

Data sheet for Median Filter Core

Introduction:

Median filter is a non-linear filter which removes speckle and salt & pepper noise from the images. It preserves all the edges in the image unlike averaging filter by which image will be blurred. In this filtering, the output pixel is the median of all pixels coming under the kernel whose center is coincided with the pixel under operation. As the size of the filter increases, the effect of filtering increases, but at the same time some of the edges will be blurred. The 3X3 kernel is most common.

Functional Description:

A kernel of proper size slides over the input image

to be filtered out. The center of the kernel coincides with the pixel under interest. The output pixel corresponds to input pixel is the median of the all the pixels coming under the kernel. This procedure is repeated for all the input pixels by moving the window over the image.

Features:

- High speed median filtering algorithm.
- Fully pipelined architecture.
- Compatible with different image resolutions.
- Fully Synchronous design
- Configurable input image size and kernel size
- Compatible, flexible and easy integration with other modules.

Architecture Diagram:

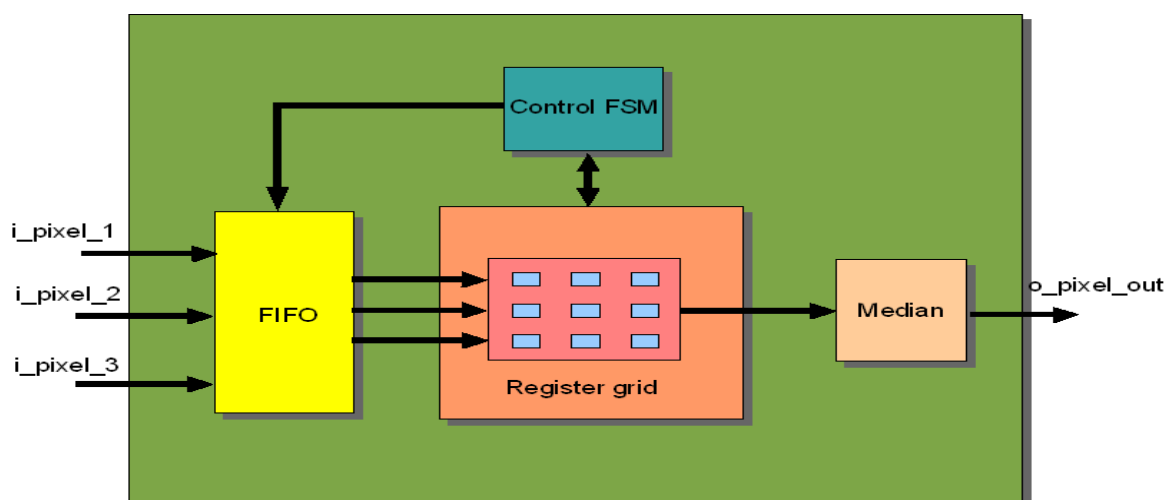


Figure 2: Median filter core architecture diagram.

Description:

1. Figure.1 shows the block diagram of the Median filtering core. Input is image with noise (salt & pepper) and the output is filtered image.
2. The size of the filter kernel has proportional effect on filtering capability. As the size increases output image quality also improves at the cost blurring of some of the edges in the image.
3. Figure.2 shows the architectural diagram of the Median filtering IP core.
4. Image data is fed to the core from image

5. This input image data is fed to FIFO which is of proper width and depth.
6. **Control_FSM** generates control signals to read the data from FIFO and store it in the 9 ($FILT_SIZE * FILT_SIZE$) register grid.
7. These pixels are sent to module **median**, in which median value of these pixels.
8. This median pixel is sent as output filtered image pixel.

9. Since this **median** block is pipelined, after some latency, output starts coming out continuously.
10. Signal **o_data_valid** (Schematic) will be asserted as long as the output data is valid.
11. Table. 1 describes the different parameters used in the IP core.
15. Figure.3 shows the schematic symbol of the Median filter IP core, showing all the input and

- output ports with bus width.
16. Table.2 explains briefly about top level port of median filter core.
17. Table. 3 shows the performance numbers, slice register and slice LUT count for both Virtex-4 and 5 families.

