dpcontrol

Edge AI Vision today's

User Guide
ISPido on VIP board

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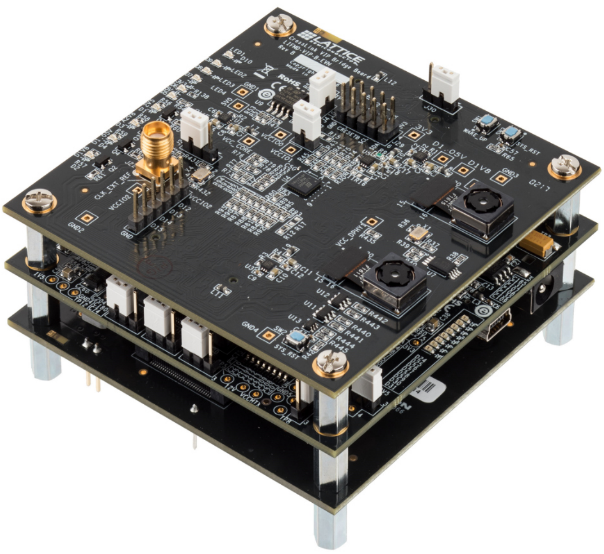

Contents

Introduction

The purpose of this user guide is to show the opportunities offered by ISPido, the video stream processing system developed by DPControl Srl and shown in the demo.

After the presentation of the hardware peripherals used, the individual IPs of ISPido will be explained and the potential of this system will be shown.

The proposed system provides a video stream, over HDMI, at 1080p 60 fps (frames per second). The individual IPs are configured via RiscV and the menu can be accessed via a serial port. Furthermore, no external RAM memory has been used.

1. Hardware

1.1 General harware configuration

Fig. 1.1 shows the basic connection to be able to evaluate the video signal proposed by ISPido on VIP Board.

This output signal is in YCbCr 4:2:2 mode and a monitor with HDMI input is required.

In order to use the menu offered by the demo it is necessary to use a USB to TTL Serial Uart converter to be connected to a PC with appropriate data reading software. The cable has a yellow dot on the upper side.

