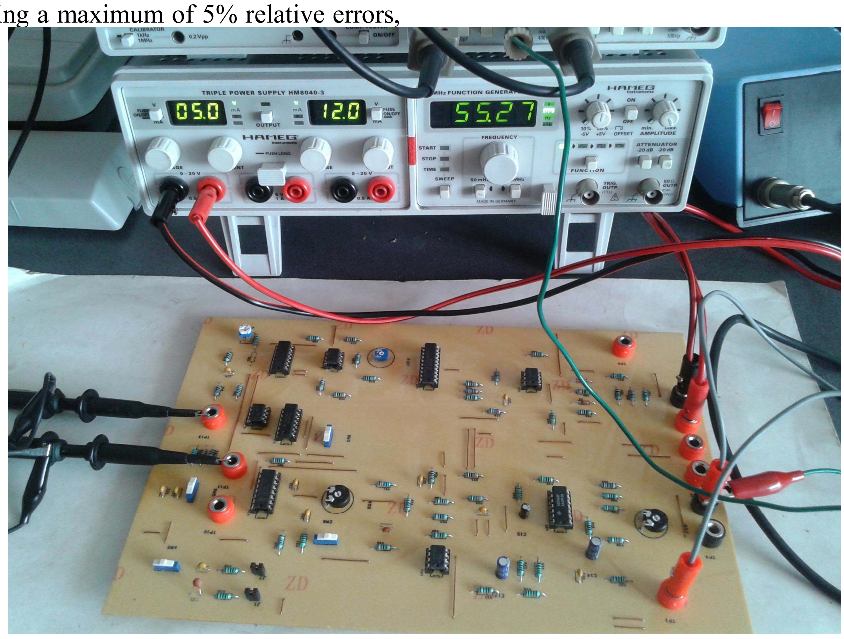

Figure 5. The experimental prototype of the conditioning and transmission module for resistive bridge sensors.

VI. Conclusions

The multiplexing of information regarding the temperature and the unbalance of a resistive bridge sensor, using a single pulsed carrier, represents a very economical method for implementing efficient conditioning circuits for remote measurement and data acquisition systems.

The proposed module has the advantage of an increased immunity against perturbations because it operates with inherently robust transmission method based on frequency and pulse width modulations.

In the case of resistance-to-frequency converters the interfacing with a microcontroller can be made simpler because the analog-to-digital conversion can be realized through counting method that can achieve higher resolutions compared with classical converters but with the drawback of a reduced measurement speed.

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