Line Encoder with Serial Data Transmission for Automotive Applications

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***bstract*—In this paper are presented the results regarding the implementation of a reliable encoder that is intended to be used in automotive applications for accurately transferring digital signals from different types of sensors, control elements and other peripheral components to a central processing unit. The designed module is capable to operate with various line coding schemes such are: NRZ (non-return-to-zero), RZ (return-to-zero), AMI (alternate mark inversion) and Manchester (phase encoding). During extensive simulations and practical measurements it was revealed that the maximum data communication speed achieved by the designed system is around 1 Mb/s, when the signal-to-noise ratio is maintained above 10 dB. The enhanced implementation of the proposed encoder, based on synchronized line-codes, offers good performances regarding the resistance to perturbations as well as an improved spectral shaping and clock recovering capabilities for obtaining efficient internal data transmission systems for vehicles.**

Keywords*—*line codes, data transmission, in-vehicle networking, automotive applications.

I. Introduction

The transmission of information between various electronic components of a modern car and the integration of the resulted data exchange fluxes for obtaining new features that inherently improve de traffic safety and comfort of the drivers remain a difficult objective to achieve. The key element of this problem is represented by the communication techniques employed for the implementation of the in-vehicle network. Also, the arising of the new concepts of autonomous and cooperative vehicles based on artificial intelligence generated an additional impulse for developing enhanced data transmission methods for automotive applications. In correlation with these trends, the transport infrastructure has been adapted for integrating a large variety of additional electronic equipments which are involved in real-time collection of information that are necessary especially for the operation of the management systems for vehicle fleets. All this evolutions require enhanced data transmission capabilities between different systems, using reliable communication networks. In this context, this paper propose a improved line encoder structure which is capable to operate with the most known baseband data transmission codes including: NRZ (non-return-to-zero), RZ (return-to-zero), AMI (alternate mark inversion) and Manchester [1], [2].

II. Protocols For Automotive Communications

Over the time the architectures for in-vehicle communications have advanced and crystallized as standards but due to the continuously increasing expectations regarding the connectivity of automobiles, the domain is still in rapid evolution. The main network protocols used for in-vehicle data transmission are: Local Interconnect Network (LIN), CAN (Controller Area Network), MOST (Media Oriented Systems Transport), FlexRay, and even Bluetooth and Ethernet, in a form that was adapted to the requirements imposed by the automotive communications (Fig. 1). The Controller Area Network (CAN) technology has been widely adopted by a large spectrum of automobile producers. This type of bus allows the internal communication between the large numbers of electronic control units that exist on a modern vehicle using a message-based protocol. The communication between the nodes that compose the CAN network is based on serial data transmission and a multi-master architecture. At the physical level, the signaling is realized through a fault tolerant line code transmitted on two wires that allows a speed of around 1Mbit/s considering a vehicle network having the length under 40m. By decreasing the data transmission speed it is possible to increase the length of the communication lines. The main advantage of the CAN systems is the ability to operate in harsh environment, been a fault tolerant protocol, but the relatively small operation speed is a drawback. The second widely used serial network protocol for automotive communication is Local Interconnect Network (LIN) which represents an easy to use and cheap data transmission solution. It is based on single-master, multiple-slave architecture. In vehicles, the LIN technology is suitable for controlling the non-critical equipments been a lower speed alternative to the CAN systems [3].

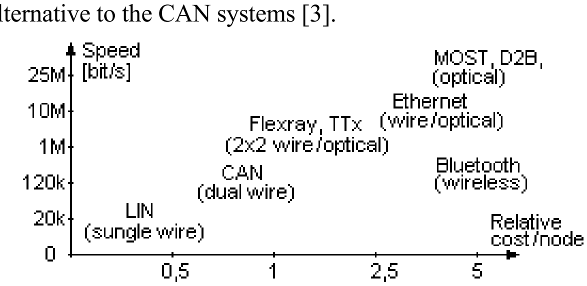

Fig. 1. Comparison between protocols used in automotive communications.