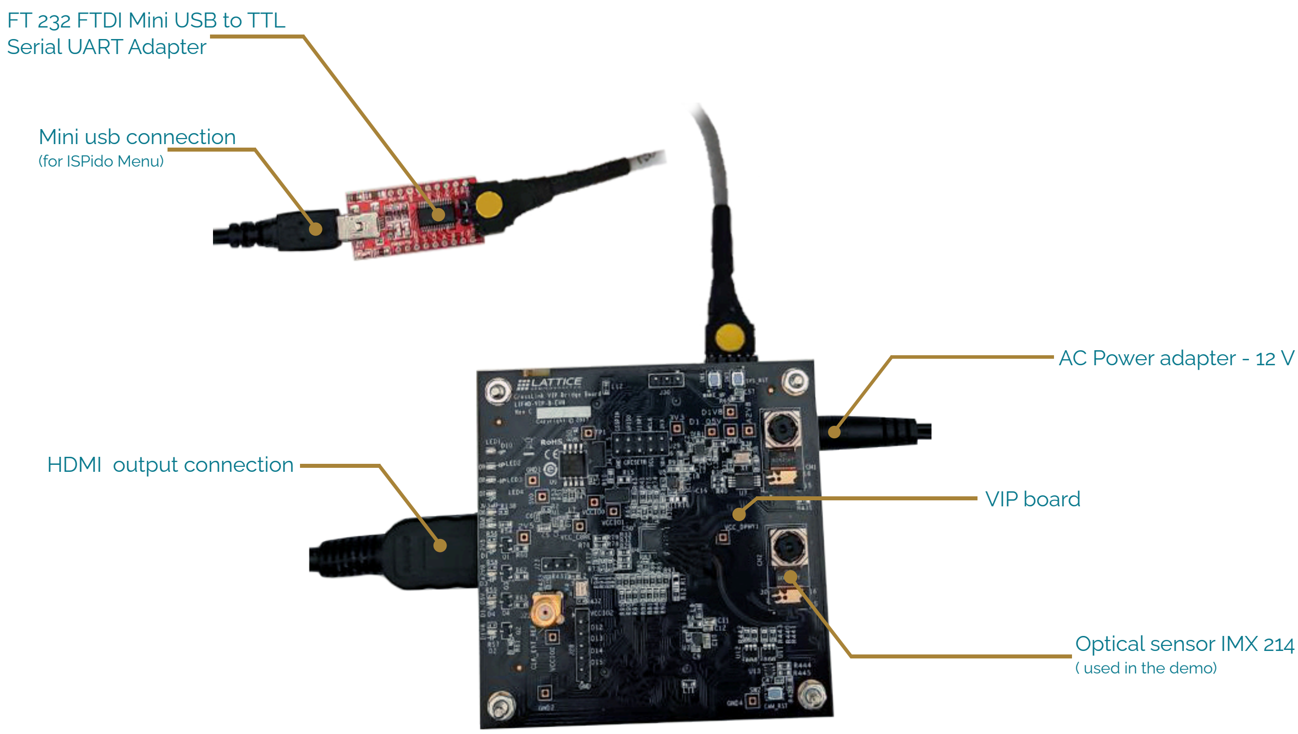

Fig. 1.1

1.2 Functional description

Fig. 1.2 shows the functional description of the project in this demo.

The CrossLink board is in charge of acquiring the video signal coming from the IMX-214 sensor and transmitting this signal to the ECP5 board. This board contains ISPido and Risc-V to process the video signal and obtain an optimised image, in real time, without the use of external memories.

Finally, the HDMI card transmits the processed video stream to an external monitor.

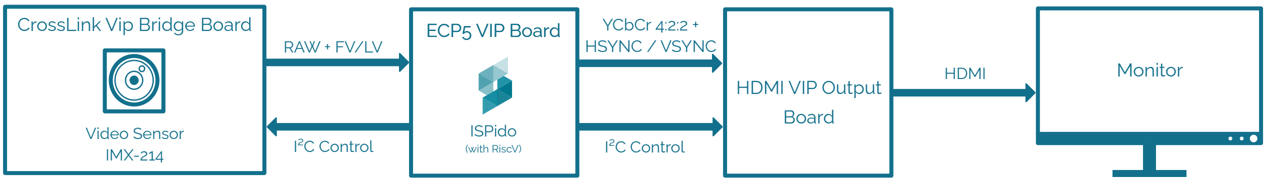

Fig. 1.2

1.3 CrossLink VIP Input Bridge Board

The proposed system uses a Lattice Semiconductor CrossLink™ Input Bridge Board that allows parallelisation of the signal from the sensor with the MIPI CSI-2 interface.

It is important to note that the current demo configuration uses only one IMX-214 sensor (marked in Fig. 1.2) of the two available. The output of the additional equipped sensor has therefore been disabled.

This board translates the MIPI signal into a RAW10 signal that is then transmitted, via parallel port, to a board equipped with an ECP5 FPGA (Lattice semiconductors) to process the video stream via ISPido.

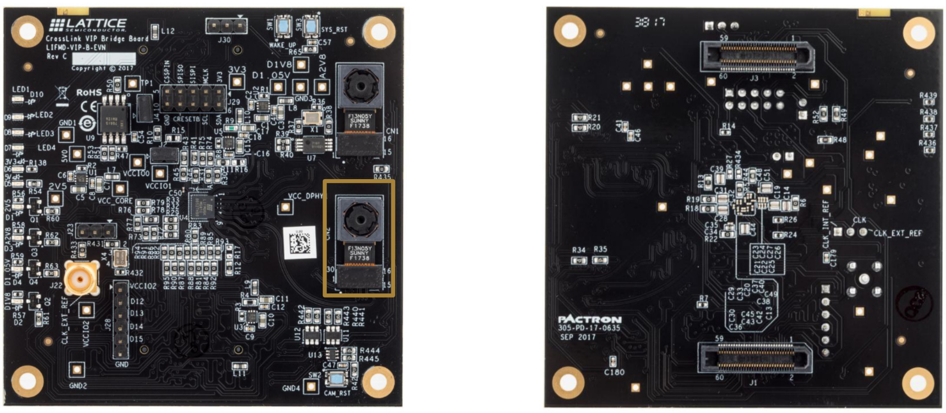

Fig. 1.3

1.4 ECP5 VIP Processor Board

The second board in the VIP system is an ECP5 Processor Board equipped with a high-performance LFE5UM-85F-BG756.

