Main Features

- 1/ 4.5” VGA (640 x 480) Digital Camera Module with Built-in Lens
  - Pixel Size: 5.0 × 5.0 µm
  - Field of View: 48°(H), 36°(V), 60°(D)
  - Focal Length: 3.6 mm
  - Color Filter: Bayer RGB with Micro Lenses
- Turnkey Solution with CMOS Color Image Sensor and On-chip Image Processing
- High Performance:
  - Ultra- compact Size 8 x 8x 5.9 mm^3
  - Very Low Power Consumption 55 mW@ 15 fps
  - High Sensitivity
  - Low Fixed Pattern Noise
  - High Dynamic Range 56 dB
  - Up to 15 fps at Full Resolution@12 MHz
  - Up to 30 fps at Full Resolution @24 MHz
- Easy to Operate:
  - On-chip Timing Generator
  - I^2C Serial Interface
  - Single 2.8V Power Supply (Range 2.6–3.6V)
  - Package: 24 Pin Flex
- Built-in Functions:
  - Region Of Interest Definition with Up to Five Times H/V Subsampling to Enable Digital Zoom
  - Photo and Video Capabilities
  - Multiple Region of Interest (Programmable)
  - Horizontal and Vertical Mirroring
  - On-chip 12-bit A/D Converter
- Built-in Image Processing:
  - Defective Pixel Correction
  - Color Saturation
  - Real Time White Pixel Blemish Correction
  - Lens Shadding Correction (Anti-vignetting)
  - Gamma Correction (Programmable)
  - Knee Correction
  - Edge Enhancement
  - RGB to YCrCb Transformation
  - Anti-aliasing Filter
  - 8-bit 4:2:2 YCrCb Output Format
  - White Balance (Auto/Manual Control Selectable)
  - Auto Exposure Control (AEC)
  - Auto Frame Rate Control (AFR)
  - Anti Flicker Control (50Hz or 60Hz and Auto Detection)

Eye-On-Si® Ultra-compact CMOS Digital Camera Module

AT76C453AC-MY19T

5446A–IMAGE–02/06

1. Description

The Eye-on-Si® AT76C453AC-MY19T CMOS camera module is a turnkey system ideal for mobile phones/cordless phones and PDA applications. This complete solution provides a VGA standard image format using on-chip processing that provides high-quality images. The module is integrated on an ultra-thin module and has a very low-power consumption.

The AT76C453AC-MY19T includes a digital zoom from x1 to x5. This digital zoom is very progressive like those available in cameras that include an optical zoom. The image resolution is the same at each step and can be adapted to the output screen.

The AT76C453AC-MY19T provides the user with the ability to adjust the image processing functionalities to obtain sharp and crisp images and to meet color fidelity requirements under various environmental conditions. Lens shadding correction, gamma correction, white pixel correction, color saturation, auto white balance and auto black reference, auto exposure control, 50Hz or 60Hz flicker avoidance. These functions can be optimized for setting. Multiple conditions for different status can be downloaded in a system to add conditional specific performance to a product using the module. In addition several image processing features are available and controllable by the 2-wire interface. This CCM windowing feature allows the user to define the active pixels used in the final image.

2. Applications

Home Phones, Cordless Phones, Mobile Phones, PDAs

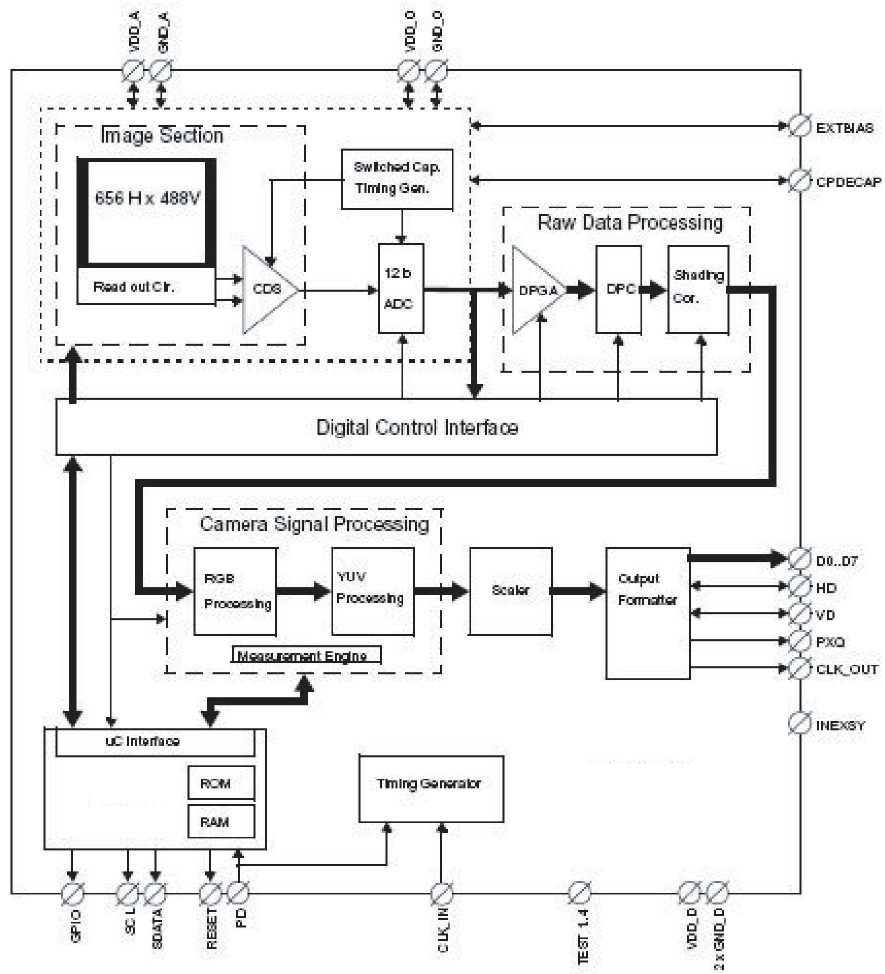
3. Definitions of Terms

Table 3-1. Definition of Terms

Term	Definition
ADC	Analog-to-digital Converter
AE	Automatic Exposure
AGC	Automatic Gain Control
AWB	Automatic White Balance
CDS	Correlated Double Sampling
CSP	Camera Signal Processing
CRT	Cathode Ray Tube
DPC	Defect Pixel Correction
FPN	Fixed Pattern Noise
MSB	Most Significant Bit
PDA	Personal Data Assistant
PGA	Programmable Gain Amplifier
PMA	Post Matrix Pixel
ROI	Region of Interest
SDA	Serial Data
Y	Luminance

4. Block Diagram

Figure 4-1. Block Diagram



5. Features Description

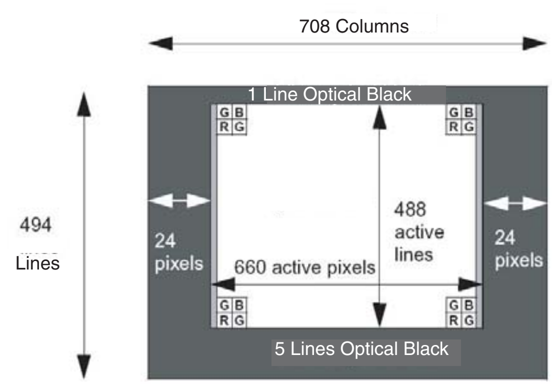
5.1 Image Section

The image section consists of a pixel array, vertical and horizontal selection circuitry, a bench of column amplifiers and a read amplifier. The pixel array contains 708(H) × 494(V) pixels. The pixels are covered by red, green and blue color filters arranged in a RGB Bayer structure. A microlens is placed on top of the color filters to increase the effective fill factor for higher sensitivity. For black reference purposes a number of rows and columns are shielded from light.

The vertical selection circuitry has a double functionality. One is to select the line to be read, the other is to select the line to reset to determine the integration time period.The integration time is determined by a rolling shutter. After a line has been selected and read by the column amplifiers, the horizontal selection circuitry takes care of the pixel data selection that is to be processed by the read amplifier.

The read amplifier performs Correlated Double Sampling (CDS) to suppress Fixed Pattern Noise (FPN).

Figure 5-1. Pixel Array



Active image diagonal	4.0 mm
Pixel size	5.0 µm × 5.0 µm
Optical active pixels	660 (H) × 488 (V)
Total no. of pixels	708 (H) × 494 (V)
Optical black columns	Left: 24 right: 24
Optical black lines	Top: 1 bottom: 5

5.2 Signal Processing

5.2.1 Analog Signal Processing

The Correlated Double Sampling (CDS) output signal is applied to a high performance Analog to Digital Converter (ADC). The ADC converts the analog CDS output signal into a 12-bit digital video stream.The input stage of the ADC converts the single ended input signal into a differential signal. Then a number of quantization stages take care for a high precision quantization.

A black loop is included around the ADC to have the average digital output code of the black reference pixels on a predefined level. The loop takes care for optimum use of the ADC input range in all operating conditions and for all production parts.

5.2.2 Raw Data Processing

Behind the ADC three raw data processing circuits are passed before the data is applied to the embedded Camera Signal Processing (CSP) function.

