USB Board Camera for 2D and 3D PC-based Vision Systems

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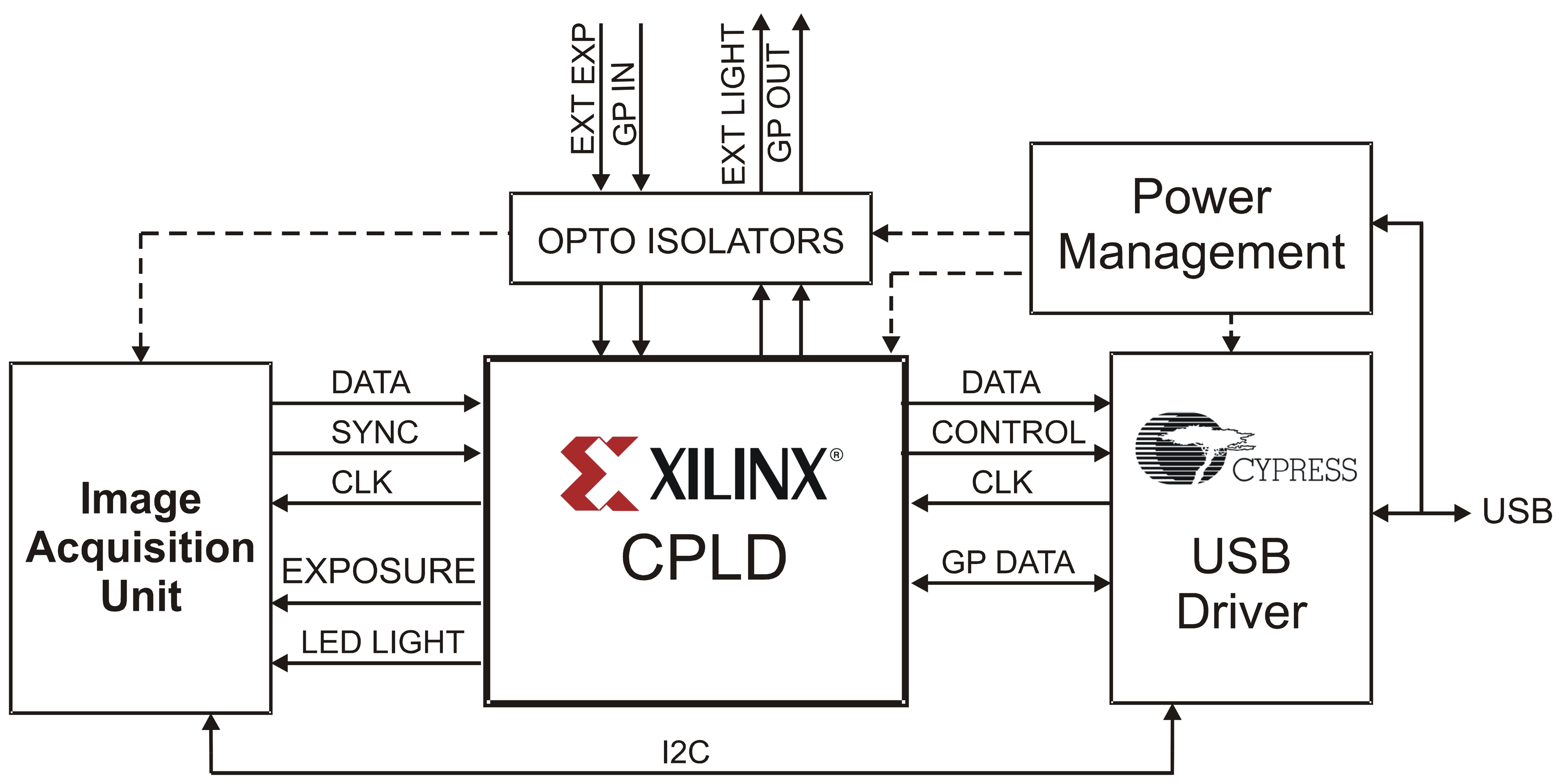
Abstract