Inside the FPGA is loaded ISPido, the video stream processing circuitry.
ISPido receives the configuration of its IPs from RiscV, loaded in the FPGA, via the AXI-Lite protocol. It is possible to communicate with the Risc-V via the serial port connected to the GPIO (marked in Fig. 1.3) provided on the board.

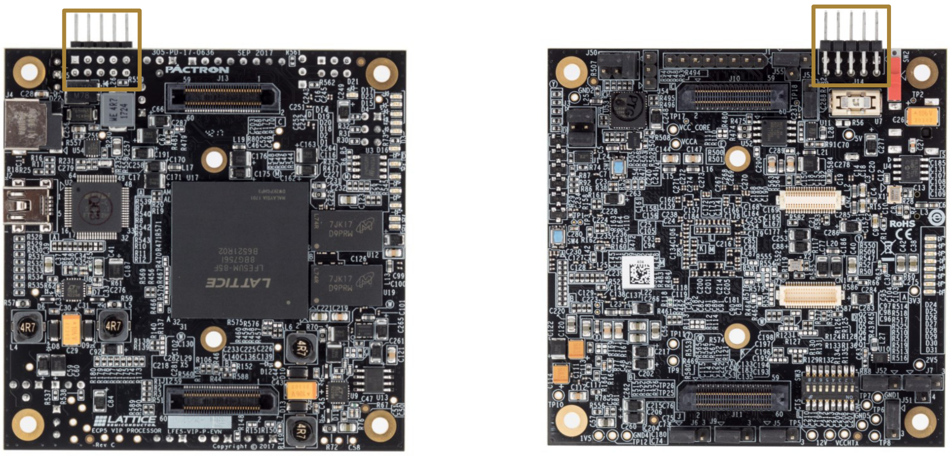

Fig. 1.4

ISPido receives the RAW10 video stream from the sensor, via the Crossilink board, converts this signal into an AXI-Stream signal and performs the following processing:

- Application of the appropriate bayer pattern to obtain a video in RGB mode
- Application of gamma factor adjustment,
- Application of convolutional filters,
- Analysis of RGB statistics,
- Application of Auto White Balance (AWB) and Auto Exposure (AE),
- RGB to YCbCr conversion and output stream in 4:2:2 mode.

In addition, the ECP5 FPGA sends the configuration, via I^{2}C, to the sensor on the Crosslink board and the configuration for the SiI1136 HDMI transmitter.

1.5 HDMI VIP Output Bridge Board (Sil1136)

The Sil1136 transmitting device, configured via I2C words of 36 bits, contains the video signal data in YCbCr format. It also receives the synchronisation signals, which are necessary for the correct display.
The information is then converted so that the video can be displayed on an HDMI monitor.

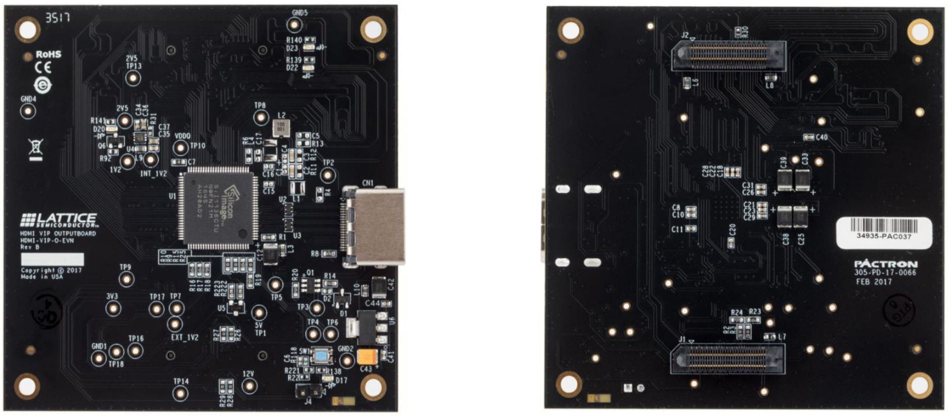

Fig. 1.5

2. ISPido

ISPido (Fig. 2.0) is a set of IPs produced by DPControl for processing video streams. This set of IPs aims to obtain a calibrated and correct video image that is as consistent as possible with the real subjects being framed.

