Remote Communication Interface for Sound and Vibration Sensors

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Abstract — **In this paper are presented the results regarding the implementation of a communication interface dedicated for conditioning and remote transmission of measurement signals acquired from sound and vibration sensors. The interface contains two parts, an analog section, responsible with long distance signal transmission and a digital section that realize demodulation and analog-to-digital conversion of the received signal. The analog part of the interface uses the frequency modulation technique that is well known for its ability to operate in environments characterized by high levels of electrical perturbations, even when are realized high speed data transmissions. The acquisition of signals from sensors is realized with a resolution of 16 bits with a maximum speed of 200kS/s. In order to ensure the compatibility with various communication media and different types of sensors, the proposed circuit has adjustable carrier frequency in the range [0,01 – 0,5] MHz and offers also the possibility to select the carrier signal waveforms: square or sinusoidal wave. In addition, for increased versatility, the communication interface combines two alternative configurations, one based on phase-locked-loop (PLL) structure and the second based on quadrature oscillator with analogue multipliers. Both configurations were thoroughly tested for evaluating the performances of the proposed design. In comparison with other structures, the remote communication interface proposed in this work revealed good stability, accuracy and reliability. Also, the robustness and simplicity of the interface due to the use of frequency modulation technique represent other significant advantages.**

Keywords — communication interface, sensor, signal conditioning, frequency modulation.

I. Introduction

In almost every practical application the transfer of information from the output of the sensor to the measurement system represents a critical step in the implementation process because it implies very small signal levels and the interface has an increased sensitivity to interferences. These aspects are even more pronounced in the case of remote configurations of data acquisition and measurement systems that operate in harsh industrial environments [1].

In this context this paper approach the problem of implementing a reliable remote communication interface dedicated for sound and vibration sensors. The proposed design was divided in two parts, one responsible with conditioning and long distance transmission of signals from sensors and the second part used for demodulation and analog-to-digital conversion of signals for facilitating the interconnection of the proposed system with a PC or other digital signal processing unit.

In the proposed configuration, because the communication is realized by using frequency modulation, no quantization errors are introduced, timing equipments are unnecessary and the communication requires less frequency bandwidth compared with digital transmission. Also the interface has a simplified structure, requires less conditioning of the input signals and this combined advantages lead to lower implementation costs of the system.

II. The Phase Locked-Loop Structure and Frequency Modulation Technique

The remote communication interface uses a phase-locked-loop (PLL) structure combined with a quadrature oscillator based on analogue multipliers. The frequency modulated signal $s_{MF}(t)$ can be expressed in generally as:

$$s_{MF}(t) = A_0 \cdot \cos\left[\omega_c \cdot t + k_\omega \cdot \int_0^t u_m(t) \cdot dt + \varphi_c\right] \quad (1)$$

where $u_m(t)$ is the information signal, ω_c, φ_c, A_0 are the angular velocity, initial phase and amplitude of the carrier signal.

One of the main parameter that characterizes a transmission based on frequency modulation is the modulation index, β, defined as the ratio between frequency deviation, Δf, and the modulation frequency, f_m.

The expression of modulation index is:

$$\beta = \frac{\Delta f}{f_m} = \frac{k_f \cdot A_m}{f_m} \quad (2)$$

where k_f is the modulator's sensibility and A_m is the amplitude of the input signal applied to the modulator.

The phase locked-loop structure is a universal module frequently used for signal processing and synchronization purposes in data transmission equipments.

In principle this type of circuit comprises a phase comparator that controls the frequency of a voltage controlled oscillator (VCO). The structure is characterized by an free oscillation frequency, f_{osc}, that is generated by VCO when no signal is applied to the input of the circuit, $u_{in}(t)=0$.

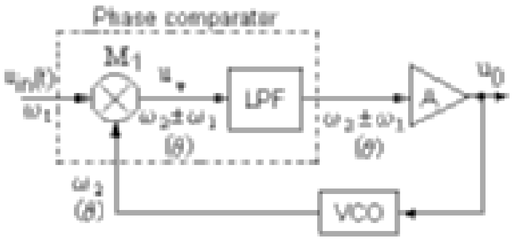

Fig. 1. The basic structure of a phase locked-loop circuit.

The phase detector is sensitive to the phase differences between the input signal and the feedback oscillation generated by VCO. When the local generated signal and input oscillation have different frequencies a proportional voltage is applied to the input of the VCO.

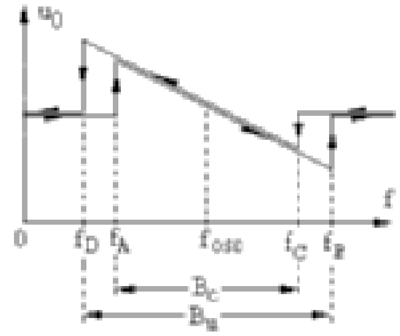

Fig. 2. The static transfer characteristic of a phase locked-loop circuit, considering the error as a function of frequency.