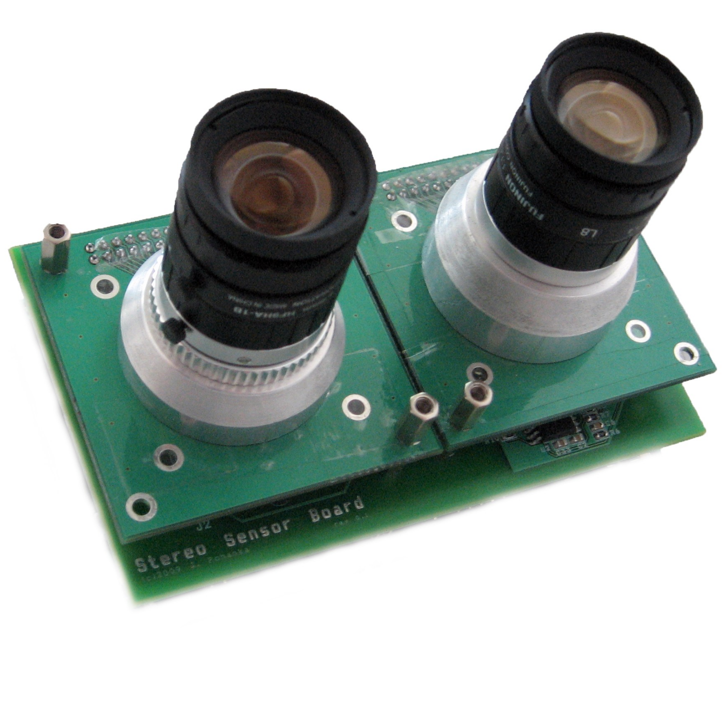
This paper deals with development of a simple direct interfaced camera device. The developed camera can be used as a source of image data for machine vision or image based measurement algorithms running on PC. For communication with a master system the USB 2.0 High Speed interface is used. The basic advantage of the introduced device is its modular conception which allows the use of various image sources – image sensors or videocodecs. Conception of the USB camera was advanced by additional timestamps and synchronization data which enhance every single frame transferred to the PC. This feature makes the developed device suitable for tasks where the precise timing of image acquisition is required together with an external synchronization. Construction of the basic single sensor 2D type was improved and a 3D version of this camera will be also introduced.

USB Board Camera Construction

The main advantage of both designed cameras (2D and 3D) is their simple, cheep and robust design. No special CODECs or image compressors are employed and all the acquired data are in the real-time transferred to the PC for processing Basic construction model of the developed camera was based on modularity, which increases the range of possible applications.

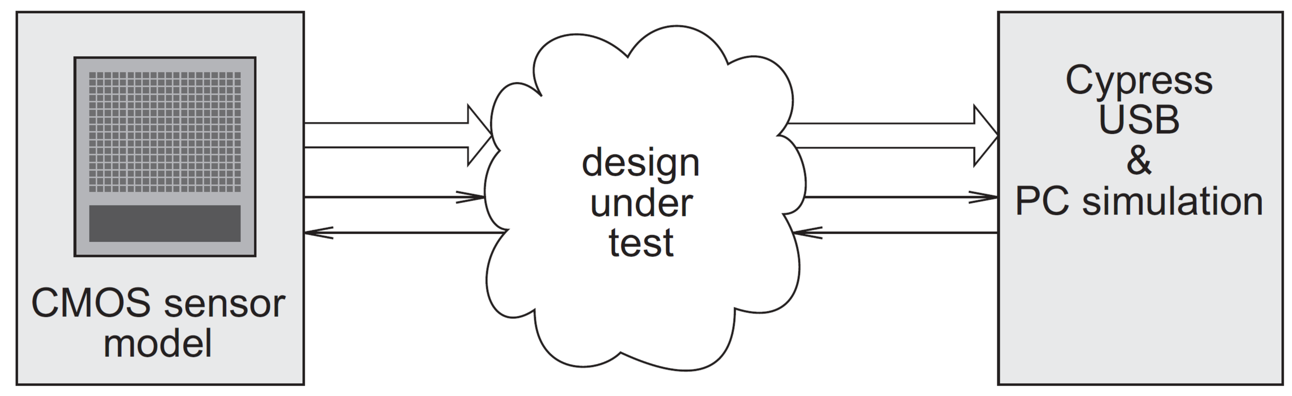


From all the interfaces available on the market and capable of providing the required throughput (20-50 MB/s), the High Speed USB 2.0 is the most common. There are also several hardware implementations of USB 2.0 interface chip varying in given design freedom. For this project the Cypress FX2 controller was chosen as it provides internal buffers for load balancing and a small x51microprocessor for configuration tasks. To interface image sensors with the Cypress chip a simple logic can be build from logic gates or in a dedicated CPLD. The first option provides cheaper solution, but it fail in case of modular system with exchangeable sensor boards, as the sensor interfacing signals differ between sensor manufacturer and even between different sensor types from the same manufacturer. Therefore the configurable platform with CPLD was employed in the final design of this board. That approach also gives the opportunity of simple image preprocessing like thresholding or 1D edge detection and also provides the platform for data fusion, where more than image data can be transmitted in one stream.



