Digital Modem for Distributed Data Acquisition and Control Systems Used in Intensive Fruit Farming

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***Abstract**: The aim of this paper is to present the results regarding the simulation and implementation of a digital modem that is intended to be integrated in multipoint data acquisition and control systems which are used for intensive fruit farming applications. For increased efficiency the proposed design is based on the well-known quadrature phase shift keying technique (QPSK). The improved architecture of the modulator and demodulator that compose the modem ensures a very good robustness to the external perturbations allowing transmission speeds of around 250 kbit/s at signal-to-noise ratios above 5 dB. The novelty of the proposed work is given mainly by the particular development of the modem. In comparison with classical solutions, the proposed approach relying on spectral efficient and synchronous operated communication modules in conjunction with the advantages offered by the multipoint data acquisition and control methods allows a significant increasing of the efficiency and sustainability for the intensive fruit growing systems.*

1. INTRODUCTION

The fast population increase lead to a growing demand for agricultural products which also create the necessity for improving the traditional farming methods. In this context a multipoint system that ensures continuously monitoring of plants and provides the control mechanisms for nutrients distribution allows dramatically productivity increase of fruit farms [1]. Because one of the key component of such distributed system is represented by the communication part, in this paper is approached the problem of implementing an efficient digital modem based on the QPSK modulation [2].

2. THE QUADRATURE PHASE SHIFT KEYING TECHNIQUE

Digital transmission methods based on phase shift keying techniques are extensively used in the implementation of various communications systems which are found in a multitude of applications, ranging from satellite and personal communication systems to local area networks. For the particular case of quadrature phase shift keying technique (QPSK), the modulation process consists in amplitude and phase variation realized in accordance with the data values that are applied to the input. The QPSK modulator uses two multipliers, an adder and a local oscillator for carrier generation. In Fig. 1 is presented the principle of this technique which uses four symbols for representing the useful data, those obtaining a high spectral efficiency and a good resistance to noise. These superior characteristics are accompanied by an increased flexibility of implementation, because the modulator allows that all parameters of the carrier signal to be modified simultaneously for representing the useful information [1], [2].

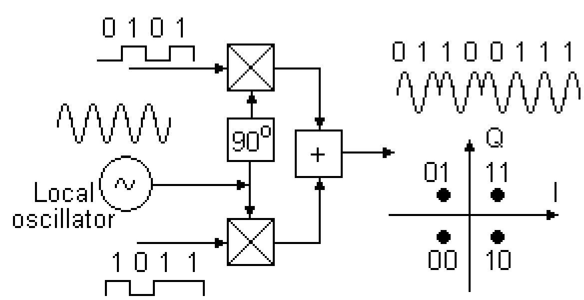

Fig. 1. The principle of quadrature phase shift keying.

3. The Structure of the Proposed System

The block diagram of the digital modem for distributed data acquisition and control systems is presented in Fig. 2. The system architecture relies on two signal processing channels: in-phase channel (I) and quadrature channel (Q). In comparison with classical communication circuits based on binary phase shift keying (BPSK) this approach allows doubling the transmission speed without increasing the transmission bandwidth. At the receiving side, the demodulation of QPSK signal is realized synchronously. The carrier is also extracted from the modulation signal using a dedicated clock recovery circuit based on a phase-locked-loop structure. The circuit is also capable to operate with differential version of QPSK for alleviating the problem of phase ambiguity that arises in the demodulation process [3].