III. The Structure of the Line Encoder

The line codes are used for adapting the raw data format to the requirements impose by the physical transmission media with the purpose to obtain improved communication performances and a simplified recovery of the information to the reception. In the case of in-vehicle networks special requirements regarding the signal integrity, data protection and reliability are imposed for the communication equipments.

The focus in serial data transmission for automotive applications is on the safety aspects which subsequently implies an increased accuracy and speed but also a good resistance to noise. The block diagram of the line encoding/decoding system with serial data transmission is presented in Fig. 2. The equipment is capable to use both bipolar and unipolar signaling versions of the codes NRZ (non-return-to-zero), RZ (return-to-zero), AMI (alternate mark inversion) and Manchester (phase encoding).

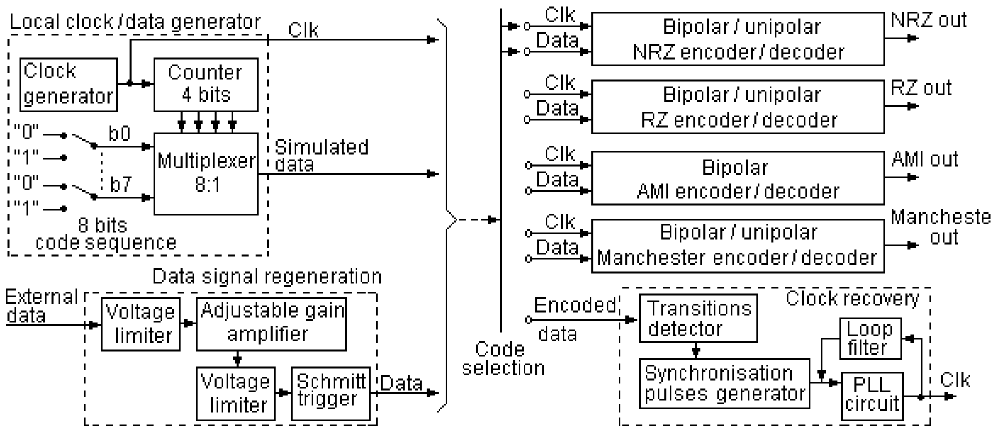

Fig. 2. The simplified block diagram of the line encoding/decoding system with serial data transmission for in-vehicle networking.

In addition, the proposed system can realize the synchronous data decoding using a clock signal recovered from the input bit stream arrived at the input of the receptor. The line encoder contains in fact both emission and reception parts, allowing a complete implementation of a reliable data link for communication between different processing units of a vehicle. In the prototype implementation of the module that is presented in this paper, besides the emission and reception parts that includes the external data signal regeneration block, the system also contains an additional circuit for local generation of a repetitive sequence compose by 8 bits that are randomly distributed. This pseudorandom data generator was introduced for simulating an external transmission signals, been very useful in the test procedures of the system [2], [3]. The clock recovery module is based on a phase-locked-loop (PLL) circuit whose inputs are connected to a synchronization generator that operates on the basis of the impulses produced by the transition detector at every occurrence of bit change in the received data stream. The data that are intended to be transmitted using one of the preferred line codes (NRZ, RZ, AMI, Manchester) are firstly conditioned and regenerated using an adjusting gain amplifier and voltage limiters, as can be observed in Fig. 2.

IV. Implementation and Results

The concepts regarding the operation of the line encoder for serial data transmission in automotive applications were verified through computer based simulations and measurements on implemented prototype boards. Also, because the coherent detection represents a key problem in data transmission, an improved synchronous decoding method was studied. In Fig. 3 is presented the schematic of the proposed synchronous decoder, particularized for operating with Manchester line code [4], [5].