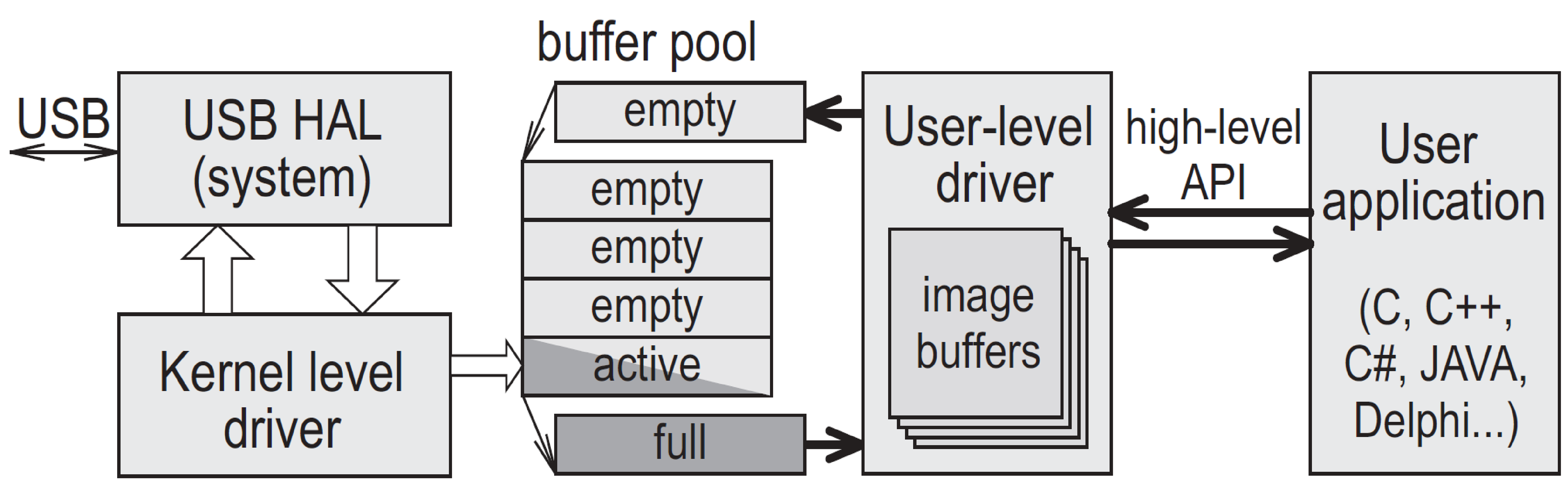
VHDL Models and Simulation

To test the designed algorithms, a universal testbench was prepared. It consists of three main blocks/files.The testbench itself, providing the simulation environment, the test data source (the sensor simulator) and the data sink (the USB simulator). All the units are fully configurable by the "GENERIC constants" and truly simulate the real devices. The virtual sensor can provide any polarity of control signals and an arbitrary delay between them and on the data signals it either internally generates simple geometrical objects like bars and rectangles or export a real image read from file. The cypress simulator on the other side truly simulates the input buffer management unit, a simplified USB transaction scheme and the latency times caused by data handling performed on PC.



PC-side Solution

In case of Cypress, the driver and API consist of two parts. The kernel driver CyUSB.sys and the high-level API distributed as a static library containing several classes compiled for Microsoft Visual C and Borland C, both commercial platforms and no support for open development tools like MinGW32. To support customers with such needs, Cypress also publishes the kernel driver communication protocol (the IOCTL codes and structures) and the whole communication layer of the designed system is based on these functions. But even with this lowest level access, the simple approach of repeating requests for whole images creates the latency-caused errors.



Conclusion

The main advantage of the designed solutions (2D and 3D) is the enhanced data stream which consists not only of acquired image data but also additional data can be included. These data can carry an external synchronization information, precise timestamps or actual frame numbering for easy detection of lost frames and image discontinuities. These features destine this camera for embedding into laboratory and precise industrial measurement chains. From the digital image processing point of view the offered uncompressed image format can decrease uncertainties of obtained results (position measurement, edge detection, fine textures etc.) and eventually increases algorithm effectivity. For the successful estimation of possible timing problems and maximal USB channel throughput rates a complex VHDL simulation model was created. The effective solution of PC-side user level driver was introduced. Having realized a set of practical measurements it has been shown that the continual frame rate from the camera with WVGA sensor to a standard PC is about 52 fps in 2D and 25 frame-pairs in 3D. According to the low construction complexity the proposed camera solution is cost-effective and opens the features of expensive image acquisition systems for simpler cost-restricted projects.

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