Schematic Symbol:

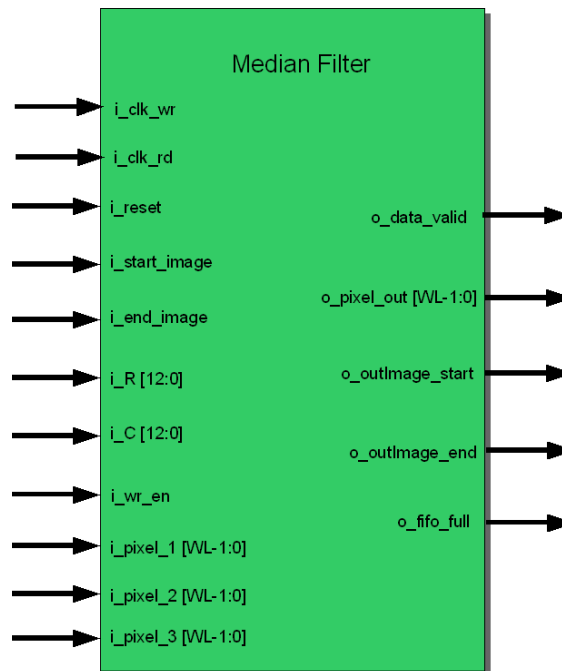


Figure 3: Median filter core schematic symbol

Median filter core Parameter Table

This table describes the general Median filter core parameters:

Parameter	Type	Description
WL	Integer	Represents width of the each data symbol.
FILT_SIZE	Integer	This parameter specifies the size of the median filter. Usually it will be 3.

Table 1:Median filter core parameter table.

Signal definition table:

Signal	Direction	Data width	Description
i_clk_rd	IN	1	This clock is used to synchronize entire logic from FIFO output onwards.
i_clk_wr	IN	1	FIFO writing is done with respect to this clock.
i_reset	IN	1	This signal resets the system whenever it is enabled and all counters, registers are set to initial value to hold and state machines are set to starting state.
i_start_image	IN	1	This is single bit input signal which is enabled when first set of three pixels of a new image is presented at the input port. Otherwise disabled.
i_end_image	IN	1	This is single bit input signal which is enabled when last set of three pixels of current image appears at input port. Otherwise disabled.
i_R	IN	13	This is 13 bit input port which specifies the number of rows of pixels presented in the image
i_C	IN	13	This is 13 bit input port which specifies the number of columns of pixels presented in the image
i_wr_en	IN	1	This is single bit input port when enabled, pixel data started writing into FIFO. When the entire image has been written, this signal gets disabled.
i_pixel_1 i_pixel_2 i_pixel_3	IN	WL	This is WL bit width input port through which three pixels of gray scale image are sent to the core.
o_data_valid	OUT	1	Asserted when actual computed data starts coming out of the port o_pixel_out . And it is high as long as data at the output port is valid.
o_pixel_out	OUT	WL	This is WL bit width output port through which Median filter core outputs filtered image pixel data.
o_outImage_start	OUT	1	This signal is enabled when first pixel of resultant median filtered image comes out of the output port o_pixel_out .
o_outImage_end	OUT	1	This signal is enabled when last pixel of resultant median filtered image comes out of the output port o_pixel_out .
o_fifo_full	OUT	3	This is 3 bit width output port which is enabled when FIFO is full of data.

Table 2: Median filter core signal definition table

Performance:

Family	Device	Slice Register count	Slice LUT count	Frequency (MHz)
Virtex-4	LX25-12sf363	500	962	270
Virtex-5	LX30-3ff324	500	551	356

Table 3: Median filter core performance table.

Verification:

| The Median filter core module has been verified

with following approaches:

- Exhaustive Functional/Timing simulation.
- Results compared with MATLAB functions and C source code functionality.

The Median filter core has been tested for gray images. The following industry resolution images are tested on median filter core by introducing salt & pepper noise.

- 256x256 resolution
- VGA resolution images (640 X 480).
- HD resolution images (1920 X 1080).

Deliverables:

- Verilog RTL source code
- The IP core test environment developed in verilog HDL (test benches).
- Synthesis and Simulation scripts.
- Detailed user documentation, including RTL source code documentation.

Applications:

Median filter is having following applications in image processing applications.

1. Median filtering extensively used for Salt & Pepper noise filtering purpose.
2. Its edge preserving quality makes it to useful in cases where edge blurring is unacceptable.
3. This filter also used to remove speckle noise from images.