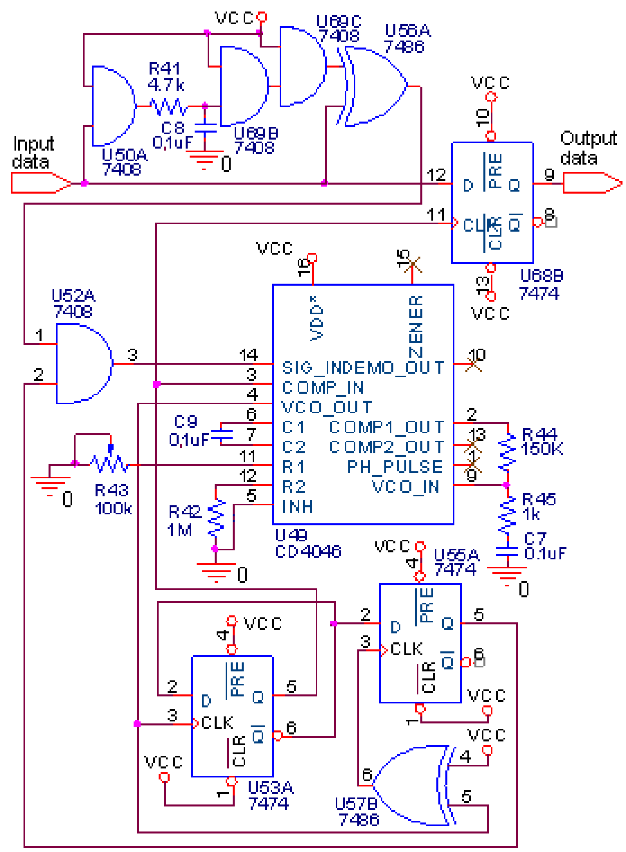

Fig. 3. The schematic of the synchronous decoder for Manchester line code.

With minimal changes the structure of the synchronous decoder presented in Fig. 3 is used for all types of line codes which contain sufficient transitions in the data stream for allowing the clock signal recovery at the receiver side. The main component of synchronous decoder is a phase locked loop realized with CD 4046 circuit that has an operating frequency range up to 1.4MHz and implements the clock recovery system used for coherent decoding of the transmitted line codes. The PLL circuit contains a linear voltage-controlled oscillator (VCO) and two phase comparators that are preceded by a common voltage amplifier that ensures a minimal conditioning of the input signal. The frequency range of the internal VCO must be correlated with the data rate of the received signal. In the presented implementation this correlation is realized through the capacitor C_9 and resistors R_{42}, R_{43}. The transition detector used for synchronizing the PLL operation was implemented in a straight manner using a set of logical gates (U50A, U69B, U55A, U69B) and a simple delaying circuit. The synchronous decoding itself is realized with a D flip-flop (U68B) which receive the recovered clock signal from the PLL circuit. In the case of simpler line codes, like NRZ or AMI, the clock recovery can be faulty due to the reduced number of transitions contained by the received signal For this reason in practice are preferred more elaborated encoding scheme, that can alleviate this problem. In the Fig. 4 is presented the electrical diagram of the generator for the synchronization signal (CLK) and for the repetitive 8 bits data sequence, both signals been necessary for testing the subsequent encoding/decoding circuits. The clock and data generator was used for all types of encoders but, for simplicity, in the Fig. 4 it is shown connected only to the RZ and NRZ encoders. These simple line encoders are realized with common circuits, the implemented module been capable to generate both, unipolar and bipolar versions of the codes. On every output of the encoders are connected pairs of diodes and resistors with the purpose of protection against overvoltage and short-circuits. Few simulation results for the proposed line encoder can be viewed in Fig. 5. As can be observed each signal is in accordance with their specific encoding rules [6].