This voltage causes the variation of the VCO's frequency until it becomes equal with the frequency of the input signal. As can be seen from Fig. 2, the phase locked loop operates as a frequency control system. It is characterized by a lock range, B_u, and a capture range, B_c. Overcoming the lock range lead the system out of the synchronization and resynchronization is possible only if the signal enter in the capture range.

III. The Presentation of the Remote Communication Interface

As was briefly mentioned before, the remote communication interface proposed in this paper is composed by two parts: the first part is based on analog signal processing and is intended for remotely connect the sound and vibration sensors to the data acquisition and measurement systems using frequency modulated signals transferred through metallic lines. The second part of the interface is responsible with demodulation and analog-to-digital conversion of the received signal from sensor. This section of the interface is necessary for proper acquisition and processing of the measured signals using a PC with a dedicated software application. In our design the modulated signal transmitted by the remote circuit is demodulated and acquired with and NI USB 6212 data acquisition board characterized by a 16 bit resolution and a speed of conversion of 200kS/s. The signal transmission between vibration sensor and data acquisition is realized through frequency modulation. The carrier frequency is adjustable in the range of [0,01 – 0,5] MHz and the system offers also the possibility to select the carrier signal waveforms: square or sinusoidal wave. The main functional blocks of the proposed design are illustrated in Fig. 3. The transmission part the system uses a phase-locked-loop structure combined with a quadrature oscillator based on analogue multipliers. The selection of the transmission configuration is realized in the initial setup of the equipment and must be correlated with the demodulation side of the system. The quadrature oscillator structure is used for transferring the information from sensor to the data acquisition board using sinusoidal carrier. The voltage controlled oscillator, VCO_1, is connected to the transmission line when it is necessary the transfer of the signal from sensor to data acquisition board using a square wave carrier. For testing purposes, when the interface is operated on very short distances, it is also possible to transfer the signal without modulation [2], [3].

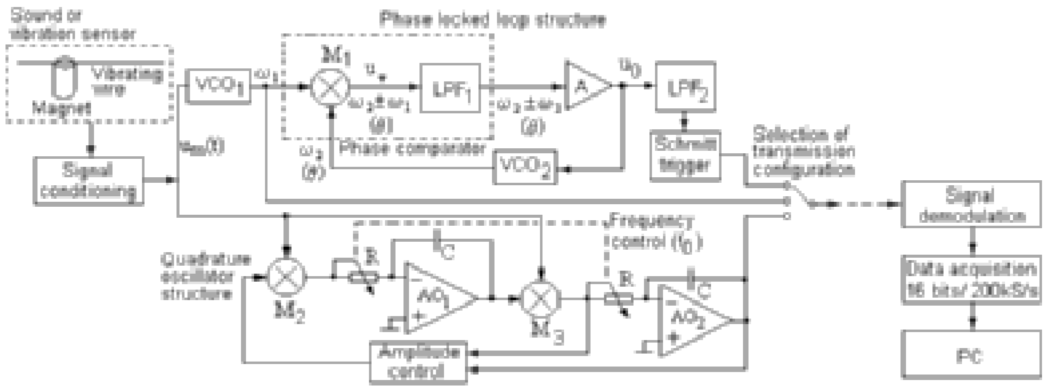

Fig. 3. The simplified block diagram of the remote communication interface for sound and vibration sensors.

IV. Implementation and Results

The performances of the analogue transmission part of the remote communication interface were evaluated through intensively tests regarding the accuracy of the transferred signals and the stability and reliability of the realized circuits.

In the Fig. 4 is presented the electric diagram of the frequency modulator based on quadrature oscillator structure.

The AD633 analog multipliers and TL082 operational amplifiers are the main active components used in the proposed design. The behavior of the modulator is deliberated guided, through the electronic switch represented by Zener diodes D_1 and D_2, towards a dumped or not dumped oscillating regime. Through this way is controlled and maintained a constant level of the amplitude of the modulated signal [4].

