Agilent ADCM-1650-3011 CIF Resolution CMOS Camera Module

Data Sheet

Description

The Agilent ADCM-1650 ultra compact CMOS camera module is an advanced, low-power CIF resolution camera component for embedded applications. The camera module combines an Agilent CMOS image sensor and image processing pipeline with a high-quality lens to deliver images in JPEG format (optional) that are ready for storage or transmission. Output data can be transmitted using a serial or parallel port.

The ADCM-1650 camera module features a quality, integral lens in a tightly integrated sensor and image processing design. The camera module is optimized for use in a variety of embedded applications, from cell phones and handheld wireless devices to image-enabled appliances and automotive design.

Incorporating an optional CCIR 656-compatible 8-bit parallel interface, or a JPEG or YCbCr interface (serial or parallel), the ADCM-1650 supports industry-leading data resolutions as well as subsampling.

The ADCM-1650 camera module also supports a range of programmable modes, including support for embedded or external synchronization capabilities which extend design flexibility.

Features

- 352 x 288 CIF resolution
- Bayer color filters – blue, red and green
- Frame rate – 15 frames per second at CIF resolution
- Flexible orientation
- Programmable to many image formats:
  - CIF (352 x 288)
  - QVGA (320 x 240)
  - QCIF (176 x 144)
  - QQVGA (160 x 120)
  - QQCIF (88 x 72)
  - Any other format 352 x 352 or smaller
- Panning and digital zoom
- Window can be placed anywhere in the 352 x 352 array
- Low power – 80 mW typical at 13 MHz input clock
- High intrinsic sensitivity for enhanced low light performance
- Single 2.8V power supply with internal voltage regulation
- High-quality F/2.6 lens
- Direct JPEG or YCbCr 8-bit parallel output port (CCIR 656-compatible)
- Embedded synchronization capability – CCIR 656
- Horizontal/vertical mirroring and subsampling
- Optimized temperature performance
- Excellent image quality – JPEG based compression with selectable quantization tables
- Fully configurable image processing
- Automatic gathering of frame statistics, including histograms for each color channel
- Automatic adjustment of compression rate for constant image file size
- Image resizer
- Auto exposure and auto white balance
- Integrated IR filter
- Compact size – 8.5 x 8.0 x 7.9 mm with cover glass

Applications

- Mobile phones
- Video phones
- Personal Digital Assistants
- Digital still mini cameras
- Image-enabled appliances
- Embedded automotive
- Monitoring equipment

General Specifications

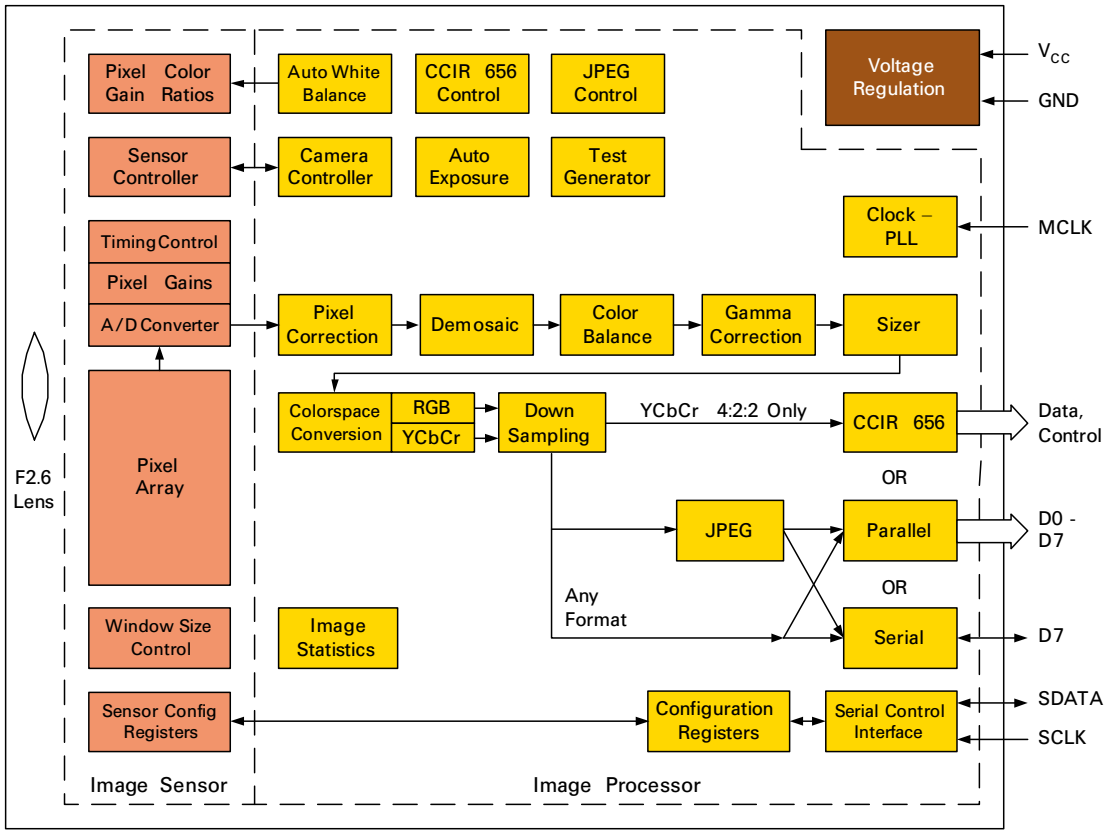
Feature	Value
Output Format	8-bit parallel YCbCr CCIR 656-compliant 8-bit parallel YCbCr or RGB or JPEG Serial YCbCr or JPEG
Maximum Frame Rates	15 fps at 352 x 288 (CIF)
Image Modes	Grayscale and full color
YCbCr (YUV) Formats	4:4:4 YCbCr and 4:2:2 $Y_1Cb_{12}Y_2Cr_{12}$
Gamma Correction	33 value programmable interpolated table
Data Synchronization	End_of_Line, End_of_Frame, Data_Clock
Video Synchronization	HSYNC, VSYNC, VCLK
Serial Control Identification	0 x 50
Supply Voltage Requirements	2.65 - 3.1 V
External Clock Frequency	4 - 32 MHz
Power Consumption	80 mW typical, 1.5mW in low power mode
Scene Illumination (Minimum)	5 lux