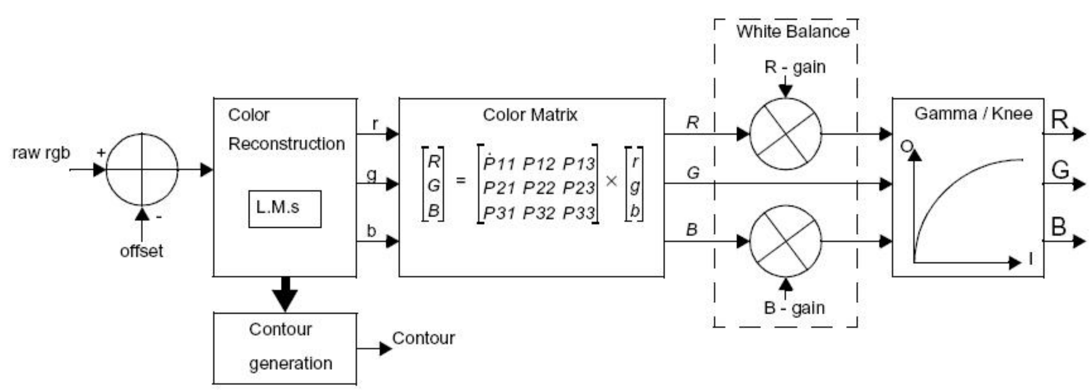
The first one is the Digital Programmable Gain Amplifier (DPGA). Because of the incorporated high performance ADC digital amplification is possible. This is justified because the noise of the analog core up to the output of the ADC is dominated by the pixel reset noise (kT/C noise). This means that the ADC is nicely quantizing the pixel noise and therefore analog gain is superfluous. The DPGA gain range is 30 dB.

Next step is the on-the-fly Defect Pixel Correction (DPC). The circuit detects and corrects single white pixels. Neighboring pixels from the same color plane as well as pixels from the other color planes are used in a quasi two-dimensional way to detect defects. Although tuning options exists it is believed that the default DPC-settings offer optimum circuit performance.

Finally the data passes a shading correction (anti-vignetting) circuit to correct forshading caused in the optical path.

5.2.3 RGB Processing

Figure 5-2. RGB Processing



First the input black level is restored to have the data referred to digital code "0". Then the raw RGB signal is applied to a reconstruction function. This function basically generates a triplet of raw RGB data for every pixel of the video stream. Red, green and blue information are recovered for every single pixel by means of spatial filtering, using the physically surrounding colored pixels.

Parallel to the reconstruction a contour signal is generated which is later on in the processing added to the video luminance signal to improve the sharpness impression of the final picture. Both horizontal and vertical contour information are generated.

Behind the reconstruction function a three by three color matrix corrects for the non-ideal spectral response of the colored pixels. The matrix takes care of the color fidelity in the finally displayed picture. It matches the spectral sensitivity of the image array with the color response of the displaying device (CRT is used for default settings).

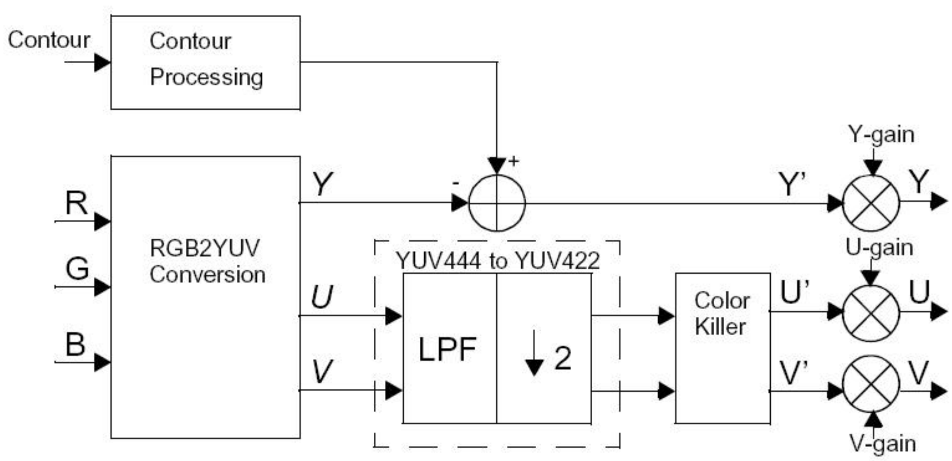
The succeeding white balance circuit takes care of the color fidelity over a wide color temperature range. The white balance consists of controllable gain circuits in the red and blue channel. By default the gains are controlled by the Auto White Balance (AWB) loop which runs on the embedded micro-controller. The loop takes care that white parts in the scene remain white when the color temperature of the scene illumination changes.

Besides automatic white balance also fixed white balance settings can be applied. A set of settings is available for incandescent, fluorescent and daylight illumination conditions. If desired the white balance settings for the red and blue gain can be overruled by the application.

After white balancing the signals are applied to a gamma/knee correction circuit. Knee compression takes care for the visibility of details in highly illuminated areas. The gamma correction compensates for the non-linear response of the displaying Cathode Ray Tube (CRT). The applied gamma correction is programmable in 64 steps. By default the gamma correction is tuned to be compliant with the normalized ARD gamma-function (0.45 gamma).

5.2.4 YUV Processing

Figure 5-3. YUV Processing



After RGB processing the channels are separated into a luminance (Y) and two color difference paths (UV). The signals are generated using the following formulas:

- Y = [19R + 38G + 7B]/64
- U = B -Y
- V = R -Y

The YUV signal is converted into a YUV 4:2:2 format by a factor two down-sampling of the UV signals. In advance of the down-sampling the UV chrominance signals are low pass filtered to suppress aliasing artefacts.

Co-sited positioning of the UV samples with respect to the Y sample. Optionally this half pixel shift of UV with respect to Y can be suppressed to ease external conversion to a JFIF (MPEG1) compliant YUV 4:2:0 data format.

Parallel to the UV down scaling the contour signal is processed. The vertical contour gain can be tuned separately from the horizontal contour. This allows it to tune the amount of vertical contour with respect to the horizontal contour. Then the horizontal and vertical contour signals are added and applied to a contour coring and a contour gain circuit. Finally the contour signal is added to the luminance (Y) signal.

After the UV down-scaling the chrominance processing includes a false color killer. The color killer suppresses wrong colors which could occur in case parts of the scene are overexposed which causes pixels to saturate.

The YUV processing function continues with separate gain controls for the Y, U and V signals. These gains are used to fine tune the Y, U and V color balance and to adjust the luminance and color saturation level without disturbing the Auto Exposure (AE) and Auto White Balance (AWB) loops.

5.2.5 Measurement Engine

The measurement engine extracts measurement data from different color domains of the camera signal processing chain. This measurement data is used by the auto-control loops which run on the embedded micro-controller.

The measurement windows can be tuned on a 40 × 40 pixels grid to enable the possibility for example back light compensation.

For auto exposure five parallel measurements are done. The intensity levels of pixels falling in the different defined measurement windows are accumulated during each frame.

For auto white balance a single measurement window can be defined. Before a pixel contributes to the white balance measurement the color tone of the pixel is checked.

When the color tone complies to the defined limited white area the signal levels are added to the measurement data.

During each frame, the micro-controller has access to the values measured in the previous frame.

5.3 Output Formatting

5.3.1 Scaler

The scaler behind the signal processing chain guarantees an optimum quality video stream for sub-VGA resolution output formats. Limiting the resolution at the input of the CSP would lead to color aliasing effects from the reconstruction block because of low spatial correlation between the image data samples in high frequent areas.

The scaler function performs Region Of Interest (ROI) selection and sub-sampling.

The flexible ROI definition in combination with an up to 5 times sub-sampling ratio, in both horizontal and vertical direction, allows for zooming and a wide range of active resolution output formats.

In advance of sub-sampling the YUV data passes a selectable low pass filter to suppress aliasing artefacts.

5.3.2 Output Formatter

Depending on the desired output format, first a YUV or RGB formatter is passed.

The YUV formatter performs a simple clipper function to limit the data according one of three supported data ranges.

In case of an RGB output format one can select between an RGB 565, RGB 555 or RGB 444 package formats. The RGB-data is regenerated from the YUV input signals. In this way the signal conditioning as performed on the YUV data is maintained. To mask the truncation for the different RGB output formats noise shaping can be applied.

After the YUV/RGB data formatting following functions are passed successively:

- Inactive video level insertion. Blanking levels for Luminance (by) and Chrominance (bc) can be selected. (by/bc = #10/#80 or by/bc= #00/#00)
- UV swapping. This function will swap the bytes of UYVY to VYUY, YUYV or YVYU (the inactive levels are also swapped)
- Synchronization code insertion. Optionally synchronization codes according the CCIR656 standard can be merged into the digital video stream.
- Data spreading. When the output resolution is reduced by means of sub-sampling, this function enables it to have a continuous or broken Pixel Qualifier signal during a line period.

5.3.3 Micro-controller (µC)

The device is equipped with a 80C51 micro-controller core.

The controller takes care of:

- Controlling of auto-loops (AE, AWB, NGC, etc.)
- I2C command handling
- Power Down
- Request processing

5.4 Digital Control Interface

This block basically generates all timing signals required for the read out of the image array and processing of the raw RGB output signal.

The block takes care of:

- Video frame format definition: The number of clocks per line and the number of lines per frame can be programmed (max. 1023 clocks/line and 1023 lines/frame). The video frame should have at least 484 lines / frame and 800 clocks/line.
- Vertical / horizontal mirroring
- DPGA gain
- Exposure time
- Timing windows for analog signal processing
- Interfacing with the embedded micro-controller

5.5 Timing Generator

This circuit generates the clock signals required by the different functions incorporated. To avoid interference from the digital into the analog core the overall chip timing is properly tuned.

The timing generator supports the option to have different frame rates available at stable input clock. Clock division factors of 2, 4, 8 and 16 can be selected. For the default 12 MHz input clock the device supports frame-rates from 15 down to 1.875 fps. The maximum frame-rate is 30 fps VGA for a minimum input clock frequency of 24 MHz.