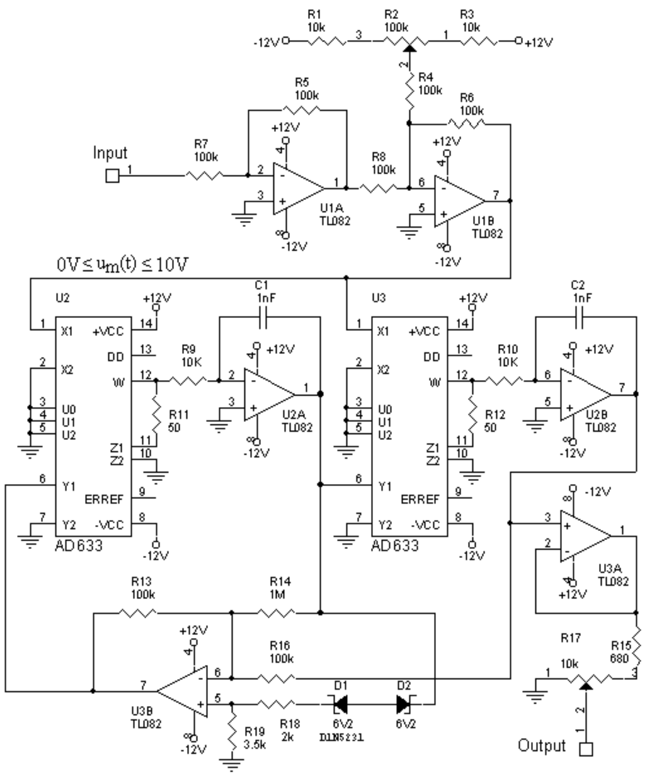

Fig. 4. The electronic diagram of the frequency modulator based on quadrature oscillator structure.

The frequency of the output signal for the modulator structure presented in Fig. 4 is controlled by the amplitude of the input signal. Some sample results obtained through simulation in Orcad Pspice are depicted in Fig. 5, 6 and 7. From these pictures we can remark the proper operation of the circuit.

For practical implementation, the multipliers used in the schematic must have a good precision and a relatively high slew rate and bandwidth. In the practical realization of the quadrature oscillator were used AD633 analog multipliers and TL082 operational amplifiers. As phase-locked-loop was chose LM565 general purpose circuit.

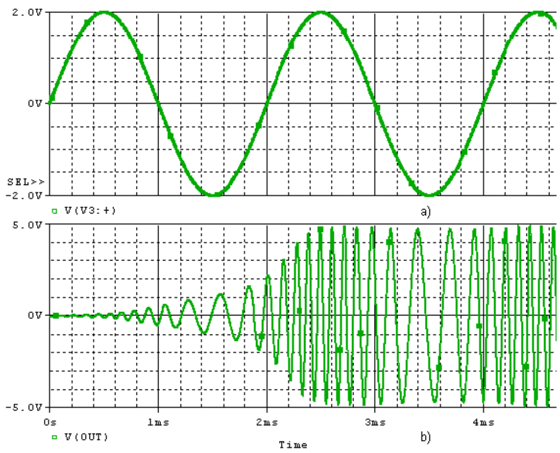

Fig. 5. a) The input test signal: $A = 2V_{pp}$, $f = 500Hz$; b) The output of the frequency modulator based on quadrature oscillator structure.

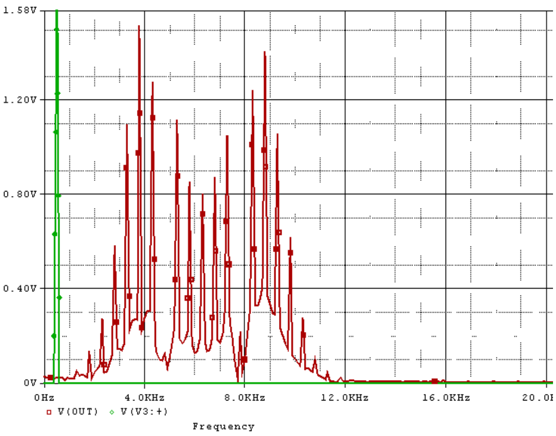

Fig. 6. The spectral analysis of the signal obtained at the output of the frequency modulator based on quadrature oscillator structure.

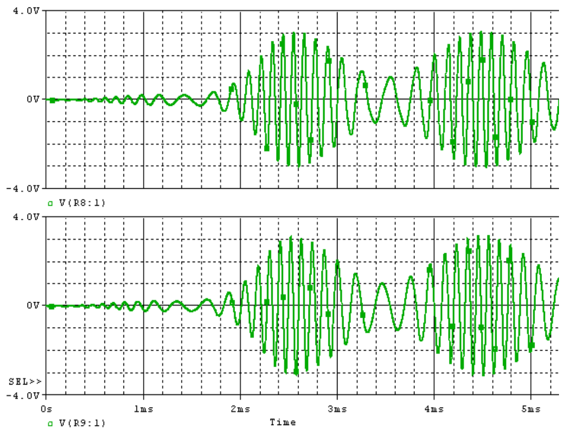

Fig. 7. The intermediate signals visualized at the output of the AD633 multipliers that compose the frequency modulator based on quadrature oscillator structure.

The four quadrants multiplier AD633 achieve a cumulated error of less than 2% considering signals in full scale range of operation. Also, the multiplier was choose because ensure relatively high operation frequency of 1 MHz and an acceptable slew rate of $20\,V/\mu s$.

