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COMPUTER SCIENCE MEETS AUTOMATION

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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M. Rosenberger/ M. Schellhorn/ P. Brückner/ G. Linß

Uncompressed digital image data transfer for measurement techniques using a two wire signal line

Abstract

Image processing technologies attain an ever higher value in the industrial measuring. Presently growth amounts to approx. 10-15% [1] and according to current studies this trend will continue. The transition from analog interfaces to digital pixelsynchronous systems is in many applications already realized. A disadvantage in the purchase to analog systems is the increased number of necessary wires. Interfaces from the consumer sector as for example Universal Serial Bus (USB) or Fire Wire usually utilizing a lesser number of wires and would be applicable here. Disadvantageously, these interfaces are limited by transmission length and/or transmission rate. The new Firewire standard IEEE 1394b for example, permits transmissions to maximally 100 Mbit/s over Category 5 unshielded twisted pair (UTP) cable. Higher data transmission rates limit the transmission length or require special cables such as plastics optical for fiber (POF) or hard polymere clad fiber (HPCF) known as glass optical fiber (GOF). [2] However, in complicated superstructures respectively old systems often only existing cable systems are usable. In most cases only an analog two wire system is available. There is therefore a demand for a broadband signal transmission on existing line systems. Current developments of the Department for Quality Assurance and Image Processing are dealing with the construction of a low voltage differential signal (LVDS) transmission line for transmitting digital video data over two wires. Based on a parallel digital interface of a CCD camera a possible serialization of the data was analysed. In a prototype application video data with a resolution of 782 pixel (px) to 538 px could be transferred over a distance of 20 m. Furthermore a signal repeater was developed to emphasize the transmission distance. A specification and first test results of the application shows the following paper.

Introduction

As described in the abstract there is a need for image processing technologies in industrial measurement and university research. Mostly some standardized interfaces like USB or Fire Wire were deployed to transmit the digital data from a Charge Coupled Device (CCD) or Complementary Metal Oxide Semiconductor (CMOS) camera. The disadvantage of these interfaces is the limited cable length. Furthermore actual there exist some measurement setups using analog image signals. For the signal transmission often a coaxial cable or a balanced two wire cable is used. The devices working very well, but a digital transfer gives the possibility of a higher accuracy and more transition safety. That is one of the reasons to research for the possibility to transmit digital images trough existing two wire signal cables, where actually analog signal transfer is used. For a significant range of cameras with a pixel count under 1Megapixel were used. Bridging the distance over 10 m or more is another reason for the actual development. Famous serial digital interfaces like USB, Fire Wire or others use a differential signaling for transmitting the data trough the line. The advantage of use is the high failure safety. Another important technique is the Low Voltage Differential Signaling (LVDS) technique. Therefore a lot of transducers were developed by several companies. The driver generates two signals mostly so called D+ and D- without a ground connection. These signals are inverse. The receiver subtracts the both signals. If there were any interference during the cable length, then it was subtracted too. The principle of work is also shown in figure 1.

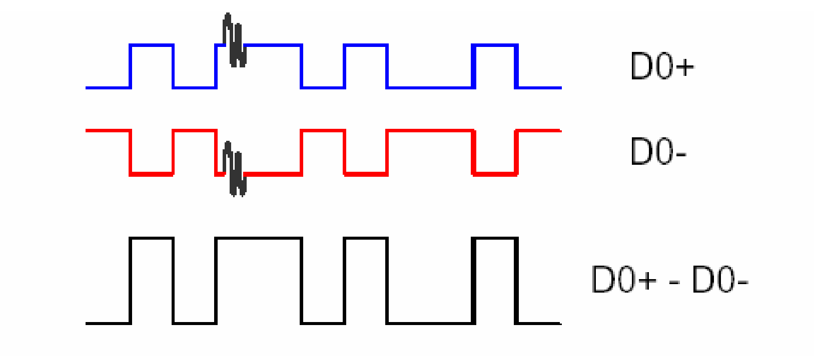

Figure 1: principle of differential signal processing [3]

The need for more resolution in anyway, for example High Density Tele Vision, drives the industry to develop LVDS driver-receiver systems with large bandwidth up to 1Gigabit per second (GBits). The advantage of these systems is the need of only one cable pair. Two conditions must be attended: the cable impedance of 100 Ohm for a twisted pair line and a impedance controlled layout for the LVDS Lines on the Printed Circuit Board (PCB). Historically the LVDS standard was a joint development of Texas Instruments and National Semiconductors.