6. Device Control

6.1 Master/Slave Mode Operation

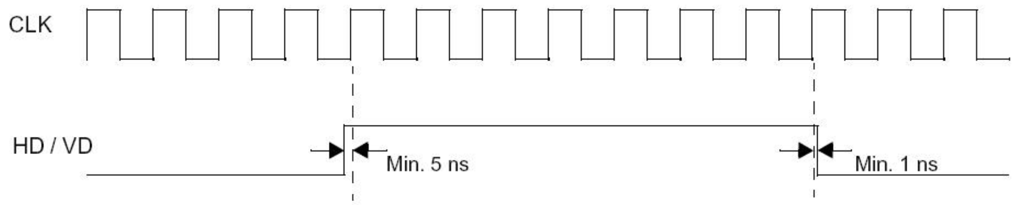
The device supports master/slave mode operation. In master mode the horizontal (HD) and vertical (VD) synchronization signals are generated by the sensor. In slave mode these signals have to supplied.

When pin INEXSY is left unconnected (or logic *low* level applied) the master mode is defined by means of an internal pull down resistor. The HD and VD output signals are programmable with the pixel clock resolution. This allows it to shape these signals with respect to the digital video stream.

The slave mode is activated when pin INEXSY is connected to a logic high level. Now the HD and VD pins are input. In this mode it is not possible to tune the position of the digital video with respect to the applied HD and VD signals.

For external synchronization the device performs a rising edge detection on both the HD and VD input signals. To avoid sensitivity for glitches some digital filtering is performed. The high and low duration of the applied HD signal should be at least three clock periods to be detected as a valid HD signal. For VD the minimum duration should be at least 2 clock periods. The maximum supported frame-format is 1023 clks/line and 1023 lines/frame.

Figure 6-1. HD/VD Setup Timing



6.2 Device Reset

For automatic device initialization a Power On Reset (POR) function is included. When the supply voltage level raises above a certain trip-level (about 2 volt) the initialization is triggered. The register settings are programmed now to its default settings as they are stored in the embedded ROM.

A separate RESET input is available to trigger the initialization process independent from the POR function. The RESET is active at a logic high level.

6.3 Power Down (PD)

The power down function can be activated via the PD pin. When pulling this pin to a logic 'high' level, the embedded micro-controller generates the signals to put the device into power down. The applied input clock as well as the supply voltage do not have to be suppressed externally to reach a typical power down current of 1.3 uA. Keeping the supply voltage up maintains the register settings in the device.

The PD mode can also be activated via an I2C command. In this case the input clock has to be suppressed externally to reach the low power down current.

6.4 I²C Interface

The standard I2C interface is used with a maximum clock frequency of 400 kHz. The communication is two wire and the sensor operates always in the slave mode. The sensor device slave address is (starting with MSB AD7) 0110100(0). The LSB determines read/write mode: 0 = write, 1 = read. In read mode the sensor ID can be checked. For this module it is (MSB....LSB) 00010010.

7. Data Output Formats

The supported output formats are given in table Figure 7-1.

Table 7-1. Output Formats

Output pin	4:2:2 CCIR-656 (8 bit)				RGB 565		RGB 555		RGB 444	
D7	U07	Y07	V07	Y17	R4	G2	X	G2	X	G3
D6	U06	Y06	V06	Y16	R3	G1	R4	G1	X	G2
D5	U05	Y05	V05	Y15	R2	B4	R3	G0	X	G1
D4	U04	Y04	V04	Y14	R1	B3	R2	B4	X	G0
D3	U03	Y03	V03	Y13	R0	B2	R1	B3	R3	B3
D2	U02	Y02	V02	Y12	G5	B1	R0	B2	R2	B2
D1	U01	Y01	V01	Y11	G4	B0	G4	B1	R1	B1
D0	U00	Y00	V00	Y10	G3	G1	G3	B0	R0	B0

Note: An option exists to internally bypass the CSP and to have 10 bits raw RGB data externally available. In this case the output clock is suppressed. The data capturing device should use the input clock to capture the sensor data.

7.1 YUV Data Ranges

Following data ranges are supported:

1. Data clipping according the ITU-R BT.601 standard
   – Y-range : 16 .. 235 (220 levels)
   – U-range: 16 .. 240 (225 levels; colorless at 128)
   – V-range : 16 .. 240 (225 levels; colorless at 128)

Optionally CCIR656 synchronization codes can be merged into the digital video stream.

2. Data clipping between levels 1 and 254. A maximum dynamic range maintaining the option to use CCIR 656 synchronization codes is achieved.
3. No data clipping. Data acquisition should be performed by using the PXQ and VD signals.

For all ranges the video blanking codes can be selected between 10/80 or 00/00.

7.2 YUV Swapping

Following YUV formats are supported:

- CCIR 656 standard. The data sequence is:
  U0Y0V0Y1 U1Y2V1Y3 U2Y4V2Y5
- FOURCC definition YUY2. Swapping of Y/UV data. In this mode the sequence becomes:
  Y0U0Y1V0 Y2U2Y3V2 Y4U4Y5V4
- FOURCC definition YVYU. Swapping of Y/UV and U/V data. In this mode the sequence becomes:
  Y0V0Y1U0 Y2V2Y3U2 Y4V4Y5U4
- U/V swapping.In this mode the sequence becomes:
  V0Y0U0Y1 V1Y2U1Y3 V2Y4U2Y5

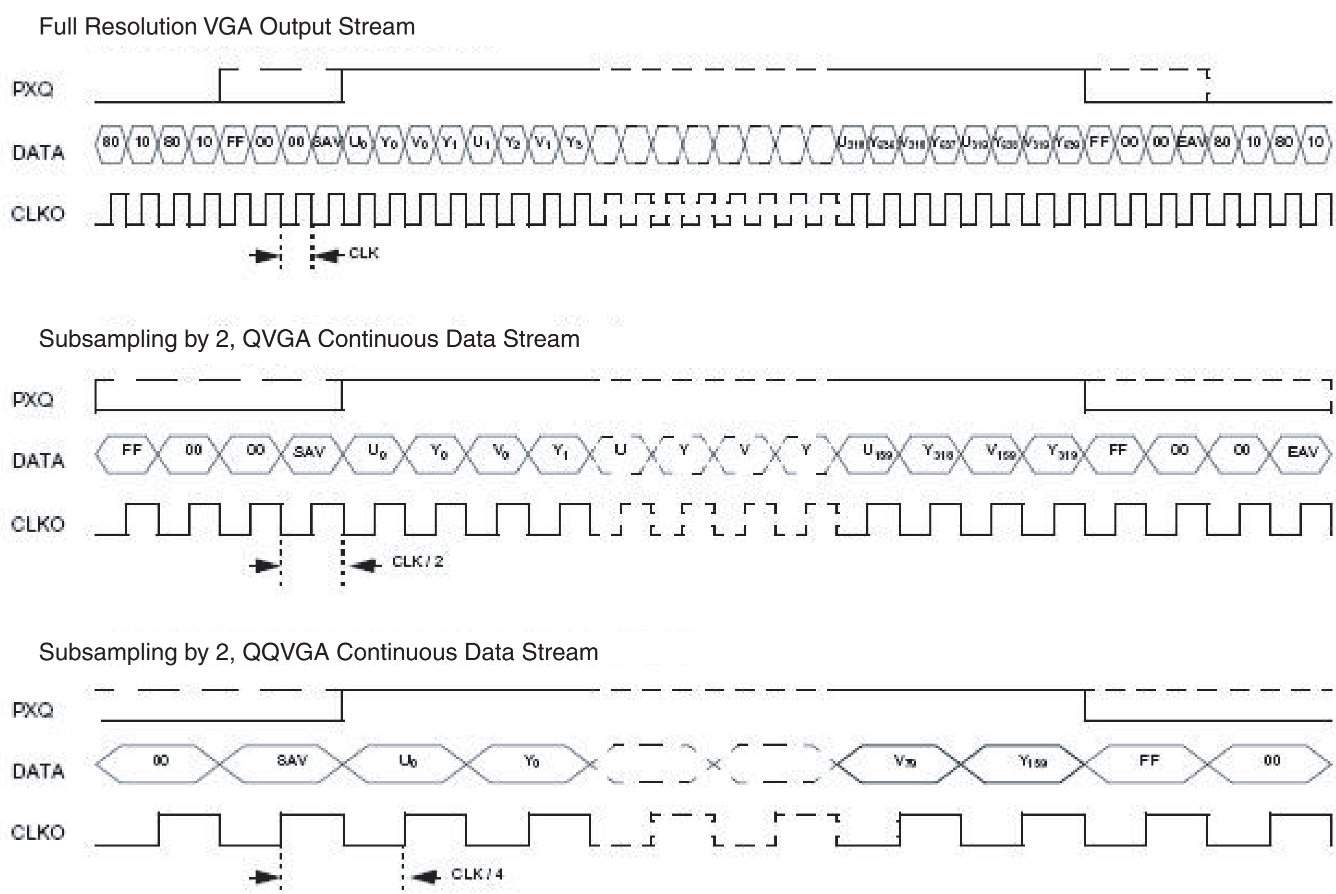
7.3 RGB Output Data

The RGB data stream is regenerated from the processed YUV data stream. Because of the limited word length of the different RGB formats truncation errors are introduced. To mask these truncation errors noise-shaping is applied. CCIR656 synchronization codes are not supported for the RGB output streams.

7.4 Video Timing

The timing diagrams on the next pages depict the waveforms for two and four times sub-sampling in both horizontal and vertical direction. For three and five times sub-sampling the waveforms look similar.