The processing of the video stream is therefore carried out partly by the dedicated IPs and partly via software, obtaining the correct configuration parameters for the video sensor.

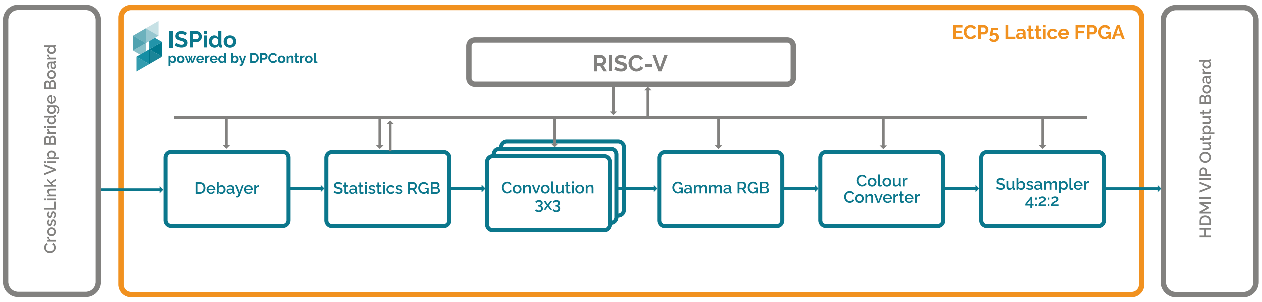

Fig. 2.0

ISPido is set up and started by RiscV, which also processes the information provided by the IPs to perform Auto Exposure (AE) and Auto White Balance (AWB).

It is possible to transmit commands or read information from the IPs via serial port and the interactive menu provided (see next chapter).

2.1 Debayer

The sensor provides a bayerised image that needs a procedure, known as demosaicing, in order to obtain RGB video showing colours similar to those we are used to seeing in real life.

The debayerization procedure, designed in this IP (Fig. 2.1), allows the matrix of the values of each plane to be completed by interpolation in order to obtain a complete RGB image

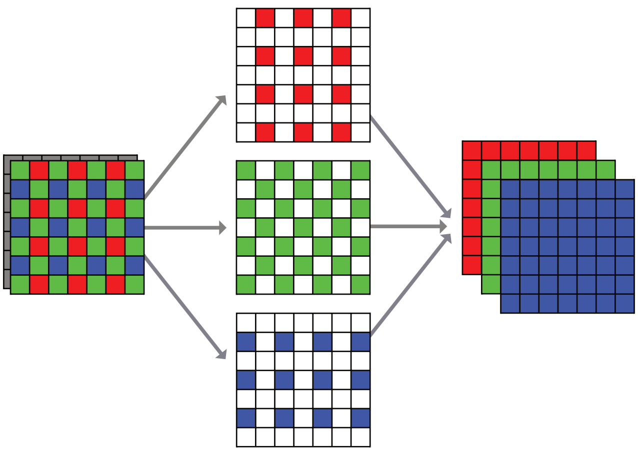

Fig. 2.1

2.2 Statistics RGB

The Statistics RGB IP provides histograms of the individual RGB channels (Fig.2.2). When all analysed frame information is available, an interrupt is raised and the data is available on demand via AXI-Lite commands.

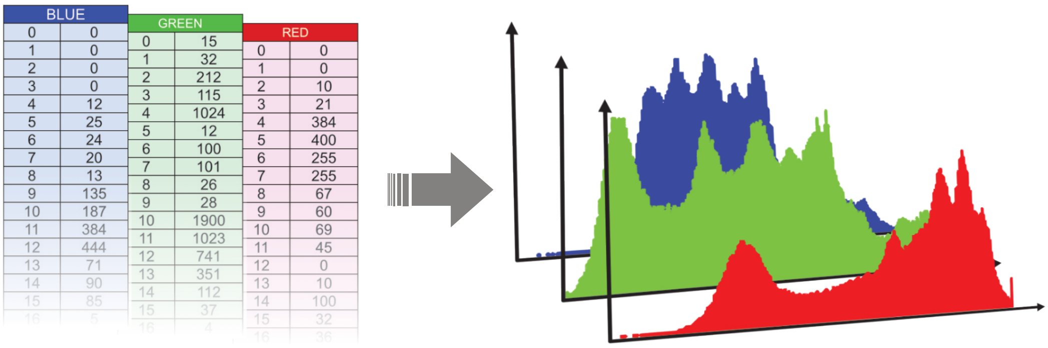

Fig. 2.2

This data, used for internal calibrations, can also be displayed on a serial port (see next chapter).