The phase locked-loop circuit LM565 in combination with active filters based on TL 082 operational amplifiers was used as main elements in the implementation of the second configuration of frequency modulator for remote transmission of signals from sensors. The LM 565 has an frequency stability of the internal VCO of around $200 ppm/^{o}C$ and a 0,2% linearity of the demodulated output. In the initial tests the PLL was the main limiting factor of the maximum frequency of the signal that can be accepted and processed from the vibration sensors but this aspect can be improved by choosing a more performing circuit [3].

In Fig. 8 can be observed the implementations of the electronic boards for the quadrature oscillator configuration and phase-locked-loop configuration, respectively.

Also, in Fig. 9 can be seen few sample results visualized with an oscilloscope connected to the input and output ports of the two implemented boards, one based on phase-locked-loop structure and the second based on quadrature oscillator with analogue multipliers. In both visualizations the oscilloscope was operated with the following deflection settings: vertical 2V/div. and horizontal $2\mu s/div$. As can be seen from this pictures waveform at the outputs of the implemented circuits are in accordance with the simulations results and prove the correct operation of the proposed interface. A further improvement in performances and a higher integration degree doubled by a increased reconfigurability of the structures can be obtained by using field programmable analog array circuits.

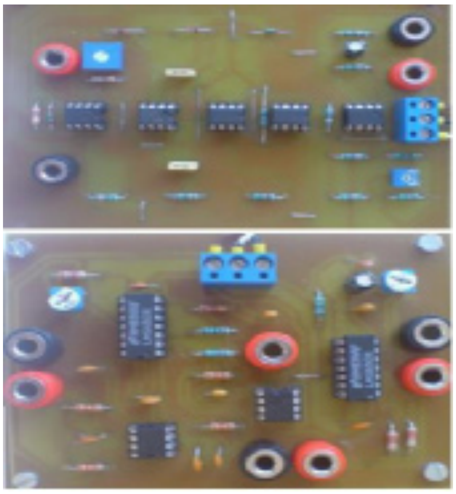

Fig. 8. The implementation of the communication interface using quadrature oscillator configuration (top) and phase-locked-loop configuration (bottom).

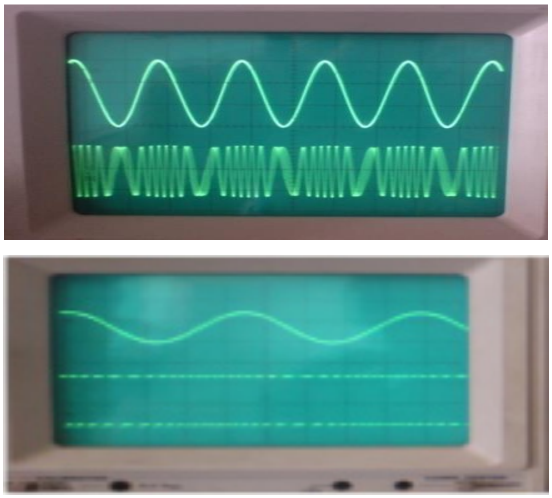

Fig. 9. Input and output waveforms for quadrature oscillator configuration (top) and phase-locked-loop configuration (bottom) The oscilloscope deflection settings: vertical 2V/div. and horizontal $2\mu s/div$.).

V. CONCLUSIONS

Due to the very small signal levels and the increased sensitivity to interferences, the acquisition of information from the sensors represents an important problem in the implementation of accurate measurement systems.

In the proposed configuration, no quantization errors are introduced, timing is unnecessary and the communication requires less frequency bandwidth compared with digital transmission, because the communication is realized by using frequency modulation.

Also the proposed remote communication interface has a simplified structure, requires less conditioning of the input signals and this combined advantages lead to lower implementation costs of the system.

REFERENCES

[1] L. Swathy, Lizy Abraham, "Analysis of vibration and acoustic sensors for machine health monitoring and its wireless implementation for low cost space applications", First International Conference on Computational Systems and Communications (ICCSC), pp. 80 – 85, 2014.

[2] Andrei Drumea, Marian Blejan, and Ciprian Ionescu, "Differential inductive displacement sensor with integrated electronics and infrared communication capabilities," Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies ATOM-N2012, pp. 841116-841116-7, November 2012.

[3] Roberto Mugavero, Giovanni Saggio, Valentina Sabato, Mariano Bizzarri, "The multisensory integrated modules for training", 2014 International Carnahan Conference on Security Technology (ICCST), pp. 1 – 6, 2014.

[4] Daniel Alexandru Visan, Ioan Lita, Marian Raducu, "FSK transmission circuit for remote sensors integration in distributed measurement systems", 2012 IEEE 18th International Symposium for Design and Technology in Electronic Packaging (SIITME), 25 – 28 Oct., pp. 237 – 240, 2012