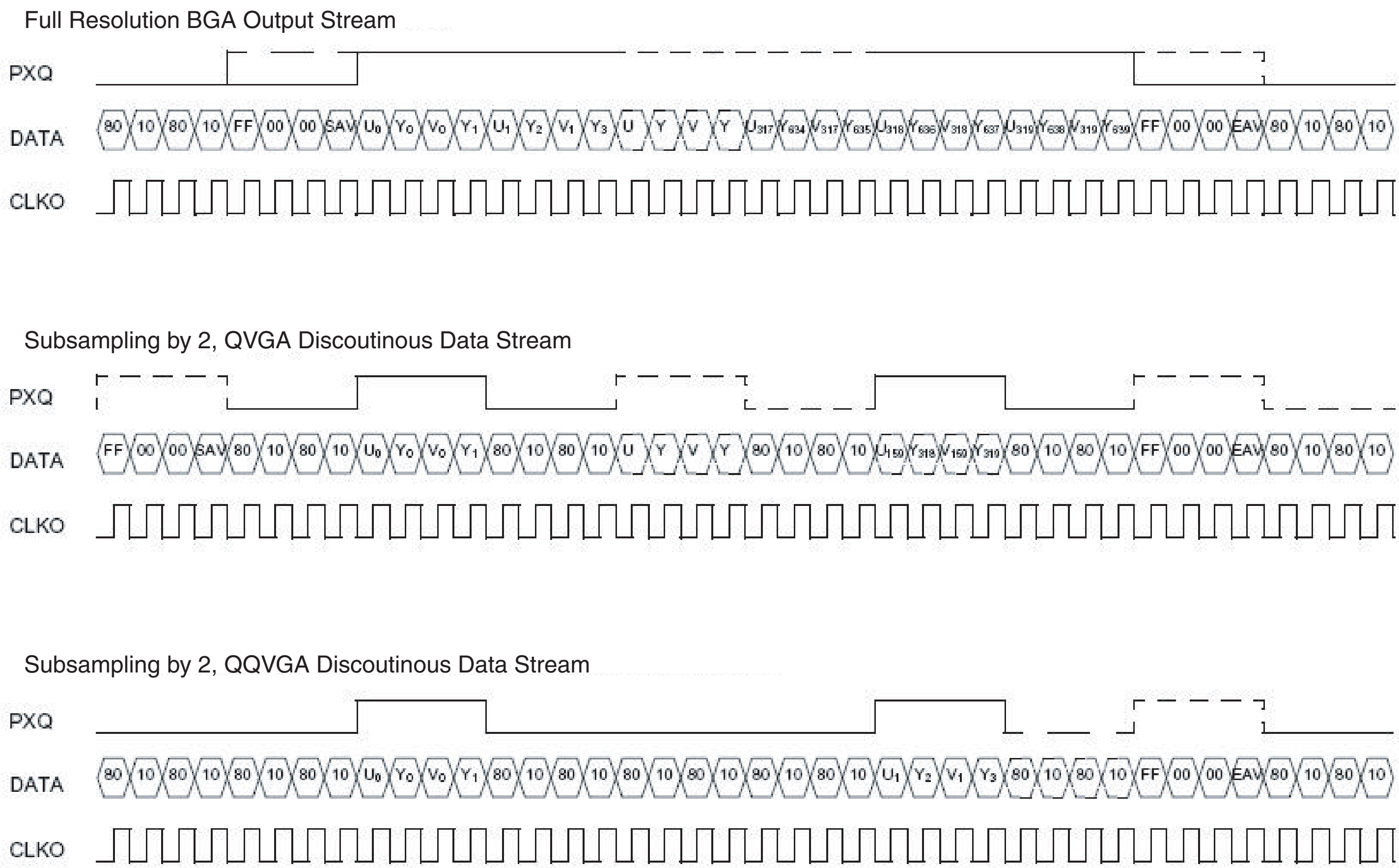
Figure 7-1. Timing Diagrams



-Above timing diagrams depict 2 and 4 times subsampling 3 and 5 subsampling is done in a comparable way

-Used bc/by codes are no. 80/no. 10

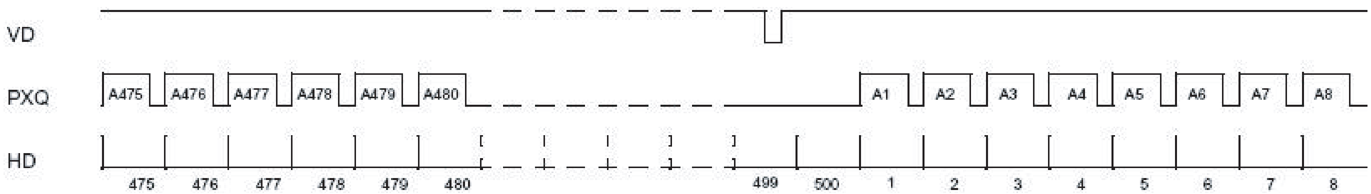
Figure 7-2. Timing Diagram



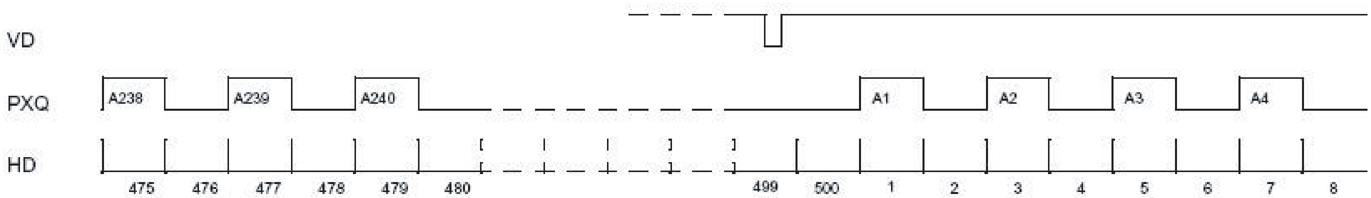
-Above timing diagrams depict 2 and 4 times subsampling 3 and 5 subsampling is done in a comparable way
-Used bc/by codes are no. 80/no. 10

Figure 7-3. Timing Diagram

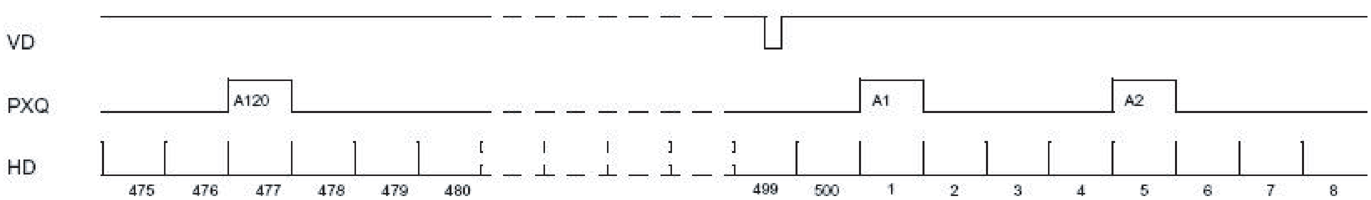
Full Resolution VGA Output Stream



Subsampling by 2, QVGA Output Stream

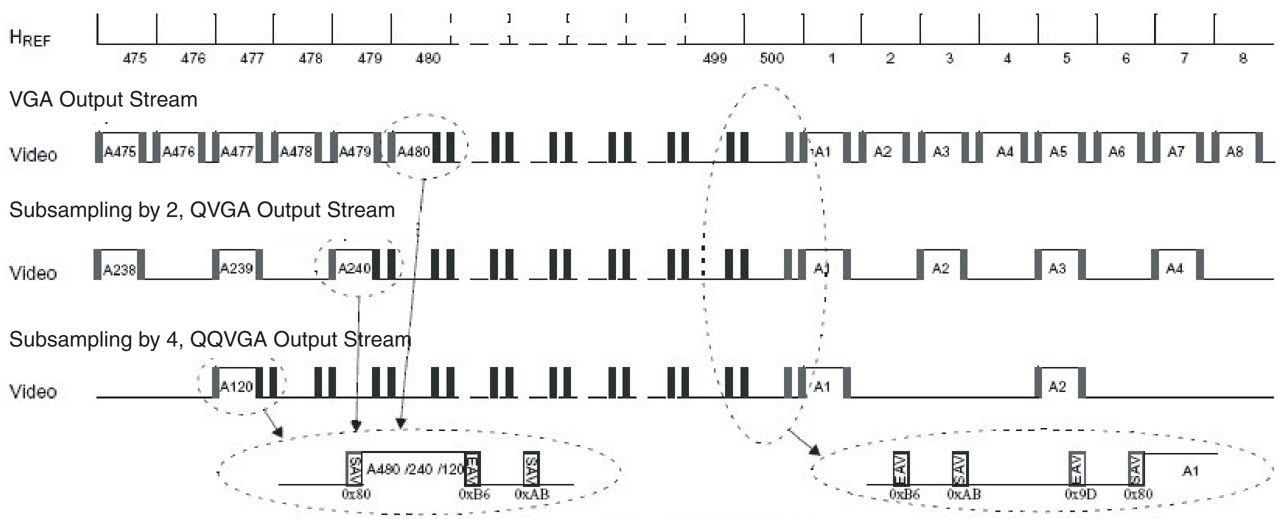


Subsampling by 4, QQVGA Output Stream



Above timing diagrams depict 2 and 4 times subsampling 3 and 5 subsampling is done in a comparable way