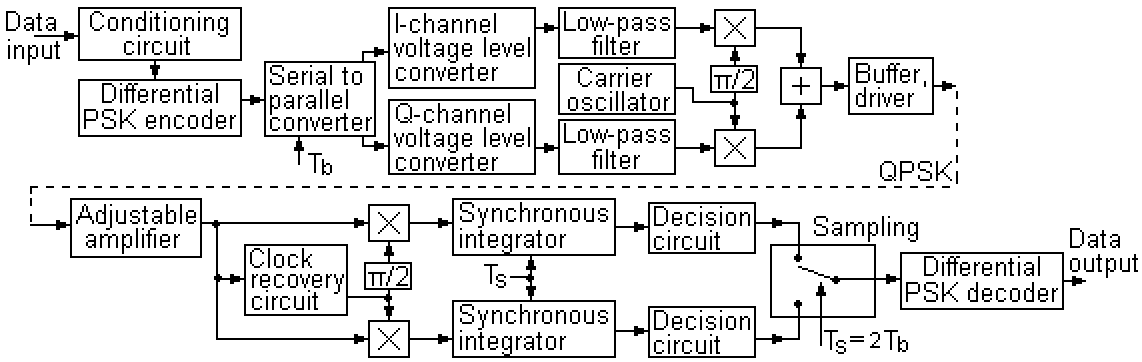

Fig. 2. The structure of the digital modem for distributed data acquisition and control systems.

4. Implementation and Results

In the prototyping phase of the project, the practical implementation of the digital modem was based on discrete components, especially the AD633 analog multiplier and TL082 operational amplifier. For example, in Fig. 3 can be observed the electrical diagram of the quadrature oscillator used for generating the carrier signals for I and Q channels (in-phase and quadrature). The two 90° out of phase carrier signals consisting in two sinusoidal waveforms with the frequency around 150 kHz are used further for conveying the data to the receiver. The field effect transistor J1 that can be remarked in the schematic shown in Fig. 3 is used as variable resistor for controlling the gain of the summing amplifier U10A that was implemented with a high speed TL082 operational amplifier. Also, the control voltage for J1 is received from an integration stage realized with U11A. The diodes D1 and D2 compose a simple rectifier that has on its input just the out waveform of the oscillator. The purpose of these stages is to operate as a negative feedback loop that continuously monitor and stabilizes the amplitude of the output signals of the quadrature oscillator. The final voltage repeaters placed on the outputs of the carrier oscillator ensure the proper separation between this module and subsequent stages from the digital modem. An important attention was accorded to the implementation of the two integration circuits U10B and U11B because they constitute the basis of the quadrature oscillator, having direct influence on the performance of the entire structure of the digital mode.

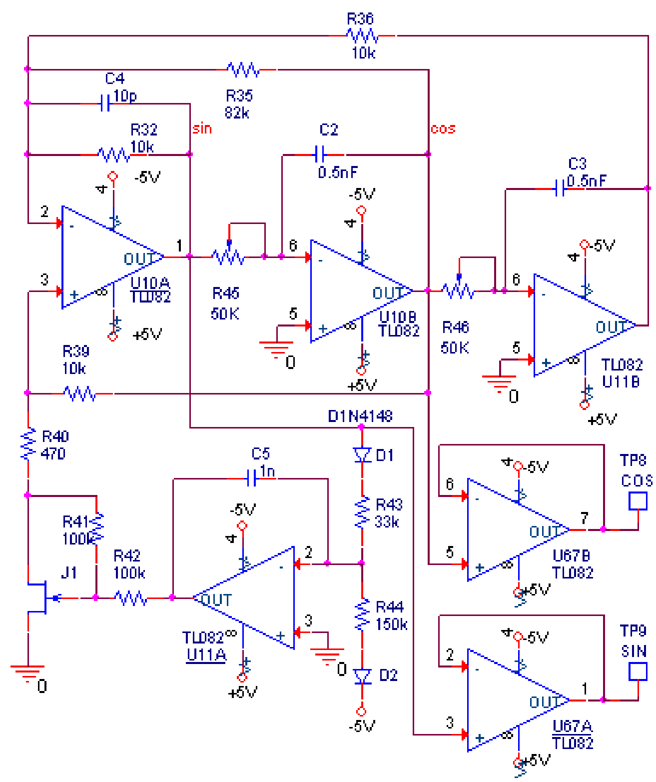

Fig. 3. The schematic of the quadrature carrier oscillator.