2.3 Convolution 3x3

Convolution IP allows the image to be filtered using a 3x3 kernel. This filtering processes the pixel of interest with its neighbours using the weights set by the selected kernel mask. This allows the recognition of gradients in the image or the enhancement of specific details.

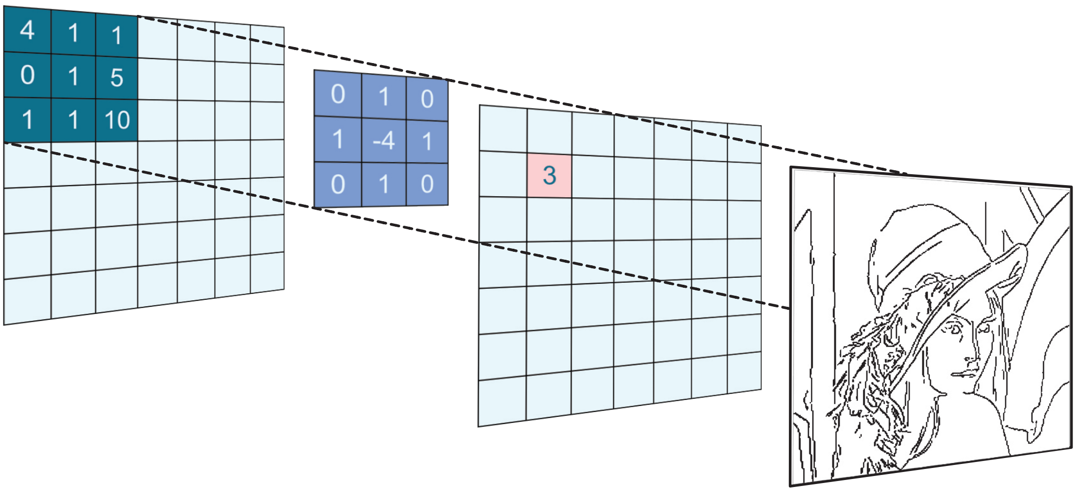

Fig. 2.3

Different matrices can be applied to obtain different effects (e.g. edge recognition in Fig 2.3 or bas-relief, sobel, etc.).

2.4 Gamma

There are substantial differences in the perception of light by the human eye compared to that of an optical sensor. We have a much greater sensitivity to variations in dark tones than light ones). Gamma defines the ratio between the numerical value of a pixel and its actual luminance. Without gamma correction, the tones captured by digital cameras would not appear as they do to our eyes and would be distorted in video reproduction.