Figure 7-4. Timing Diagram



P-code table for SAV/EAV-codes

'1'	F	V	H	P3	P2	P1	P0	XAV
1	0	0	0	0	0	0	0	80
1	0	0	1	1	1	0	1	9D
1	0	1	0	1	0	1	1	AB
1	0	1	1	0	1	1	0	B6
1	1	0	0	0	1	1	1	C7
1	1	0	1	1	0	1	0	DA
1	1	1	0	1	1	0	0	EC
1	1	1	1	0	0	0	1	F1

H = '1' in case of EAV and '0' in case of SAV

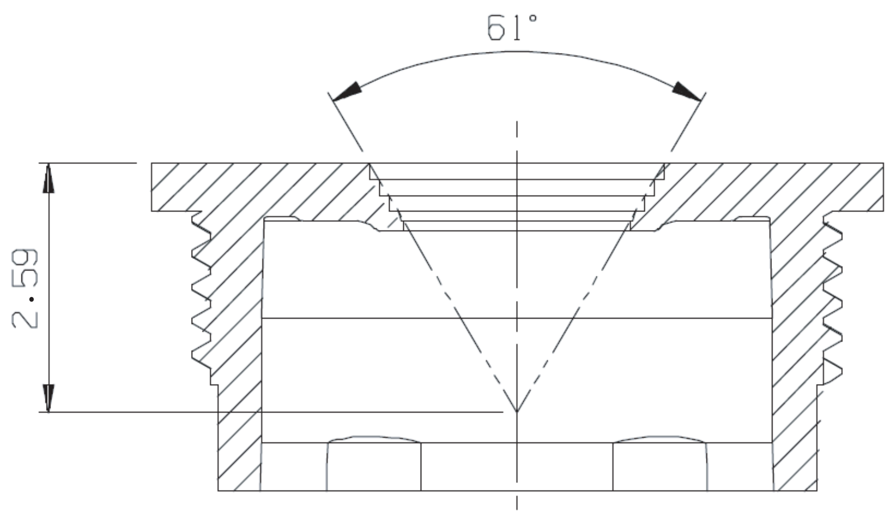
-Above timing diagrams depict 2 and 4 times subsampling 3 and 5 subsampling is done in a comparable way

8. Sunshade

Figure 8-1 is intended to serve as a guideline for designing the sunshade in the application:

- DFOV: Diagonal field of view. (60 degrees)
- A: Mechanical free field of view
- B: Opening diameter. Exact dimension depend on the module alignment accuracy in the application.
- C: Partly covered area outside DFOV. Should be minimized for optimum sunshade performance.
- D: Fully covered area
- E: Sunshade thickness. Largely determines the sunshade quality.

Figure 8-1. Optical Design Information



9. Limiting Values

Symbol	Parameter	Min	Max	Unit
V_{DD}	Supply voltage	-0,5	4.6	V
I_{DD}	Supply current		40	mA
II	DC input current at any input	-10	+10	mA
I/O	DC output current at any output	-10	+10	mA
VI	DC input voltage (not exceeding 4.6 V)	-0.5	V_{DDD} +0.5	V
T_{amb}	Ambient temperature [1]	- 20	70	°C
T_{stg}	Storage temperature Pressure on barrel Torque on barrel	- 40	75 t.b.d. t.b.d.	°C Pa Nm

Note: 1. Image quality might degrade at high-temperature range and condensation might occur at low-temperature range. These effects will slowly disappear when the device is brought back to standard operating conditions.

In accordance with the Absolute Maximum Rating System (IEC 60134)

10. Device Characteristics

10.1 Interface Characteristics

Table 10-1. Timing and Levels of Control, Sync and Output Signals (Default Operation, $V_{DDD} = V_{DDO} = V_{DDA} = 2.8$ V, fclk = 12 MHz, $T_{amb} = 25°C$)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
fcl	Clock frequency			12	24	MHz
Input levels HD, VD (INEXSY = 1)						
V_{IH}	Input high voltage		0.7*V_{DDD}			V
V_{IL}	Input low voltage 0				0.3*V_{DDD}	V
Output levels HD, VD, D0...D7 (INEXSY = 0)						
I_{OH}	High-level output current	$V_{OH} = V_{DDD}$ - 0.4 V	-2			mA
I_{OL}	Low-level output current	V_{OL} = 0.4 V	2			mA
V_{OH}	high-level output voltage		V_{DDD} - 0.4			V
V_{OL}	Low-level output voltage				0.4	V
t_{PHL}, t_{PLH}	Output transition time- D0..7, HD, VD, PXQ CLK_OUT	load = 30 pF 10 –90%	8.0 4.0	13.5 6.5	18 9	ns ns
Timing HD, VD, RESET (Inputs)						
t_{SETUP}	Set-up time		5			ns
t_{HOLD}	Hold time		1			ns

Figure 10-1. Set-up and Hold Output Timing

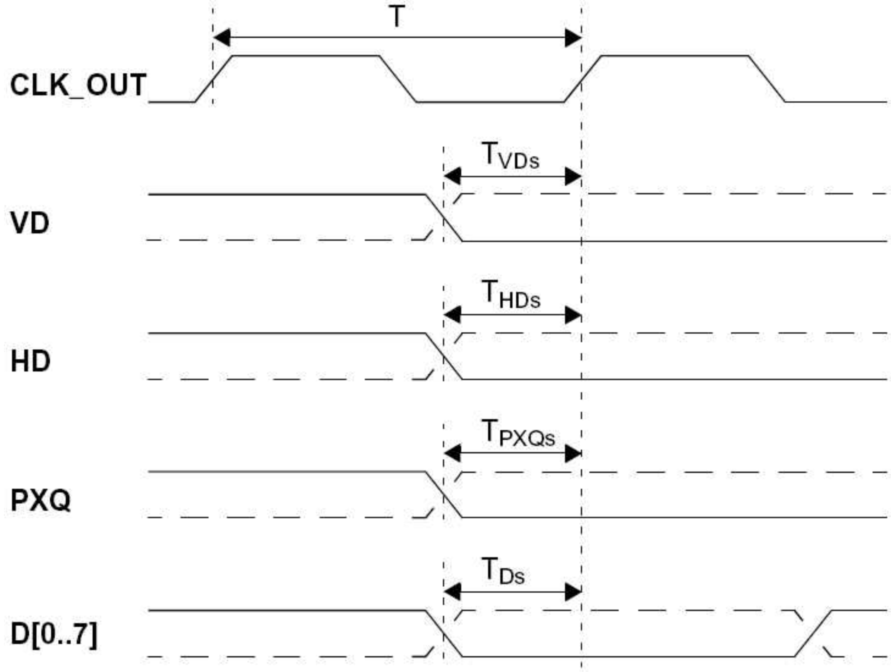


Table 10-2. Setup and Hold Times Related to CLK_OUT [1] [2] [3]

Time	Description	Min. (ns)	Max. (ns)
T_{VDs}	Setup time for VD	(T/2) - 2	(T/2) + 2
T_{HDs}	Setup time for HD	(T/2) - 2	(T/2) + 2
T_{PXQs}	Setup time for PXQ	(T/2) - 2	(T/2) + 2
T_{Ds}	Setup time for D0..7	(T/2) - 2	(T/2) + 2
T_{Dh}	Hold time for D0..7	(T/2) - 2	(T/2) + 2

Note:
1. Figures refer to a full CLK_OUT period having 50 % duty cycle
2. For highest frame-rate CLK_OUT is equal to the device input clock. In this case the tabulated figures have to be corrected according the duty cycle of the applied input clock.
3. Figures are valid for equal capacitive loads on device outputs. Capacitive load dependency is given Table 10-3 on page 19.

Table 10-3. Data Output Delay Versus Capacitive Load

	Propagation delay (ns)		
	Cload = 5 pF	Cload = 12 pF	Cload = 30 pF
Rising Edge	4.0	5.4	7.9
Falling Edge	4.9	6.4	9.1

10.2 Optical Characteristics

Table 10-4. Optical Characteristics ($V_{DDD} = V_{DDO} = V_{DDA}$ = 2.8V, fclk = 12 MHz, T_{amb} = 25 °C)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
SNR	Signal to noise ratio for luminance	Applied light intensity is 100 lux		46		dB
F	Aperture			2.5		
f	Focal length			3.6		mm
	Focal range -nearest point -farest point			 35 inf.		cm
DFOV	Diagonal field of view- Horizontal F.O.V. Vertical F.O.V.			60 48 36		°
	MTF 25 cy/mm [1]	Position in image field Center 60% image height	 70 50			% %
	Distortion	Total field		3		%
	Relative illumination (vignetting)	At 100% of image height [2]	40	48		%
	Flare ratio	According to ISO/DIS 9358			6	%

Note: 1. MTF definition and relevant conditions

– The MTF in a window of interest is defined as:

$$F = \frac{Max - Min}{Max + Min} \times \frac{1}{C} \times 100$$

with C the contrast of the scene, maximize the highest pixel signal and minimize the lowest signal in the WOI.

– The MTF is determined with a special test chart at 50 cm distance from the module.

– The test chart consists of a chess pattern horizontal and vertical repetition of black and white squares with a frequency of 25 cy/mm on the sensor.

– The MTF is measured in five windows of interest as indicated in Figure 10-2 on page 21

– MTF is measured on only green pixels on raw RGB video output.

