FPGA BASED FRAME GRABBER FOR VIDEO BEAM DIAGNOSTICS

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Abstract

TV-based accelerator diagnostics are widely used for machine operation and beam diagnostics. It is planned to renew the video memory modules of the TV monitor data acquisition systems for the injection and transfer lines at DESY. New FPGA based Frame Grabber (FG) modules were developed within this project. The modules are required to be able to work with different analog signal formats, to capture video frames on trigger and to provide live mode operation. The main feature of this FG is the possibility of reprogramming. This allows us to optimize its functionality, for example to operate with non-standard or corrupted video signals. This has proved especially useful for grabbing images from CCD-cameras suffering from radiation damage.

INTRODUCTION

Beam diagnostic systems based on TV image acquisition are widely used at accelerators for tuning of transfer lines and for studying physical properties of the beam [1]. Beam monitoring using TV-cameras has a long history and this method is still popular today. These systems have a wide distribution due to their unsophisticated structure, low price because commercially available components can be used, and their relative simplicity in maintenance.

The hardware of a system consists of a movable scintillator or OTR screen, lens, a commercially available TV-camera, and a frame grabber. One example at DESY is the video beam diagnostics for the injection and transfer lines for the electron synchrotron DESY-2. A block diagram of the readout scheme is shown in Figure 1.
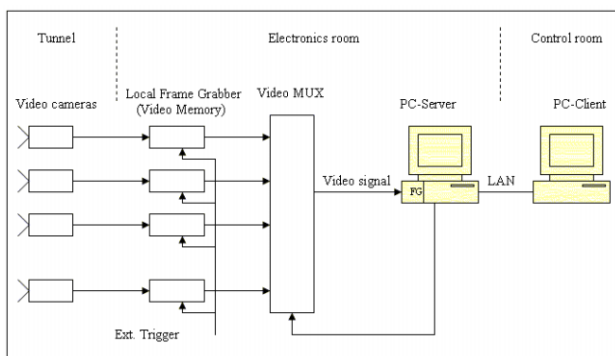

Figure 1: Block diagram of the readout scheme.

Images of the beam from the movable thin luminescence screens are read out by CCD video cameras. Radiation hard cameras are used in highly irradiated areas. The output signals of the cameras are digitized by local frame grabbers after an external trigger. The frame grabbers are triggered at the transfer or injection of electrons or protons. The two TV-half-frames

are stored until the next trigger; the local FG therefore operates as a video memory. The output of the FG is an analogue TV signal of the stored half-frames.

The number of FG modules in a system varies from 1 (e.g. a synchrotron light monitor) up to 24 (e.g. a proton transfer line). The output signals of the local FG are connected to a video multiplexer which is controlled by a server in the control system.

The analogue FG output can be viewed in the control room using a TV or a PC with integrated frame grabber. For improved functionality, we now use a control system PC with integrated grabber [2] to grab the images, perform analysis, and to distribute the digitized images over the control system [3], [4]. In this way digitized and stored images of the beam from all screens can be displayed and analyzed off-line using client programs (see Fig. 2).
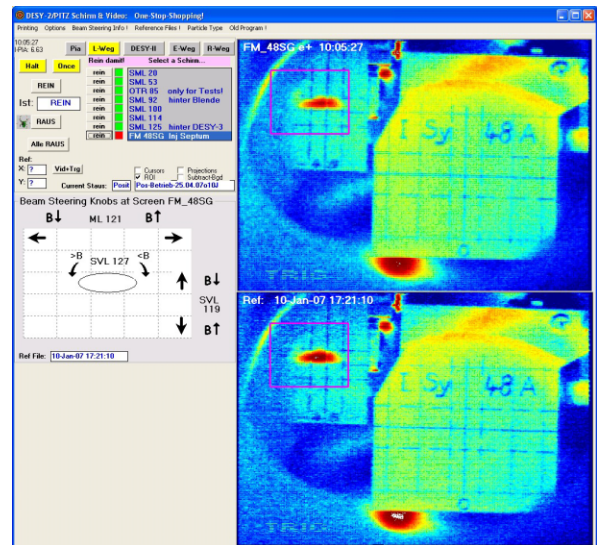

Figure 2: Image of the beam displayed using a transport line video client program. Upper image: live picture; lower image: reference picture; left side: control of the video equipment of the transfer lines.