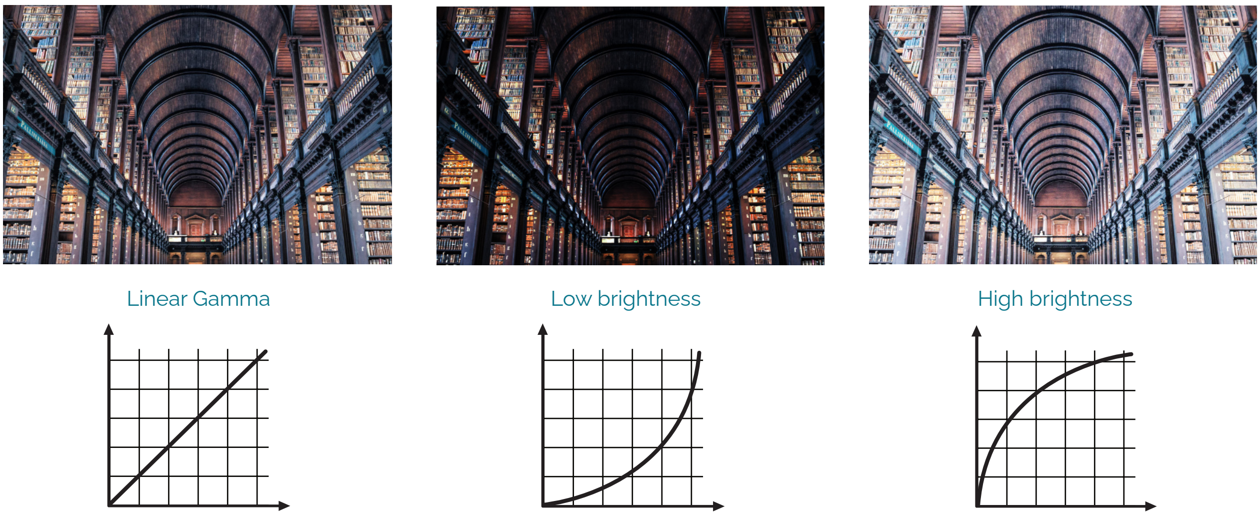

Fig. 2.4

Gamma correction is a non-linear operation that uses tables of values to re-establish the relationship between light and dark tones in order to obtain images that are more reliable and closer to human perception (e.g. Fig.2.4).

2.5 Colour Converter

YCrCb is a colour model that separates intensity from colour information (Fig. 2.5). Humans are much more sensitive to light intensity than to colour information.

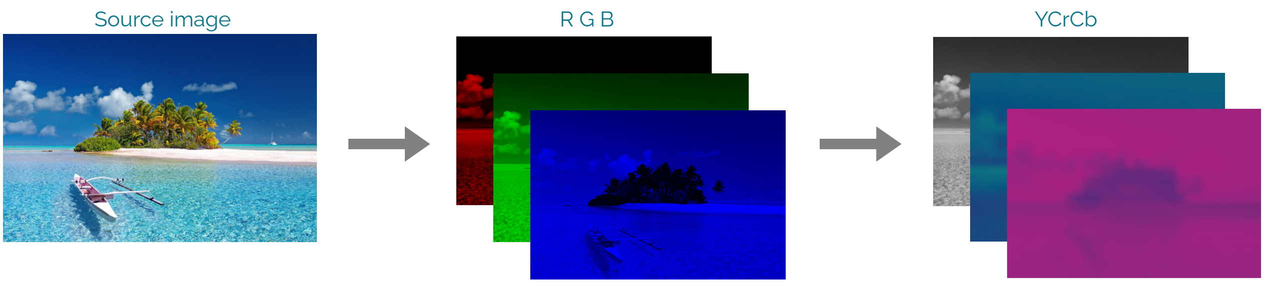

Fig. 2.5

For this reason this colour space (YCrCb) is more suitable for bandwidth-saving video transmission. In fact, it is possible to reduce the colour information without perceptual loss.

2.6 Subsampler 4:2:2

As mentioned in the previous section (2.5) the human eye is more sensitive to variations in luminance (Y) than chrominance (Cr Cb). This makes it possible to transmit data by reducing colour information without losing perceptual image quality. The IP Subsampler 4:2:2 reduces the Cr and Cb chrominance channels by a factor of 2 while leaving the Y channel unaffected, as shown in Fig. 2.6.

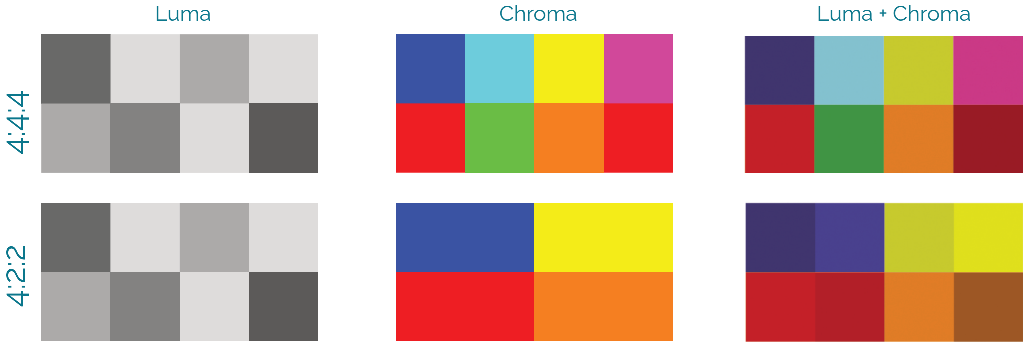

Fig. 2.6

Although in Figure 2.6 we can see markedly different colours between the 4:4:4 and the 4:2:2 configuration, on a real image this difference is substantially less pronounced given the large number of pixels present with relative homogeneity of tone between neighbouring pixels. In a video stream, where there are at least 24 frames per second (around 60 fps in the case of the VIP board), these differences are imperceptible to the eye.