2. Checked during final test with shading correction active

Figure 10-2. Position of MTF Measurement Windows

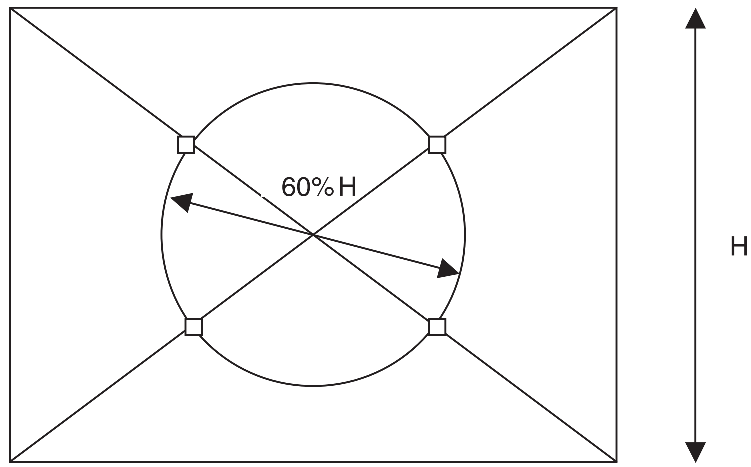


Table 10-5. Pixel Characteristics (Tint = 1/30 sec, T color = 3200 K)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{sat}	Output saturation voltage	At analog sensor output, Gain = 0 dB	1000	1100		mV
CF	Conversion Gain	At analog sensor output, Gain = 0 dB		52		µV/e-
I_d	Photodiode dark current	T_{amb} = 25°C T_{amb} = 60°C		0.1 1.6	0.2 3	nA/cm² nA/cm²
FPN	Fixed pattern noise	T_{amb} = 25°C T_{amb} = 60°C		0.3 2.4	0.5 4	mV_{rms} mV_{rms}
Noise	Random noise	T_{amb} = 25°C		1.7	2.0	mV_{rms}
DR	Dynamic Range	T_{amb} = 25°C	54	56		dB
SEN	Sensitivity red green blue	At image centre, gain = 0 dB, IR cut-off @ 650 nm		70 67 44		mV/lx mV/lx mV/lx

10.3 Power Consumption

Table 10-6. Operating Conditions (fclk = 12 MHz, 15 fps VGA, T_{amb} = 25° C, Outputs D0-D7 Loaded with 5 pF)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DDD}	Supply voltage	$V_{DD\_D} = V_{DD\_A}$	2.6	2.8	3.6	V
I_{DD}	Supply current	$V_{DD\_D} = V_{DD\_A} = 2.8V$ from V_{DD_D} from V_{DD_A} power down		 13.7 7.5 0.8	 16 13.0 2	 mA mA µA

11. Camera Modes

Three camera modes are available, which can be selected via the REQ_ENTER_FACTORY_MODE request.

These modes are the following:

- Normal mode: the default mode
- Factory mode: a debug mode
- Register access mode: a debug mode

11.1 Normal Mode

This is the default operating mode. Desired changes of camera settings can be done via the different available SW requests. Only a limited set of embedded registers is directly accessible Table 11-1 on page 22 to change default settings.

Table 11-1. Normal Mode

Register Address	Register Mnemonic
0x05 .. 0x0D	addr_cic_tbg_05…addr_cic_tbg_13
0x15 .. 0x1D	addr_cic_rgb_matrix_00….addr_cic_rgb_matrix_08
0x20	addr_cic_gamma_00
0x29	addr_cic_lum_process_04
0x2A	addr_cic_lum_process_05
0x6E	DCI_GINCB
0x86	DCI_DPC_PARAM
0x8B .. 0x8D	DCI_50HZ_FD DCI_60HZ_FD, DCI_FD_H
0x90	DCI_HDREL
0x91	DCI_HDFEL
0x92	DCI_HDRCL
0x93	DCI_VDFCL
0x94	DCI_VDRLL

Table 11-1. Normal Mode (Continued)

Register Address	Register Mnemonic
0x95	DCI_VDFLL
0x96	DCI_VRFLH
0x97	DCI_VHRFCH

The way to access these registers is described hereafter (compare to the I2C requests):

- Control identifier code = register address
- Control Mnemonic = value to be written in the register

11.2 Factory Mode

A *debug mode*, which is not meant to be used in the application.

In factory mode, the auto-loops are switched off, but all hardware registers are accessible via I2C.

11.3 Register Access Mode

This mode is the association of the 2 previous ones: in this mode, auto loops are running and all hardware registers are accessible.

12. Camera Requests

To ease the device application a high-level interface is defined for easy access and tuning of the most commonly used camera parameters. Settings like, contrast, brightness, color saturation, sharpness, etc. are easily accessible via the defined request bytes.

After sending a command to one of the request registers the embedded micro-controller takes care of a proper device programming. All internal registers related to the request are properly set.

When settings different from the predefined request bytes have to be changed contact should be taken with the sales office for further application support.

12.1 Status Requests

Table 12-1. Default Factory Restoration

Control identifier code	Control Mnemonic
0xFC	*REQ_RESTORE_FACTORY_DEFAULTS*
Data byte value	0x11
Function	The purpose of this request is to restore the default configuration by downloading the default settings (called factory settings), which are the following: – auto exposure on off flicker less mode backlight compensation mode auto_ngc auto_contour white balance mode black & white / color mode – default ngc_contrast_preset – default awb_manual_red_gain – default awb_manual_blue_gain – default exposure time – default gain – default brightness – default gamma – default contour – default Saturation
Default value	Not applicable

Table 12-2. Resolution and Frame Rate

Control Identifier Code	Control Mnemonic				
0xFD	*REQ_RESOLUTION_FRAMERATE_ZOOM*				
Data byte value	**Bits**	**ID**	**Description**		
	bit 7	 0 1	Scan direction Left / Right Left to right Right to left (horizontal mirror)		
	bit 6	 0 1	*Scan direction Up / Dow*n Top to bottom scan (vertical mirror) Bottom to top scan		
	Bits[5..0]		**Resolution**	**Frame_rate**	**Zoom**
		0	VGA	15	NO
		1	VGA	7.5	NO
		2	VGA	3.75	NO
		3	VGA	1.875	NO
		4	QVGA	15	NO
		5	QVGA	7.5	NO
		6	QVGA	3.75	NO
		7	QVGA	1.875	NO

Table 12-2. Resolution and Frame Rate (Continued)

Control Identifier Code	Control Mnemonic				
			Resolution	Frame_rate	Zoom
		8	QVGA	15	Max
		9	QVGA	7.5	Max
		10	QVGA	3.75	Max
		11	QVGA	1.875	Max
		12	QQVGA	15	NO
		13	QQVGA	7.5	NO
		14	QQVGA	3.75	NO
		15	QQVGA	1.875	NO
		16	QQVGA	15	Max
		17	QQVGA	7.5	Max
		18	QQVGA	3.75	Max
		19	QQVGA	1.875	Max
		20	Sub-QCIF	15	NO
		21	Sub-QCIF	7.5	NO
		22	Sub-QCIF	3.75	NO
		23	Sub-QCIF	1.875	NO
		24	Sub-QCIF	15	Max
		25	Sub-QCIF	7.5	Max
		26	Sub-QCIF	3.75	Max
		27	Sub-QCIF	1.875	Max
		28	CIF	15	NO
		29	CIF	7.5	NO
		30	CIF	3.75	NO
		31	CIF	1.875	NO
		32	QCIF	15	NO
		33	QCIF	7.5	NO
		34	QCIF	3.75	NO
		35	QCIF	1.875	NO
		36	QCIF	15	Max
		37	QCIF	7.5	Max
		38	QCIF	3.75	Max
		39	QCIF	1.875	Max
		40	QQCIF	15	NO
		41	QQCIF	7.5	NO
		42	QQCIF	3.75	NO

Table 12-2. Resolution and Frame Rate (Continued)

Control Identifier Code	Control Mnemonic				
			Resolution	**Frame_rate**	**Zoom**
		43	QQCIF	1.875	NO
		44	QQCIF	15	Max
		45	QQCIF	7.5	Max
		46	QQCIF	3.75	Max
		47	QQCIF	1.875	Max
		48	QQSIF portrait	15	NO
		49	QQSIF portrait	7.5	NO
		50	QQSIF portrait	3.75	NO
		51	QQSIF portrait	1.875	NO
Function	This request defines the different frame rate and video resolutions				
Default value	0x40				

Table 12-3. Auto Frame Rate Modes

Control identifier code	Control Mnemonic		
0xEF	*REQ_SET_AUTO_FRAME_RATE_MODE*		
Data byte value	**Bits**	**ID**	**Description**
	7	 0 1	Lowest Frame rate @ 12 MHz input clock 7.5 fps 10 fps
	6	 0 1	Contour Gain Leave Contour Gain as defined Force Contour gain to be set to 0 (at lowest frame rate)
	5	 0 1	YUV Filter Disable [12221]/4 YUV filter Enable [12221]/4 YUV filter (at lowest frame rate)
	4	 0 1	Matrix Normal Matrix Alternate Matrix (at lowest frame rate) When this bit is set one four alternate matrices is used when the lowest frame-rate is reached. Alternate matrix can be set via bits 5..7 of request REQ_SET_COLOUR_MODE.
	[3...0]	 0x0 up to 0xF	Gain Milestone Level When 0x0 the Auto Frame Rate (AFR) function is switched off. When different from 0x0 AFR is ON, and the value represents the Gain Milestone Value. When AFR is ON, the bit Low light condition is ignored (bit 7 of request REQ_SET_LUMINANCE_MODE). Auto Frame Rate can work only if Auto Exposure Mode has been set to ON (bit 6 of REQ_SET_LUMINANCE_MODE).
Function	Request defines the Auto Frame Rate settings		
Default value	0x00		

