

CannyCamera is a high-resolution camera module suitable for embedding in a System-on-Chip.

- Customizable SoC component with direct programming interface via memory-mapped I/O
- Gray-scale image capture up to 1920 by 1080 pixels resolution with 8-bit precision per pixel
- Automatic image capture for video streaming up to 60 frames per second (FPS)

Mapped into a 32-bit address space at any word-accessible memory address (the lowest two address bits must equal 0), *CannyCamera* occupies 16 MB of address space (allowing sufficient room for future extensions and higher resolutions). *CannyCamera* is easily configured via special-purpose registers and a directly accessible frame buffer containing the captured image frame, as detailed in the following table.

Address Offset	Size	Name	Purpose	Unit
\$0000 0000	2,073,600 bytes	Frame buffer	Stores the latest captured photo image	2D array of 8-bit pixels
\$00FF 0000	4 bytes	Capture interval register	Specifies timing interval for automatic capturing of image frames	Microseconds
\$00FF 0004	4 bytes	Image width register	Requested width of captured images (number of columns)	Pixels
\$00FF 0008	4 bytes	Image height register	Requested height of captured images (number of rows)	Pixels

Table 1: Memory map of *CannyCamera*

Frame buffer stores the latest captured image as a 2-dimensional array of 8-bit pixels where the value 0 indicates black color, 255 indicates white color, and gray-scale intensities are represented in between, respectively. Pixels are ordered in rows (top down) and columns (left to right), from the top-left of the image to the bottom right.

The contents of the frame buffer will be overwritten with every newly captured image. Thus, pixel intensities need to be retrieved (copied) from the frame buffer within the specified capture interval (see below).

Capture interval register specifies the timing interval (delay) between capturing image frames in microseconds. The value 0, which is the initial default value at power-on, turns the camera off. To turn the camera on, a value greater than 0 must be written into the capture interval register. The value then specifies the time interval in microseconds in which the camera automatically captures images. For example, a value of 33,333us will result in a frame rate of 30 frames per second (FPS). The maximum supported frame rate of *CannyCamera* is 60 FPS (minimum capture interval is 16,666us). The minimum supported frame rate is 1 frame per minute (maximum capture interval is 60,000,000us). For values outside the valid range [16,666 – 60,000,000], the behavior of *CannyCamera* is undefined.

Note that writing to the capture interval register resets the *CannyCamera* timing. The next image will be captured with the specified delay.

Image width register specifies the requested width of captured images (i.e. the number of pixel columns) and should be written by the software driver before the camera is turned on. The initial default value is 640 pixels. For values outside of the valid range of [64 – 1920] pixels, the behavior of *CannyCamera* is undefined.

Image height register specifies the requested height of captured images (i.e. the number of pixel rows) and should be written by the software driver before the camera is turned on. The initial default value is 360 pixels. For values outside of the valid range of [64 – 1080] pixels, the behavior of *CannyCamera* is undefined.

Interrupt Pin

CannyCamera offers an interrupt request (IRQ) output pin that can be connected to any programmable interrupt controller (PIC) so that it results in a specified interrupt request to the device driver. The interrupt request pin is usually set to low (0). It is raised to high (1) for the period of one clock cycle whenever the camera has completed capturing a new image.

SystemC TLM-2.0 Module for Virtual Platform Integration

CannyCamera can be easily integrated as a module into standard SystemC TLM-2.0 system-on-chip (SoC) models by use of an available bit-accurate simulation model. The behavior of the actual SoC component is accurately reflected in the model by the bit-accurate TLM-2.0 target socket interface. Timing is approximated in the model and adheres to loosely timed (LT) modeling guidelines.

For realistic simulation purposes, the *CannyCamera* SystemC module accepts application-specific images that can be supplied in form of PGM files with parameterized file names. Three parameters are available, namely <W>, <H>, and <N>. Parameter <W> specifies the image width in pixels. Parameter <H> specifies the image height in pixels. Parameter <N> specifies a 3-digit frame number starting from 001. If such files are accessible in the current directory during simulation, they will be used as the captured images. If no suitable files are found, the *CannyCamera* SystemC module defaults to using built-in images showing diagonal stripes with a variation of gray intensity values.

When configured with VERBOSE=1, the *CannyCamera* SystemC module will report to the standard error stream every captured image with a printed line similar to the following:

10000ns: CannyCamera captured image 1 [640x360] (FileName).