3. ISPido Menu

This section will explain the functionality provided by the ISPido menu.

In order to access this menu, it is necessary to connect the FT 232 FTDI serial converter (shown on page 2) via USB port to the PC.

In addition, the use of Putty software (available for both Windows and Linux) is recommended to display the desired text.

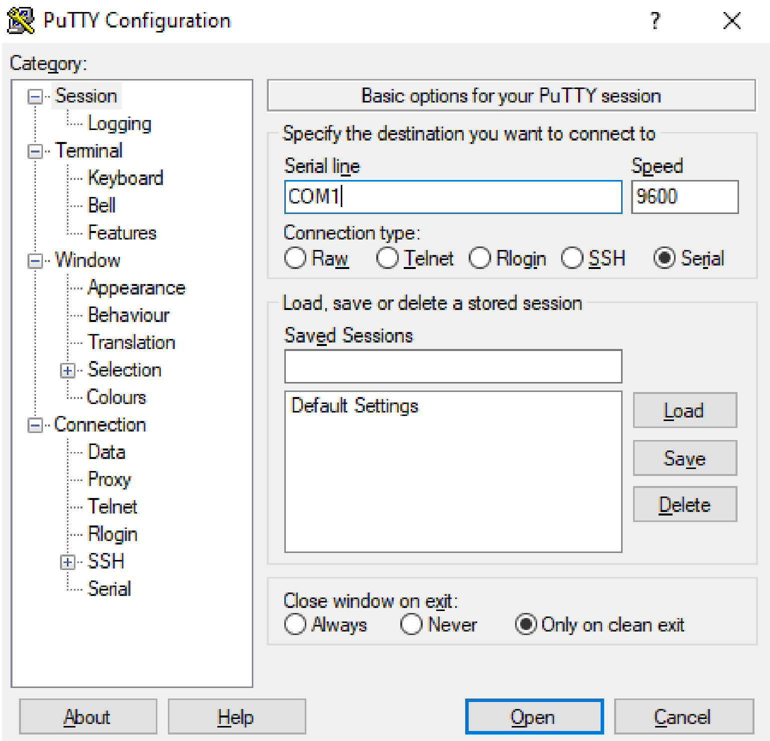

Fig. 3.0

As shown in Fig. 3.0, it is important to configure the software for serial communication with a baundrate of 9600.

The serial port number to be entered in the Serial Line field is defined automatically by your PC, so it is necessary to search (via device management in Windows or from the terminal in Linux) to which port the converter is associated.

3.1 ISPido menu interface

The ISPido menu looks like Fig. 3.1

Currently it is possible to select up to 9 different commands that allow automatic and manual calibration

Fig. 3.1

<u>Command Choice :</u>

3.1.1 - 0 : Start Calibration

This command starts the automatic calibration in real time. Once this item is selected, the start of calibration will be confirmed by a message as in Fig. 3.2 and you will no longer have access to the other functions of the menu until the next time the device is restarted.

```
Automatic run-time calibration started!
```

Fig. 3.2

3.1.2 - 1 : Read RGB Statistics

This command displays the weighted average of the histograms (Fig. 3.3) of the RGB channels on the serial line. Once the data has been acquired, the IP that generates the histograms raises an interrupt and waits for the data to be read.