Optical Specifications

Function	Description
Pixel Count	352 x 352 (programmable: 352 x 288 landscape mode; 288 x 352 portrait mode)
Pixel Size	4.9 μm x 4.9 μm
Effective Fill Factor	~ 80%
IR Filter	Integrated
Lens Type	Plastic singlet aspheric
Focal Length	1.85 mm
F/#	2.6
Focus	Fixed focus
Depth of Focus	100 mm to infinity
Field of View	55° full angle (horizontal in landscape mode, vertical in portrait mode)
Distortion	≤ 4%

Block Diagram

The ADCM-1650 camera module is a complete image processing system.



ADCM-1650-3011 Block Diagram Description

Function	Description
A/D Converter	Converts analog pixel output voltages to 8-bit digital values
Auto Exposure	Adjusts the image sensor exposure for the amount of light present in the window using both exposure time and pixel gain
Auto White Balance	Accommodates the slight color shifts that affect white in different kinds of light (daylight, fluorescent, incandescent). The camera module performs white balancing by digitally changing the gain ratio of the red, blue and green channels and by adjusting the color balancing matrix. White objects in the window always look white in the final image.
Camera Controller	Overall functions of the camera module are centrally controlled by the camera controller
CCIR 656 Control	Determines the logic levels and which type of synchronization codes to use
CCIR 656 Output	Accomplished by using the parallel port with CCIR 656 formatted data. Data can be output with either external horizontal and vertical synchronization signals, or by using embedded synchronization codes.
Clock – PLL	Allows very fine control over the system and image sensor clock speeds
Color Balance	Physical properties of the optics dictate that images from the sensor are not perfectly matched to the human eye. This block improves the color fidelity of the image and increases saturation.
Color Space Conversion	Programmable color space conversion function to convert RGB values to different color spaces (default is RGB to YCbCr)

ADCM-1650-3011 Block Diagram Description (continued)