The beam position as well as size and emittance can be measured from the screen images. This helps to improve injection efficiency, emittance preservation and beam optics matching.

It was decided to replace the more than 10 years old video memory modules [5] which were becoming difficult to maintain. Beam instrumentation has special demands compared to those of the consumer TV data acquisition market. There should be the possibility to treat the output analogue signal of the video camera before final digitization. It was not possible to find a commercial frame grabber with this feature. Another reason for the in-house development follows from the layout of the readout
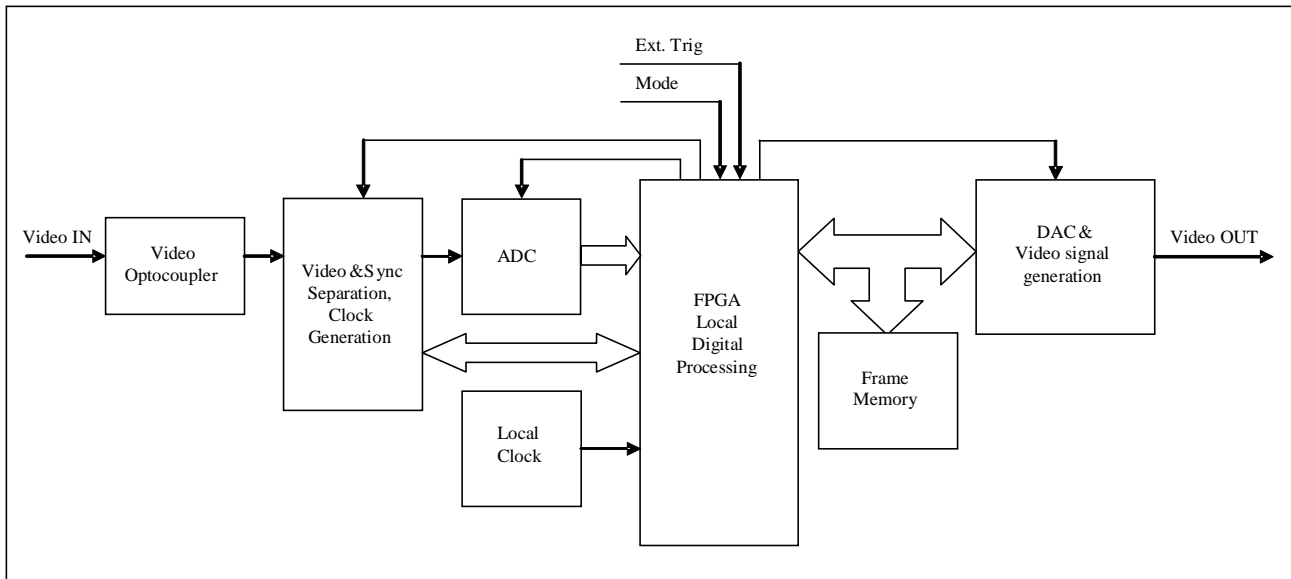
Figure 3: Block scheme of frame grabber.

schemes. In some locations we have up to 24 local FG, in others only one module is needed. Commercially available frame grabbers are mainly performed in PCI-standard. There is little sense in using either a group of PCs in the first case or a dedicated PC in the second case, only as a video memory. Therefore it was decided to develop a module which can operate either stand-alone, or as part of a multi-channel system.