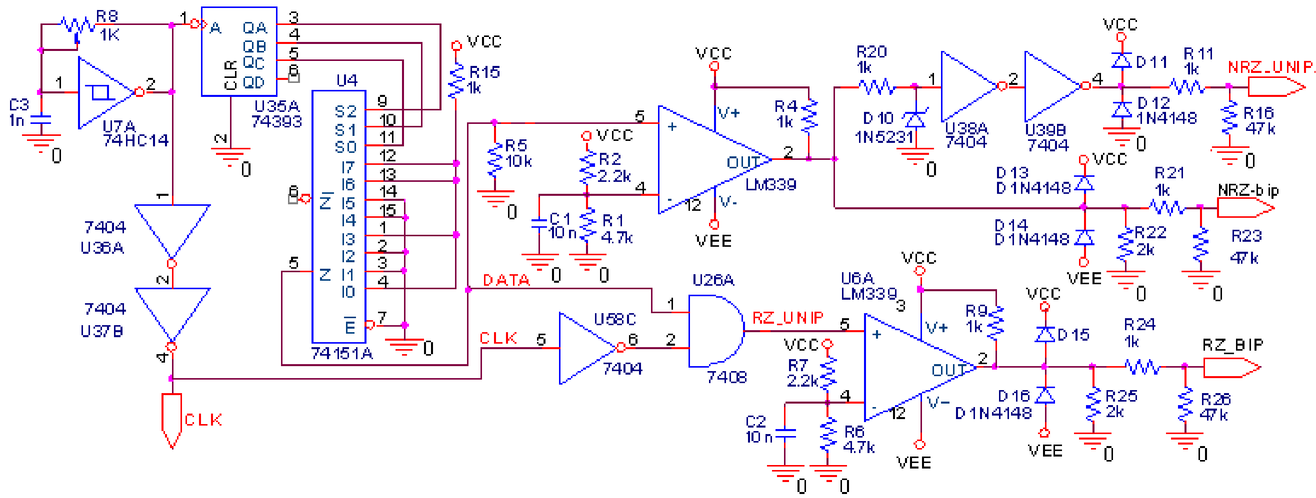

Fig. 4. The schematic of the clock and data generator connected to the RZ and NRZ encoders

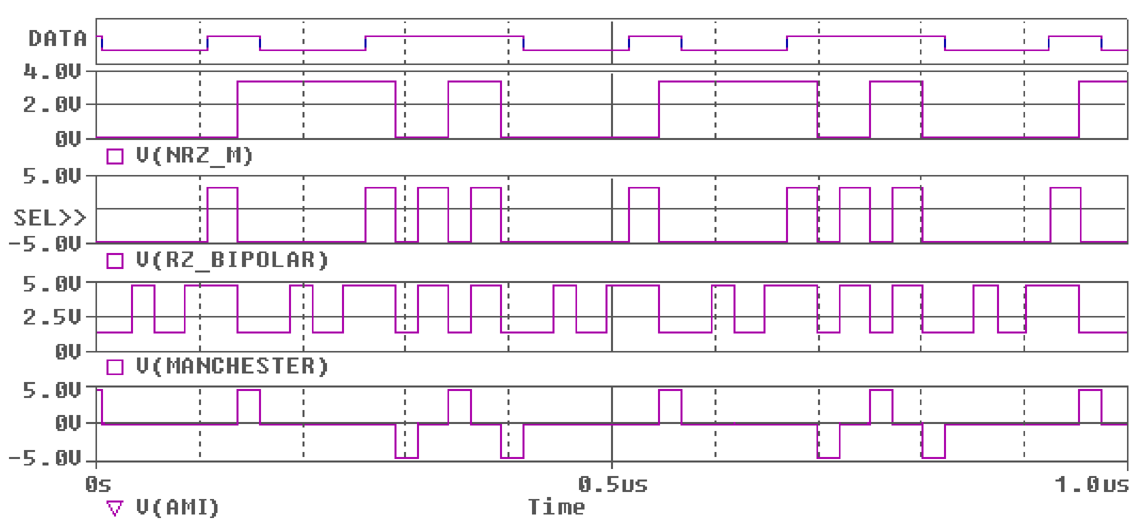

Fig. 5. Waveforms obtained at the output of the line encoder, considering different types of codes (NRZ, RZ, Manchester and AMI).