Once the reading is complete, the interrupt signal is lowered and another analysis can be carried out.

```
00
08
10 XXXXXXX
18 XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
20 XXXXXXXXXXXXXXX
28 XXXXX
30 XXX
38 XXXXX
40 XXXXXX
48 XXXXXX
50 XXXXXX
58 XXXXX
60 XXXX
68 XXX
70 XXX
78 XX
80 XX
88 XX
90 X
98
A0
A8
B0
B8
C0
C8
D0
D8
E0
E8
F0
F8 XXXXXXXX

GPIO interrupt cleaned
```

Fig. 3.3

3.1.3 - 2 : Gamma Table Selection

Several non-linear curves can be selected for Gamma variation. (Fig. 3.4)

```
****************************
Choose the Gamma configuration:
0.  Gamma linear
1.  Gamma18
2.  Gamma22
3.  Gamma1_12
4.  Gamma1_14
5.  Gamma1_18
6.  Gamma1_22
Your choice:
```

Fig. 3.4

Ratio*	Effects
Linear Gamma	No variation is applied
1,8	Dark tones are accentuated
2,2	
1 / 1,2	Light tones are accentuated
1 / 1,4	
1 / 1,8	
1 / 2,2	

*Ratio between the numerical value of a pixel and its actual luminance.

3.1.4 - 3 : Convolution Matrix Selection

Eight items can be selected in this sub-menu (Fig 3.5). The first one (by default) does not apply any filtering,

```
****************************
Choose filter to apply:
0.  Passthrough
1.  Gaussian Blur
2.  Sobel
3.  Sharpen
4.  Bas-relief
5.  Laplacian
6.  Edge
7.  Blur
Your choice:
```

Fig. 3.5

Command	Effect
Passthrough	No variation is applied
Gaussian Blur	It uses a kernel in which pixels closer to the central pixel have a higher weight and those further away a lower weight in order to achieve blurring
Sobel	It is used in particular in edge detection algorithms, and provides an image with emphasised edges.
Sharpen	It is a process of differentiation where the goal is to find the difference by the neighborhood and enhancing them even more.
Bas-relief	It is an effect that creates the optical illusion of three-dimensionality.
Laplacian	emphasises the edge areas and de-emphasises the slowly changing areas
Edge	A simple filter for edge recognition
Blur	A simple blur filter with a uniform kernel

3.1.5 - 4 : Analogue Gain Calibration

The analogue calibration procedure uses the data acquired from IP Statistics. Once the offset is calculated, it writes it to the registers and repeats the operation until a reliable balance is reached (Fig. 3.6).

```
Start Analog Gain calibration:
------------------- 1 attempt ----------------
First step 012F
Check AGB
AGB 012F
Start Analog Gain completed:
****************************
```

Fig. 3.6

3.1.6 - 5 : Digital Gain Calibration

Same procedure as shown in point 4. The focus this time is on the digital gain registers

3.1.7 - 6 : AEC Calibration (Auto Exposure)

This automated procedure is necessary to adjust the amount of light reaching the optical sensor. An incorrect exposure may result in an image that is too bright or too dark.

3.1.8 - 7 : AWB Calibration (Auto While Balance)

White balance means adjusting colours so that the image appears more natural, removing colour patinas that can make the image look distant from what we actually see.

3.1.9 - 8 : Manual Writing Register

This option allows you to manually write one of the internal registers of the optical sensor (Fig.3.7).

It is recommended that this option should only be used by experienced users who are aware of the records that will be changed.

The procedure requires first of all the address, in hexadecimal, of the register (four digits) and then the value to be recorded, also in hexadecimal, (two digits).

If the operation is successful, a register reading with the previously written values will be displayed (Fig.3.8), otherwise an error message.

```
****************************
Insert 1 char at a time in hexadecimal mode
Ex: Address: 0x1234 - Value: 0x56

*************Address*************
Insert Address 0x
```

Fig. 3.7

```
****************************
Insert 1 char at a time in hexadecimal mode
Ex: Address: 0x1234 - Value: 0x56

*************Address*************
Insert Address 0x0202
*************Value*************
Insert Value data 0x30
Address insered: 0x0202 - Value insered: 0x30
Read data: Address: 0x0202 - Value: 0x30
```

Fig. 3.8

References

Documents are available on the Lattice Semiconductors website (**www.latticesemi.com/VIP**) in the Embedded Vision Development Kit section:

(PDF) CrossLink VIP Input Bridge Board Evalutation Board User Gudide FPGA-EB-02002

(PDF) EPC5 VIP Processor Board Evaluation Board User Guide FPGA-EB-02001

(PDF) Embedded Vision Development Kit Quick Start Guide QS042

(PDF) HDMI VIP Output Bridge Board Evaluation Board User Guide FPGA- EB-02003

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