The detailed architecture of the QPSK modulator that was used for implementing the digital modem for distributed data acquisition and control systems is depicted in Fig. 4. The four flip-flops placed on the input of the modulator (U48A, U48B, U49A, U49B) converts the input bit stream from serial to parallel format. From this functional block will result a series of digits that are successively applied to the LM311 comparators and AD633 four-quadrant multipliers [4]. At the outputs of the multipliers are obtained the primary components BPSK_Q and BPSK_I which are finally summed for generating the more complex waveform of QPSK modulated signal. The non-inverting summing amplifier was realized with a simple structure based on the TL082 operational amplifier, as can be seen in Fig. 4.

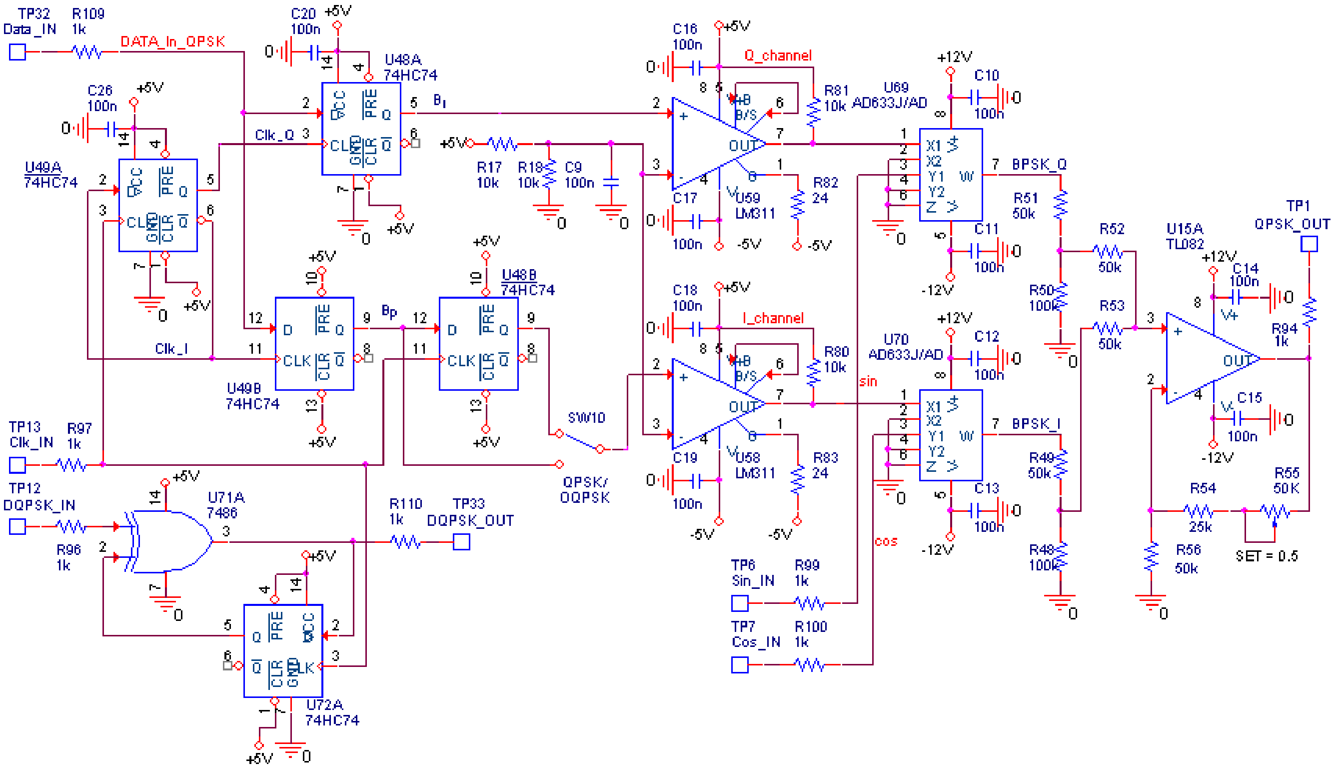

Fig. 4. The simplified structure the modulator that was used for implementing the digital modem for distributed data acquisition and control systems.