For increasing the reliability and for simplifying the testing procedures, the proposed line encoder was realized using a modular structure. In Fig. 6 are presented two waveforms representing the local generated input data and clock signals. The aspect of the implemented module representing the clock recovery circuit can be seen in the Fig. 7.

For verifying the operation of the line encoder were used real data signals as well as locally generated data and clock signals. Two examples of visualized waveforms, considering Manchester and RZ codes are presented in Fig. 8. In all cases the oscilloscope settings are: 5V/div. and 5μs/div. respectively. Compared with other realizations in this domain, the proposed encoder can be viewed as a reliable solution for implementing in-vehicle connectivity networks that have multiple benefits including data sharing between multiple sensors, improved serviceability and greater flexibility in configuration of various functions.

A method for increasing the performances of the proposed line encoder is to integrate the presented design into a reconfigurable development board based on field programmable gate arrays (FPGA) and field programmable analog arrays (FPAA) that will ensure almost entire support for the required analogue and digital signal processing. This approach will increase very much the flexibility of the design, giving the possibility to extend the number and the complexity of the encoding techniques [7], [8].

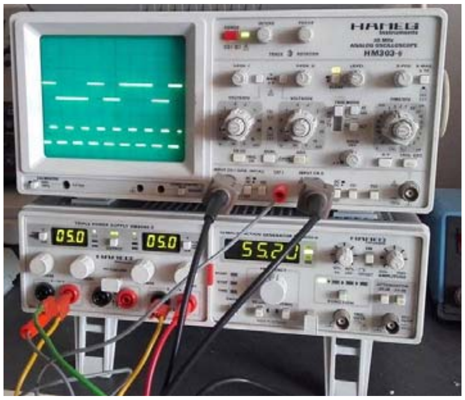

Fig. 6. Generated data and clock signals that are used for testing the correct operation of the line encoder.

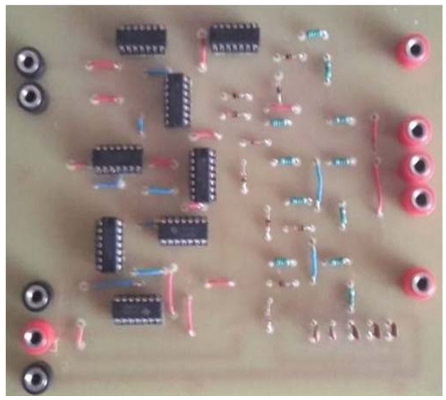

Fig. 7. The clock recovery circuit used for coherent decoding of the transmitted line codes.

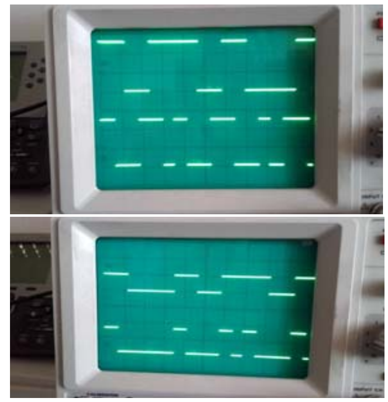

Fig. 8. The Manchester code in the figure above and RZ code in the figure below

V. Conclusions

For interconnection and integration of various electronic components of a modern car for obtaining the advanced functionalities based on the new concepts of autonomous and cooperative systems with artificial intelligence the key element is represented by the in-vehicle communication technique. The enhanced design of the proposed line encoder, based on synchronized line-codes, offers good performances regarding the resistance to perturbations as well as an improved spectral shaping and clock recovering capabilities, been suitable for communications applications in the automotive industry. For increasing the flexibility and the reliability of the line encoder, the proposed design can be transferred, with minimal changes, into reconfigurable circuits that can be programmed to operate with an extend number of coding techniques. Although the circuits presented in this paper was intended to be used for in-vehicle communications they can be also useful for didactical purposes, for teaching the principles of baseband data transmission using various line codes.

Acknowledgement

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