Theory of the setup

The LVDS standard is standardized by the American National Standards Institute ANSI and the Telecommunication Industry Association (TIA) / Electronic Industries Association (EIA). The standard describes the electrical interface. The signal transition is realized by a current loop. A switchable current source drives the current loop. At the end of the line a termination resistor (cable specific) converts the current signal into a voltage. Under optimal conditions the voltage level reaches +/-350mV. The Receiver interprets a negative voltage level as a logical 0 and a positive level as logical 1.

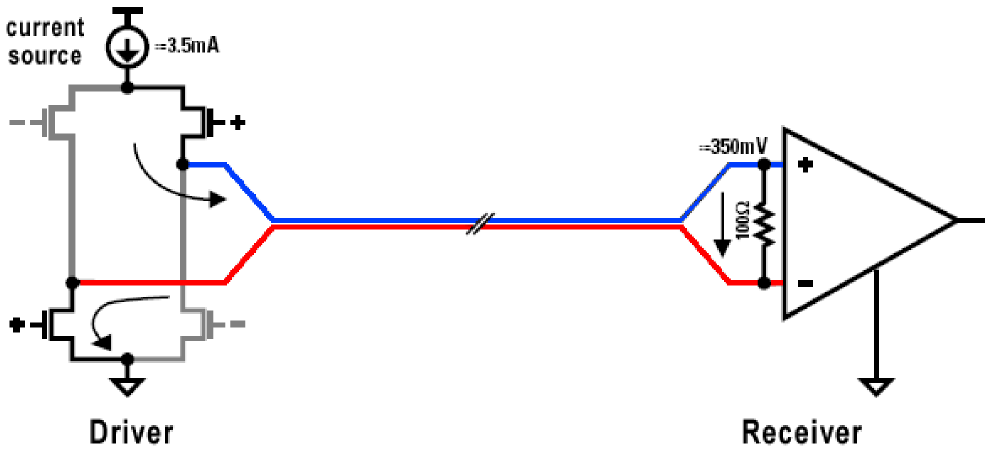

Figure 2: principle of the electrical interface [4]

The low voltage level gives the chance of a higher switching frequency. Therefore a high data rate can be transmitted. Actually it is possible to reach data rates up to 1 Gbits [5]. But it depends on the cable length and the signal frequency. An approximation of reachable data rates and cable length is given in [5]. For the planned setup it is possible to bridge a distance until 10 meters at 0,5 Gbits data rate. The output of a digital interface of a CCD Sensor is mostly parallel. Sometimes it is directly the interface from the analog to digital converter. Often there is a digital filter or a image buffer between CCD Sensor output and digital interface. To transmit these data over LVDS it is necessary to convert these signals in a serial data stream. It is beneficial to convert the output in a LVDS conform signal. This offers the possibility to connect the output directly on a LVDS line driver. The principle of serialization is shown in figure 3. It works like a inverse shifting register. After every clock cycle the actual bit state is shifted into serial data. For imaging systems normal the pixel clock is used to drive the serializer. The clock recovery in the deserializer is realized by sending a special start and stop pattern with the bit stream. For example a 10 bit Information is covered with start bit at the beginning and a stop bit at the end.