Table 12-4. YUV/ RGB Output Formats

Control Identifier Code	Control Mnemonic		
0xDD	*REQ_YUV_RGB_OUTPUT*		
Data byte value	**Bits**	**ID**	**Description**
	7	 0 1	YUV/ RGB out RGB YUV
	[6..5]	 00 01 10 11	YUV swapping U0Y0V0Y1 V0Y0U0Y1 Y0U0Y1V0 Y0V0Y1U0
	[4..3]	 00 01 10 11	*RGB forma*t RGB 444 RGB 555 RGB 565 Raw RGB
	2	 0 1	YUV MPEG/JPEG (1/2 T UV shift) no ½ T U/V shift ½ T U/V shift, REC 601 compliant
	[1..0]	 00 01 1X	Data clipping No clipping ITU-R BT.601compliant Y[16..235]; U[16..240] YUV[1..254]
Function	Defines the YUV and RGB output format		
Default value	0x93		

Table 12-5. Synchronization Parameters

Control Identifier Code	**Control Mnemonic**		
0xDE	*REQ_SYNCHRONISATION*		
Data Byte Value	**Bits**	**ID**	**Description**
	7	 0 1	SAVEAV codes on/off Off On
	6	 0 1	SAVEAV codes inactive lines Off On
	5	 0 1	XAV-code bit 6 Low High
	4	 0 1	XAV-code bit 7 Low High
	3	 0 1	Output clock period Output clock equal to pixel clock. Data qualification in combination with PXQ Output clock qualifies data on every clock
	2	 0 1	Inactive level select 00 00 00 00 80 10 80 10
	1		Unused
	0	 0 1	Output clock polarity Not inverted Inverted
Function	Defines output format and CCIR656 synchronization codes		
Default value	0x5C		

Table 12-6. Factory Parameters Control

Control Identifier Code	Control Mnemonic
0xDF	*REQ_ENTER_FACTORY_MODE*
Data byte value	Password (0x6D = factory mode; 0x12 = register access mode)
Function	By default the NORMAL mode is active (only some specific embedded registers can be accessed).In FACTORY_MODE, the picture processing is OFF (auto loops are not running), but access to all hardware registers is possible. Note that a reset is needed to leave this debug mode. In REGISTER ACCESS_MODE, the picture processing is running (auto loops) and access to all hardware registers is possible. In this case, the auto loops behavior can not be guaranteed due to the fact that the hardware registers can be modified. Note that a reset is needed to leave this debug mode.
Default value	**Not applicable**

12.2 Luminance Requests

Table 12-7. Gain (LSB)

Control Identifier Code	Control Mnemonic
0xE0	*REQ_GET_GAIN_LSB*
Data byte value	Returns LSB of the Gain value
Function	Reads LSB part of gain value When handling this request, the returned value of request REQ_GET_GAIN_MSB, REQ_GET_ITLSB, REQ_GET_IT_MSB are frozen to keep coherent values.
Default value	Not applicable

Table 12-8. Gain (MSB)

Control Identifier Code	Control Mnemonic
0xE1	*REQ_GET_GAIN_MSB*
Data byte value	returns MSB of the Gain value (as it was last time when requiring REQ_GET_GAIN_LSB).
Function	Reads MSB part of gain value
Default value	Not applicable

Table 12-9. Integration Time (LSB)

Control Identifier Code	Control Mnemonic
0xE2	*REQ_GET_IT_LSB*
Data byte value	Returns LSB part of the Integration Time value (as it was last time when requiring REQ_GET_GAIN_LSB) in number of lines
Function	Reads LSB part of integration time value
Default value	Not applicable

Table 12-10. Integration Time (MSB)

Control Identifier Code	Control Mnemonic
0xE3	*REQ_GET_IT_MSB*
Data byte value	Returns MSB part of the Integration Time value in number of lines (as it was last time when requiring REQ_GET_GAIN_LSB).
Function	Reads MSB part of integration time value
Default value	Not applicable

Table 12-11. Preset Integration Time

Control Identifier Code	Control Mnemonic
0xE4	*REQ_PRESET_SHUTTER*
Data byte value	0x00 .. 0xFF
Function	When AE is switched OFF, the value represents the integration time used
Default value	Not applicable because AE is ON by default

Table 12-12. Preset Automatic Gain Control

Control Identifier Code	Control Mnemonic
0xE5	*REQ_PRESET_AGC*
Data byte value	0x00 .. 0xFF
Function	When AE is switched OFF, the value represents the gain used
Default value	Not applicable because AE ON by default

Table 12-13. Preset Brightness

Control Identifier Code	Control Mnemonic
0xE6	*REQ_PRESET_BRIGHTNESS*
Data byte value	0x80 .. 0x7F (-128 .. 127)
Function	Controls the video brightness level
Default value	0x00

Table 12-14. Preset Contrast

Control Identifier Code	Control Mnemonic
0xE7	*REQ_PRESET_CONTRAST*
Data byte value	0x80 .. 0x7F (-128 .. 127)
Function	Controls the video contrast level
Default value	0x00

Table 12-15. Preset Gamma

Control Identifier Code	Control Mnemonic
0xE8	*REQ_PRESET_GAMMA*
Data byte value	0x00 .. 0x3F 0xEE for OFF
Function	Controls the gamma curve applied on the video signal
Default value	0x31

Table 12-16. Luminance Mode

Control Identifier Code	Control Mnemonic		
0xE9	*REQ_SET_LUMINANCE_MODE*		
Data Byte Value	**Bits**	**D**	**Description**
	7	 0 1	Low light condition OFF ON When Auto Frame Rate is ON, this mode is ignored
	6	 0 1	Auto Exposure mode OFF ON
	[5..4]	 00 01 10 11	Flicker less mode OFF 50 Hz 60 Hz Unused
	[3..2]	 00 01 11	Backlight compensation OFF ON AUTO
	1	 0 1	Auto NGC Mode OFF ON When ON, the noise gain control function will improve the picture quality under low light conditions.
	0	 0 1	Auto Contour Mode OFF ON When ON, the contour gain is decreased under low light conditions. The default contour gain can be set via request REQ_PRESET_AUTO_CONTOUR. Request is only functional when NGC mode is ON.
Default value	0x5F		

Table 12-17. Preset Auto Contour

Control Identifier Code	Control Mnemonic
0xEA	*REQ_PRESET_AUTO_CONTOUR*
Data byte value	0x00 .. 0x7F (register range)
Function	Defines the default value for the contour gain
Default value	0x38

12.3 Chrominance Requests

Table 12-18. White Balance and Auto Exposure

<table>
<tr><th>Control
Identifier Code</th><th colspan="3">Control Mnemonic</th></tr>
<tr><td>0xF0</td><td colspan="3">REQ_SET_WB_MODE_AE_SPEED</td></tr>
<tr><td>Data byte value</td><td>Bits</td><td>ID</td><td>Description</td></tr>
<tr><td></td><td>[7..4]</td><td>0x0
up to
0xF</td><td>Auto exposure speed
From 0x0 (low) to 0xF (fast)
The four bits control the Auto Exposure convergence speed</td></tr>
<tr><td></td><td>[3..0]</td><td>
0x0
0x1
0x2
0x3
0x4
0x5</td><td>White balance mode
Incandescent
Daylight
Fluorescent
Freeze
Auto RGB
Auto YUV
The white balance request defines the control of the white balance mode: incandescent, daylight and fluorescent modes are predefined values for R & B gains. Freeze mode freezes the current status of the R and B gains. The auto mode controls the R and B gains in an automatic way.</td></tr>
<tr><td>Function</td><td colspan="3">Controls the Auto Exposure speed and White Balance mode</td></tr>
<tr><td>Default value</td><td colspan="3">0x74</td></tr>
</table>

Table 12-19. Color Mode

Control Identifier Code	Control Mnemonic		
0xF1	*REQ_SET_COLOR_MODE*		
Data Byte Value	**Bits**	**ID**	**Description**
	[7.. 6]		Alternate matrix Selects one of four available alternate matrices (the selected matrix is used when bit 4 of request REQ_SET_AUTO_FRAME_RATE_MODE (0xEF) is set to 1.
	[5.. 2]		Unused
	[1.. 0]	 00 01 1x	Color mode Black and white SEPHIA mode Color mode
Function	Selection of the Alternate matrix used by the AFR function. Selection of the color mode		
Default value	0x02		

Table 12-20. Preset Saturation

Control Identifier Code	Control Mnemonic
0xF2	*REQ_PRESET_SATURATION*
Data byte value	Decimal: -100%-1% 0% 1% 100% Hex: 0x9C 0xFF 0x00 0x01 0x64
Function	Controls the color saturation level by modifying the U and V gains (no saturation means a black and white picture)
Default value	0x00

Table 12-21. Manual Red Gain

Control Identifier Code	Control Mnemonic
0xF3	*REQ_PRESET_MANUAL_RED_GAIN*
Data byte value	0x00 .. 0xFF
Function	Preset value for the white balance red gain in case the white balance FREEZE mode selected
Default value	0x80

Table 12-22. Manual Blue Gain

Control Identifier Code	Control Mnemonic
0xF4	*REQ_PRESET_MANUAL_BLUE_GAIN*
Data byte value	0x00 .. 0xFF
Function	Preset value for white balance blue gain in case the white balance FREEZE mode is selected
Default value	0x40

12.4 General Purpose Requests

Table 12-23. Number of Pixel Clock per Line (LSB)

Control Identifier Code	Control Mnemonic
0xEB	*REQ_WRITE_CLKLINL*
Data byte value	0x00 .. 0xFF
Function	LSB part to define the number of clocks per line (HEX value) Also the MSB part has to be send before the value is used (request 0xEC)
Default value	*0x20* (=LSB of 800 lines)

Table 12-24. Number of Pixel Clock per Line (MSB)

Control Identifier Code	Control Mnemonic
0xEC	*REQ_WRITE_CLKLINH*
Data byte value	0x00 .. 0x03
Function	MSB part to define the number of clocks per line (HEX value)
Default value	0x03 (= MSB of 800 lines)