Function	Description
Configuration Registers	Controls all camera module features
Demosaic	Performs color interpolation to produce all three (red, blue and green) color components for each pixel location
Down-Sampling	Data is sent in either 4:4:4 mode (no down sampling) or 4:2:2 mode (chrominance down sampled)
Gamma Correction	Pixel values acquired from the image sensor are a linear function of the light present in the frame. For computer monitors, the intensity produced by the display is a non-linear function of the pixel value and is characterized by a "gamma" curve. The gamma corrects the image data for display and can also make corrections to the contrast of the image.
Sizer	Allows the output size of the image to be different than the input size without changing the field of view. This is done using a sizer circuit which interpolates the new data values from the image sensor pixels down to smaller images.
Image Statistics	Registers contain data for each color plane, are used by the auto exposure and auto white balance functions and are also readable
JPEG Compression	Once the image is converted into YCbCr color space, it can then be compressed with baseline DCT JPEG compression. To reduce the amount of data transmitted, the camera module does not transmit the JPEG JFIF header, but an index to the Q-table used in the compression.
JPEG Control	Determines the degree of JPEG compression
Lens	High quality F/2.6 single element lens
Parallel Output	Outputs data using a parallel port with a data clock
Pixel Array	Image sensor consists of a 352 x 352 pixel array which can be read in portrait (288 x 352) or landscape (352 x 288) mode. The array can be windowed to any smaller dimension and can also be mirrored in both the horizontal and vertical directions.
Pixel Color Gain Ratios	Controlled by the auto white balance function, these ratios set the differential gains of the color channels
Pixel Correction	Reduces the effects of pixel mismatch
Pixel Gain	Analog gain controlled by the auto exposure block
Sensor Controller	Controls the interface between the image sensor and the image processor
Sensor Configuration Registers	Controls detailed functions of the image sensor; programming of these registers is done through four image pipeline registers
Serial Control Interface	Camera module registers are programmed using this interface
Test Generator	Generates color bars and other patterns to test the image processor
Timing Control	Exposure control for the image sensor with exposure in row times
Voltage Regulation	Internal voltage regulators
Window Size Control	Allows the image sensor output to be windowed to any location on the image sensor. Beginning and ending rows and columns can be specified, allowing the window to be any size, in any location.

Image Data Flow

The following table shows the flow of data from the sensor, through the image pipeline and out of the camera module.

Function	Description	Settings / Options
Image Data from the Image Sensor	Raw data from the image sensor is input into the image processor	
Auto Exposure	Adjusts image sensor gain and exposure time to meet target average pixel luminance	Enable/disable using the AEWB_AUTO and AEWB_STATUS registers
Auto White Balance	Equalizes average pixel luminance among color channels	
Statistics	Collects image statistics such as peak values, pixel sums and histograms on a one- to-many frame basis	Enable/disable using the STAT_CAP_CNTL and STAT_MODE_CNTL registers
Pixel Correction	Corrects pixel values for mismatched pixels	Enable/disable using the CFG_MAIN2 register
Demosaic	Converts raw Bayer pattern pixel data into red, green and blue image planes	
Color Balance	Adjusts for the color filter response of the image sensor	Use default or custom color correction matrices
Gamma Correction	Applies a non-linear transfer function to the image data	Select bottom-weighted or linear lookup table using the CFG_MAIN1 register; use default or custom table
Sizer	Interpolates the image to a smaller size	Select input and output height and width using the SZR_IN_W, SZR_IN_H, SZR_OUT_W, SZR_OUT_H registers
Color Space Conversion	Converts RGB data to the desired color space	Use default (RGB to YCbCr) or custom conversion matrices
Down Sampling	Reduces the resolution of the chrominance data to compress data	Select down sampling mode (grayscale, 4:4:4 or 4:2:2) using the CFG_MAIN1 register
Data Output	Data is output using the CCIR parallel port, or the serial or parallel port with YCbCr data or JPEG compression; output is programmable	Select modes using the CCIR_TIMING, CCIR_CONFIG, Y_MAX, Y_MIN, CbCr_MAX, CbCr_MIN, CFG_MAIN1 and CFG_MAIN2 registers

Electrical Specifications

The descriptions in square brackets are the pin definitions when in JPEG mode. The unbracketed descriptions are for parallel/CCIR mode,

Absolute Maximum Ratings

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Storage Temperature	T_S	-40		85	°C	
Operating Temperature	T_A	-25		65	°C	
Humidity	RH	5		95	%	Non-condensing
Supply Voltage	V_{CC}	-0.5		3.3	V	
ESD				2	kV	All pins, human body model MIL 883 Method 3015
Input Voltage	V_{IN}	-0.02		3.3	V	All input pins

Recommended Operating Conditions

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Operating Temperature	T_A	-25	25	65	°C	
V_{CC} Voltage	V_{CC}	2.65	2.8	3.15	V	
V_{CC} Rise Time	V_{CC_RT}			10	ms	
V_{CC} Supply Noise	V_{CC_N}			50	mV	Vp-p within 0 - 1.5 kHz
External Clock Frequency Duty Cycle	MCLK	4 45	13 50	32 55	MHz %	
Serial Control Clock Frequency	SCLK		100	100	kHz	Minimum MCLK = 4 MHz

DC Electrical Specifications (typical values at 25 °C, V_{CC} = 2.8 V)