The operation of the proposed system was verified through intensive simulations and direct measurements on a practical prototype containing the QPSK modulator and demodulator. In Fig. 5 are presented few the waveforms obtained through simulations. In the initial tests, at the input of the modulator was provided a repetitive 8-bits data sequence. As can be observed from Fig. 5, the data are transferred and recovered correctly, suffering only a minor delay of 3 clock periods (3 Tb) which has no significant influences on the transmission accuracy.

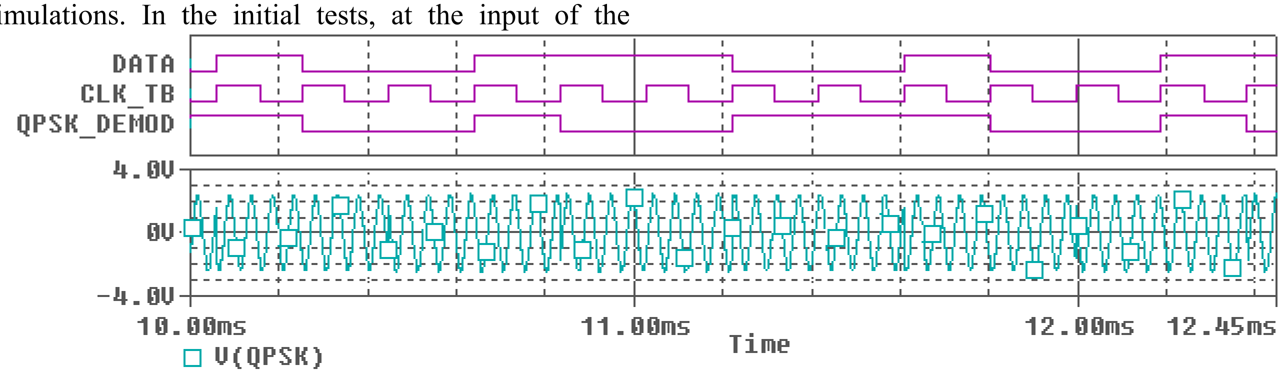

Fig. 5. The simulation results showing the signals in few significant points of the digital modem.

In Fig. 6 can be seen the board of QPSK modulator for the proposed digital modem. Also, Fig. 7 contains the two significant waveforms at the input and output of the QPSK modulator, visualized with an oscilloscope having the vertical and horizontal scale settings established at 5 V/div and 10 μs/div. A further improvement of the proposed design can be done by using a dedicated waveform synthesizer that will generate directly the phase shifted signals representing the symbols used for data transmission in QPSK [5].

Fig. 6. The prototype board containing the QPSK modulator of the proposed digital modem.

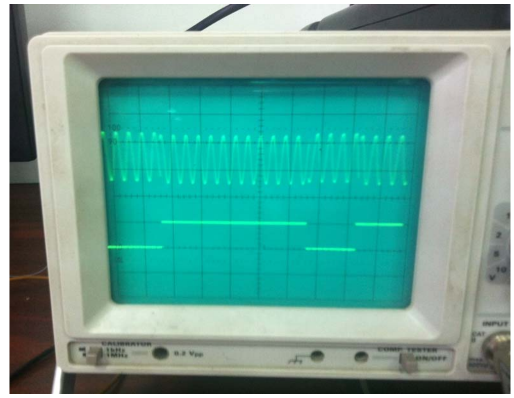

Fig. 7. The waveforms at the input and output of the QPSK modulator.

5. CONCLUSIONS

Due to its superior characteristic, the quadrature phase shift keying technique represents a promising solution for implementing reliable data transmission systems dedicated for distributed data acquisition and control systems used in intensive fruit farming applications. The design presented in this paper represent a versatile communication modem that can be easily adapted to any application that requires very reliable and stable communication link and which can operate in environments affected by moderate perturbations. The proposed modules can serve also as didactical support for teaching the basic principles of digital communications.

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