Table 12-25. Number of Lines per Frame (LSB)

Control Identifier Code	Control Mnemonic
0xED	*REQ_WRITE_LINFIL*
Data byte value	0x00 .. 0xFF
Function	LSB part to define the number of lines per field (HEX value) Also the MSB part has to be send before the value is used (request 0xEE)
Default value	0xF4 (= LSB of 500 lines)

Table 12-26. Number of Lines per Frame (MSB)

Control Identifier Code	Control Mnemonic
0xEE	*REQ_WRITE_LINFIH*
Data byte value	0x00 .. 0x03
Function	MSB part to define the number of lines per field (HEX value)
Default value	*0x01* (= MSB of 500 lines)

Table 12-27. GET Versions

Control Identifier Code	Control Mnemonic
0xF5	*REQ_GET_VERSION*
Data byte value	Returns the embedded software version
Function	Returns the embedded software version (*0x05* for ES5)
Default value	Not applicable

Table 12-28. Power Mode

Control Identifier Code	Control Mnemonic
0xF6	*REQ_SET_POWER_MODE*
Data byte value	0x11 for FULL_POWER 0xEE for POWER_SAVE
Function	To select between FULL_POWER or POWER_SAVE mode
Default value	Not applicable

Table 12-29. Enable or Stop Video Mode

Control Identifier Code	Control Mnemonic
0xF7	*REQ_STOP_FRAME*
Data byte value	0x11 to enable video 0xEE to stop video
Function	This request is used to stop or enable the video output
Default value	Not applicable

Table 12-30. Stop Mode Status

Control Identifier Code	Control Mnemonic
0xF8	*REQ_GET_FRAME_IS_STOPPED*
Data byte value	0x00 if Frame is not stopped 0x01 if Frame is Stopped
Function	This requests sends back the status of the video streaming: stopped or running.
Default value	Not applicable

Table 12-31. Input Frequency (LSB)

Control Identifier Code	Control Mnemonic
0xF9	*REQ_SET_INPUT_FREQUENCY_LSB*
Data byte value	LSB of (Frequency in kHZ * 2)
Function	In case an input clock frequency different from the default frequency (12MHz) is used, the exact input clock frequency should be specified via this request.This request represents the LSB part of the applied input clock. The MSB part in request FA has to be specified as well to validate the adapted input frequency (send first LSB-part then MSB-part!)
Default value	*0xC0* (= LSB of 2 x 12000 kHz)

Table 12-32. Input Frequency (MSB)

Control Identifier Code	Control Mnemonic
0xFA	*REQ_SET_FREQUENCY_MSB*
Data byte value	MSB of (Frequency in kHZ * 2)
Function	In case an input clock frequency different from the default frequency (12MHz) is used, the exact input clock frequency must be specified via this request. This request represents the MSB part of the applied input clock. The LSB part in request F9 has to be programmed first to guarantee proper operation.
Default value	*0x5D* (= MSB of 2 x 12000 kHz)

Table 12-33. Reserved

Control Identifier Code	Control Mnemonic
0xFB	*Not used*
Data byte value	0xEE
Function	
Default value	0xEE

Table 12-34. Maximum Gain for Auto Exposure

Control Identifier Code	Control Mnemonic
0xFE	*REQ_SET_MAX_AGC_VALUE*
Data byte value	[0x00..0x78] When 0x00 the default ROM value is used. Values different from 0x00 represent a maximum gain value used by the Auto Exposure algorithm.
Function	Controls the maximum gain used by the AE algorithm.
Default value	0x5B

Table 12-35. Module Identification

Control Identifier Code	Control Mnemonic
0xFF	*REQ_IDENT*
Data byte value	Returns 0x17 as AT76C543AC-MY19T module identification
Function	Returns the AT76C543AC-MY19T identification byte
Default value	Not applicable

13. Mechanics

Figure 13-1. Top View

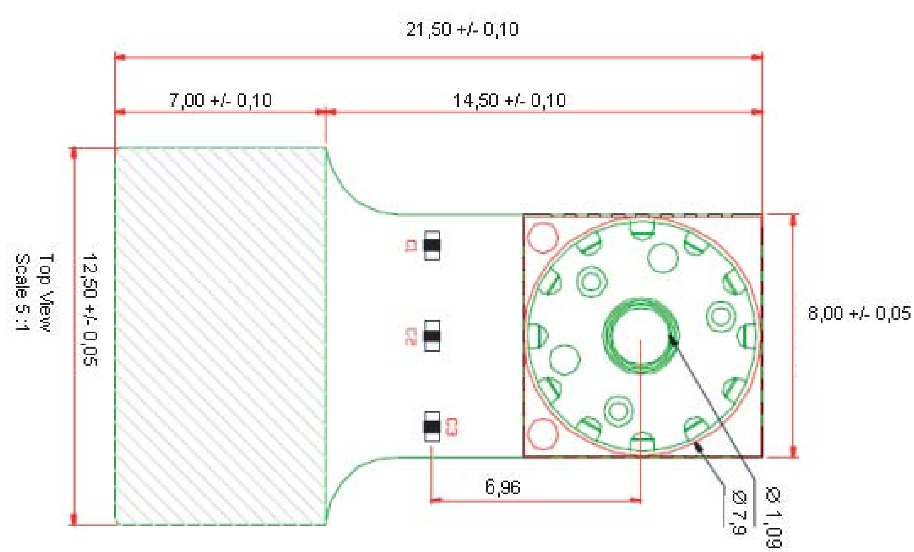


Figure 13-2. Slide View

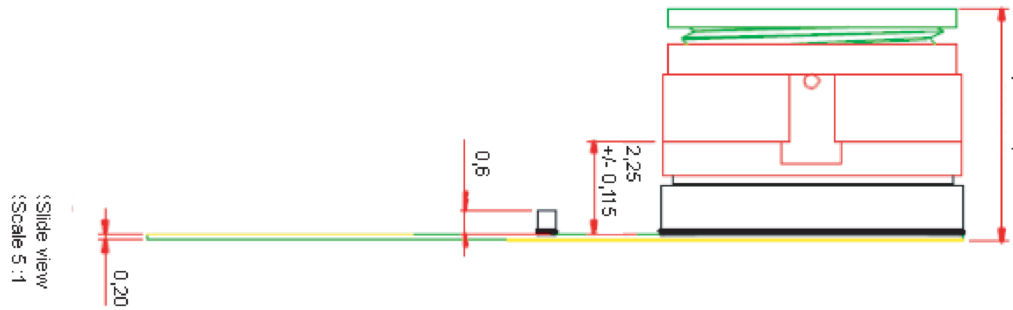
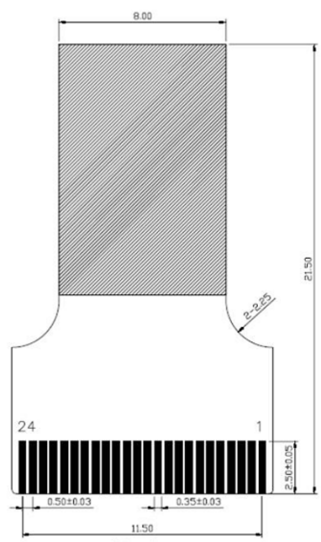


Figure 13-3. Back View



14. Pinning Information

Table 14-1. Pin Description

Symbol	Pin	Type	Description
VDD	1	Power	Power supply
D7	2	Output	Data7
D5	3	Output	Data5
D3	4	Output	Data3
D1	5	Output	Data1
CLK_I	6	Input	Clock input
HD	7	I/0	Horizontal drive
GPIO	8	I/0	General purpose I/O
SDA	9	I/O	I2C data input
RESET	10	Input	Reset input
GND	11	Power	Power ground
VDD	12	Power	Digital supply
GND	13	Power	Power ground
PXQ	14	Output	Pixel qualifier
D6	15	Output	Data6
D4	16	Output	Data4
D2	17	Output	Data2
D0	18	Output	Data0
CLK_O	19	Output	Clock output
VD	20	I/O	Vertical drive
SCL	21	I/O	I2C clock input
PD	22	Input	Power down input
GND	23	Power	Power ground
INEXSY	24	Input	Master/slave mode select input.

15. Handling information

The CMOS module is a device which can be destroyed by Electrostatic Discharge (ESD). Therefore the device should be handled with care, using ESD protection and in an ESD safe environment.

Due the fact the module has a highly sensitive optical lens, the module is limited in the applicable temperature range.

In addition to this it should be avoided to contaminate the lens with dirt and or with solvents, which both can limit the optical functions of the lens.

If these boundaries are considered, the optical parts do not have to be cleaned due the fact the module is completely functional tested before shipment to the customer.

16. Soldering

The CMOS module should not be used for reflow soldering due the fact a highly vulnerable lens is present in the lens barrel. It should be avoided at all times that the lens temperature is elevated to temperatures above the storage temperature!

So the preferred module assembly on a printed circuit board is the use of an appropriate flex foil connector.

Atmel Corporation

2325 Orchard Parkway
San Jose, CA 95131, USA
Tel: 1(408) 441-0311
Fax: 1(408) 487-2600

Regional Headquarters

Europe
Atmel Sarl
Route des Arsenaux 41
Case Postale 80
CH-1705 Fribourg
Switzerland
Tel: (41) 26-426-5555
Fax: (41) 26-426-5500

Asia
Room 1219
Chinachem Golden Plaza
77 Mody Road Tsimshatsui
East Kowloon
Hong Kong
Tel: (852) 2721-9778
Fax: (852) 2722-1369

Japan
9F, Tonetsu Shinkawa Bldg.
1-24-8 Shinkawa
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