DESCRIPTION

Figure 3 shows a block scheme of the frame grabber. The input video coupler can be used in order to avoid the possible large potential difference between the grounds of the FG and the video camera. An external trigger starts the TV data acquisition. Line and field synchronization signals from the sync-separator are used to start line and frame recording. A phase locked loop circuit synchronizes the digitization clock of the Analog to Digital Converter (ADC) with the incoming video signal. This means that a consistent number of samples are taken on each video line and more importantly that the samples are taken in a precise vertical line on the raster. This is essential for further digital processing. The 12-bit ADC converts the video signal to a digital representation at 13.5MHz sample rate. The data from the ADC is fed to a Field Programmable Gate Array (FPGA) for digital filtering. The result is stored in two 256kB high speed static memories. One or both fields of the input video signal can be recorded. Stored data is transformed to the output composite video signal by means of Digital to Analog Converter (DAC). A video line driver is used to drive the output signal. The stored picture is present on the output of the FG until the next external trigger signal is received. The FPGA controls the local digital signal processing.

Additional feature of the FG are:
- Ability to sense the standard of the input video signal,
- Automatic Gain Control,
- No signal detection,
- "Live" mode of operation,
- Status information (e.g. "No Input Signal") is integrated into the output video signal.

The module of FG is built on a compact 3U Eurocard format. In addition two types of enclosures for the FG were developed. The first type has one slot for a power supply and one for a frame grabber plus two additional slots for test and extra purposes. The second type has 17 free slots for FG modules in addition to the power supply. The boxes are based on a 19" enclosure. Two corresponding types of backplanes were developed as well. The pin assignments of the backplanes were chosen to be as close as possible to the VME-standard.

INITIAL EXPERIENCE

The main feature of the developed FG is the possibility for reprogramming. This is very important feature because the signals from the video cameras do not always meet TV-standards. Video cameras are generally located in high radiation environments. After a long period of operation, degradation of the output signal of cameras can be observed, even with extra shielding against the radiation. What we have found is that industrial frame grabbers are not always able to grab such degraded signals; they are designed for clean, standard input video signals. In such a case it would be necessary to replace the camera which is a costly and time consuming solution. The designed FG module is able to grab images with partially corrupted signal. Thus it allows us to extend the useful lifetime of the video cameras.

Figure 4 shows the composite video signal from the camera SY48a located in one of the transfer lines. One can see that the total period of one video line is 63µsec; this period in the PAL TV-standard is 64µsec. Some commercial FGs have difficulties to grab such a signal. In
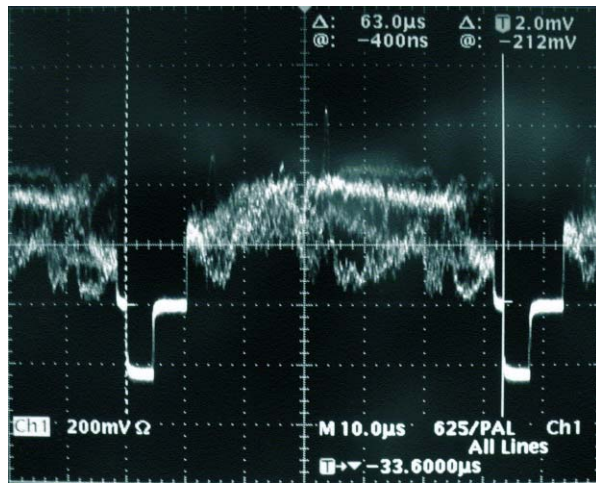
Figure 4: Degraded composite video signal.

one extreme case, for a camera in operation the total period of one line was only 61.16μsec. The developed FG was able to grab this signal. Thanks to the possibility to reprogram the FPGA it was possible to process this signal and convert it into the standard PAL format.

Another adverse factor is noise. Often the processing electronics are located hundreds of meters away from the TV-camera because of the radiation environment. This means that the incoming video signal can be noisy. In such a case additional digital filtering inside the FPGA helps to achieve a useful video picture.

SUMMARY

Commercial available frame grabbers do not always satisfy the requirements of accelerator beam instrumentation. The new FPGA based frame grabber module can be used as a video memory in TV image acquisition systems for electron and proton transfer lines and first turn analysis in storage rings.

Due to their reprogramming ability it is possible to operate the frame grabbers with noisy or corrupted video signals. This allows us to postpone the replacement of video cameras located in radiation environments.

ACKNOWLEDGEMENTS

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