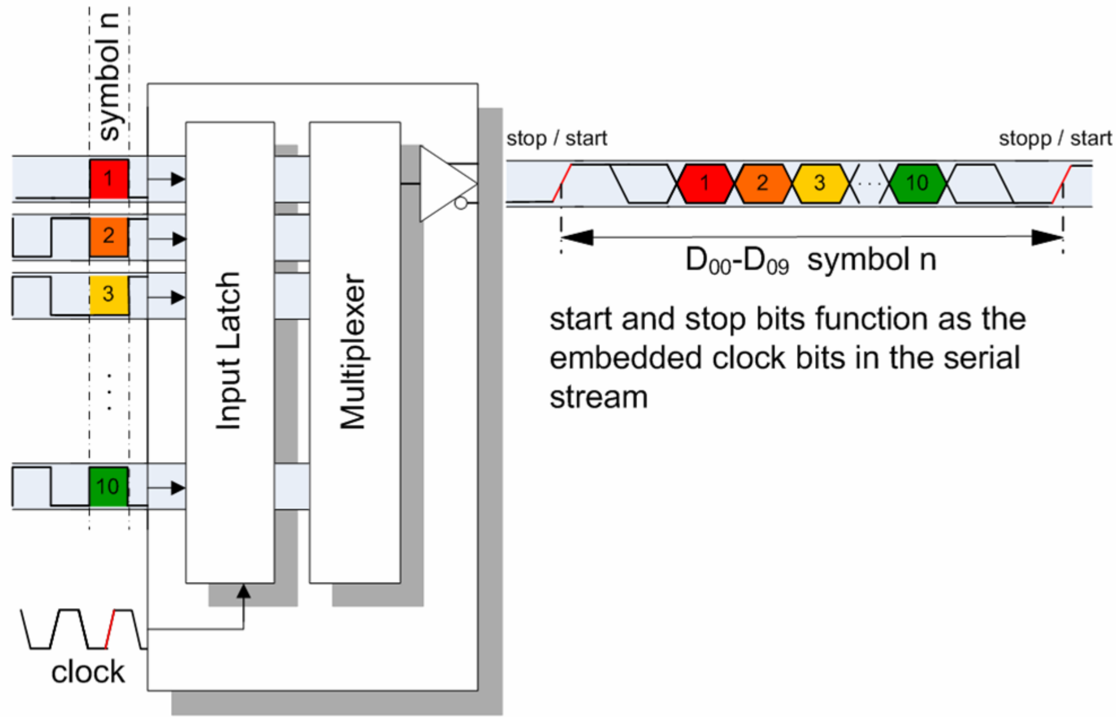

Figure 3: serializing a parallel sensor output [3]

The start condition (bit) is generated by driving both differential lines into the high level. Holding both lines in the low level state the stop condition (bit) is generated. The deserializer has the possibility to lock on these patterns with a PLL. The advantage of this kind of serializing is the need of only two lines. Therefore the data stream will be expanded until n+2 Bit. So the signal frequency on the signal lines increase rapidly. Actual there is a convention between number of input bits and input clock frequency.

Experimental setup

As described in the abstract, a setup with two signal lines transmitting a digital image was realized. Figure 4 gives an overview about the whole setup. The CCD Sensor streams with a pixel clock of 14,1875 Mhz and a picture size of 768x538 px. The image reference signal, the start-stop conditions and the eight bit image information per each pixel leads to a serial signal frequency of 170,25 MBit.

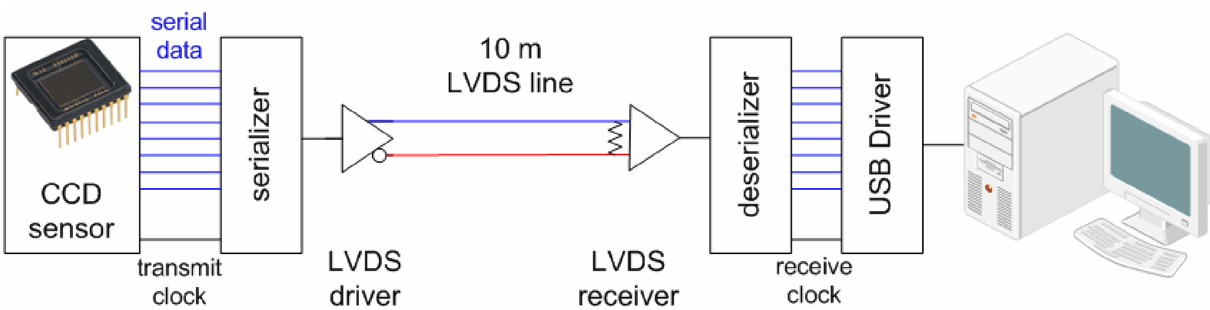

Figure 4: serializing a parallel sensor output

For transmitting of the image data a serializer/deserializer couple from the Texas Instruments company was chosen. The front end, getting the picture into the PC, was a self developed USB interface. For testing the setup, a special printed circuit board was developed. Firstly, both the driver and the receiver were connected on the same PCB. Special attention was paid for the correct differential signaling. So it is necessary to support a differential impedance of 100 Ohms for the LVDS Lines. The simplified dual strip line model was used to estimate the correct impedance on the PCB. The designed board offers the possibility to cut it in the middle. So a separate driver and receiver unit can be generated extreme easily. After the first general test it was cut. Then some different cable lengths were connected between the two units. Looking forward to reaching higher transmit distances a LVDS repeater based on the line driver couple was also developed.

Experiments

After the general function test with the test setup the board was cut into the driver and the receiver. The picture on the right hand side contains the whole test board.

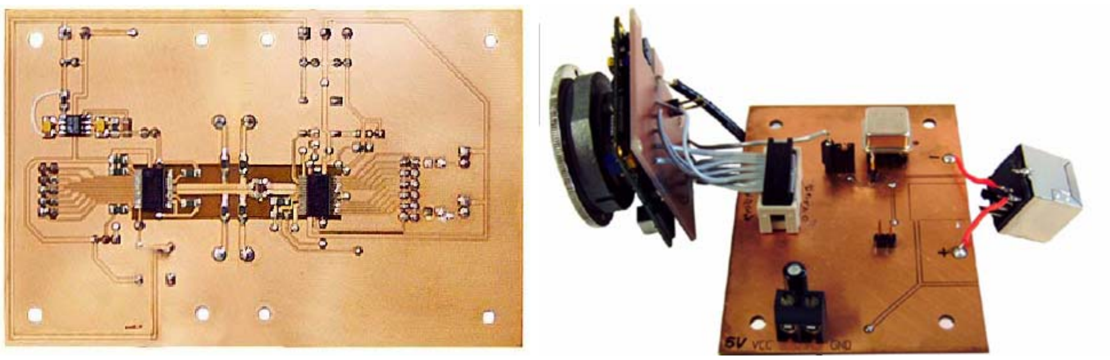

Figure 5: test board for LVDS streaming (left), sender unit after cutting (right) [3]

To get some information about the locked receiver, an error Light Emitting Diode (LED) was connected on a monitor port. A normal RJ 45 Connector was used as the interface for the differential lines. This gives the possibility to utilize standard network cables (normally with Z=100 Ohms). The picture on the right hand side shows the driver unit. A comparable device was build as a receiver. In accordance to the standard the test cable length was 10 meter. For this distance the setup works very well and stable. To get some information about the boundaries the cable length was increased by 5 meter steps. The system works stable until 15 meter cable length. At higher cable length the synchronization was lost accidentally. Therefore a signal repeater was developed to gain the signal. A special adapted driver receiver circuit was discovered at the Texas Instruments Company for this purpose. The repeater gives the capability to bridge higher distances. Theoretically it is possible to connect every 10 meters a repeater. For the test only one repeater was used.

Results

The setup demonstrates that LVDS signaling gives the possibility to transmit uncompressed digital image data image over a balanced two wire cable. A distance until 10 meter can be bridged with this setup. Using a repeater helps bridging higher transition distances. So it gives the chance to exchange some old analog systems trough digital ones or bridging distances that standard solutions can not bridge.

Conclusion and Outlook

The actual setup is in an experimental state. So an optimized layout will bring better working conditions for the data transfer. The error LED on the receiver can be used for error recognition in the data transfer. Only the electrical signal must be transferred and analyzed in the Host PC. Furthermore the next step should be the integration of a redesigned layout in an application, where analog signal transfer is actually used. After that, it is possible to get information about the better measurement conditions with the digital data transfer. In the industrial development some LVDS devices were developed. These devices deal with higher transfer distances and give new possibilities for application.

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