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Supply Current (Normal Mode)	I_{CC}		26		mA	At 13 MHz
Supply Current (Low Power)	I_{CC}		500		μA	Power-on, MCLK stopped
Supply Current (Power OFF)	I_{CC}			5	μA	ON/$\overline{\text{OFF}}$ = OFF
All pins except S_CLK and SDATA						
Input Low Voltage	V_{IL}			0.6	V	
Input High Voltage	V_{IH}	1.8		2.8	V	
Output Low Voltage	V_{OL}	0		0.4	V	
Output High Voltage	V_{OH}	1.8			V	

DC Electrical Specifications (typical values at 25 °C, V_{CC} = 2.8 V) (continued)

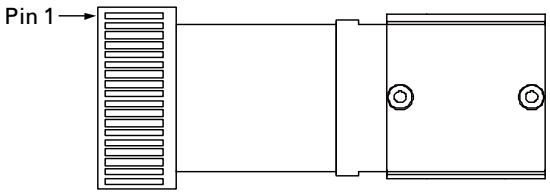
Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Input Low Current	I_{IL}	< - 5		< 5	µA	At 0.0 V
Input High Current	I_{IH}	< - 5		< 5	µA	At 2.5 V
S_CLK and SDATA						
Input Low Voltage	V_{IL_S}			0.6	V	
Input High Voltage	V_{IH_S}	2.2		3.6	V	
Output Low Voltage	V_{OL_S}			0.4	V	At 3 mA sink current
Output High Voltage	V_{OH_S}				V	Output voltage depends on external pull-up resistor and V_{CC} value

AC Electrical Specifications (typical values at 25 °C, V_{CC} = 2.8 V)

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Video Clock Frequency	V_{CLK}	4	13	32	MHz	Programmable
Frame Rate				15	frame/s	Programmable
ON/$\overline{\text{OFF}}$ Rise Time	t_{OF}		40		mV/µs	Slew rate
Data Output (DATA_[7:0], VCLK, HSYNC, VSYNC)						
Rise Time	t_{DR}	1.9	2.9	4.2	ns	V_{OH} = 2.4 V
Fall Time	t_{DF}	2.1	3.1	4.3	ns	V_{OH} = 2.4 V
S_CLK, S_DATA						
Rise Time	t_{DCR}				ns	Depends on external pull-up resistor, V_{CC} value, line capacitance
Fall Time	t_{DCF}	20		250	ns	
Input Pin Capacitance	C_{IN}		5.2		pF	

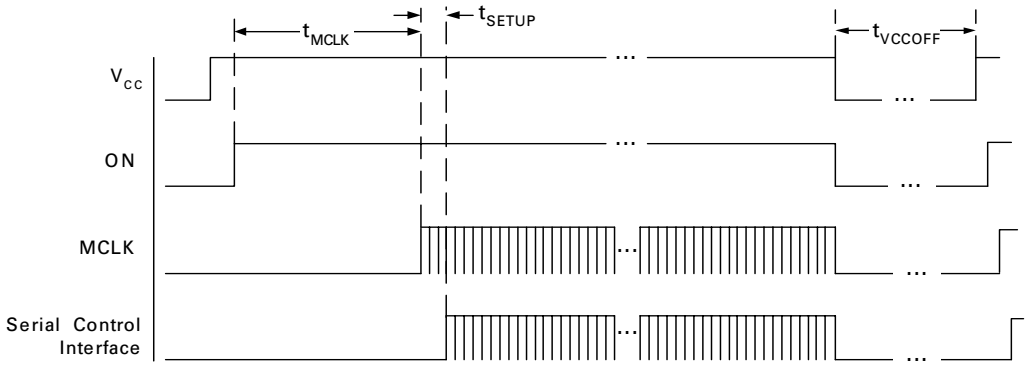
Pinout

Location	Signal Name	Type	Description	Notes
1	GND	Common	System Ground	
2	MCLK	Input	Module Clock	
3	VSYNC	Output	Vertical Synchronization	[End_of_Frame]
4	DATA0	Output	Parallel Data 0	
5	DATA1	Output	Parallel Data 1	
6	DATA2	Output	Parallel Data 2	
7	DATA3	Output	Parallel Data 3	
8	DATA4	Output	Parallel Data 4	
9	DATA5	Output	Parallel Data 5	
10	DATA6	Output	Parallel Data 6	
11	DATA7	Output	Parallel Data 7	
12	VCLK	Output	Video Clock	[Data_Ready]
13	HSYNC	Output	Horizontal Synchronization	[End_of_Line]
14	ON/$\overline{\text{OFF}}$	Input	Voltage Regulator Control	
15	SCLK	Input	Serial Interface Control Clock	
16	SDATA	Input/Output	Serial Interface Control Data	
17	V_{CC}	Input	Voltage Input	
18	GND	Common	System Ground	

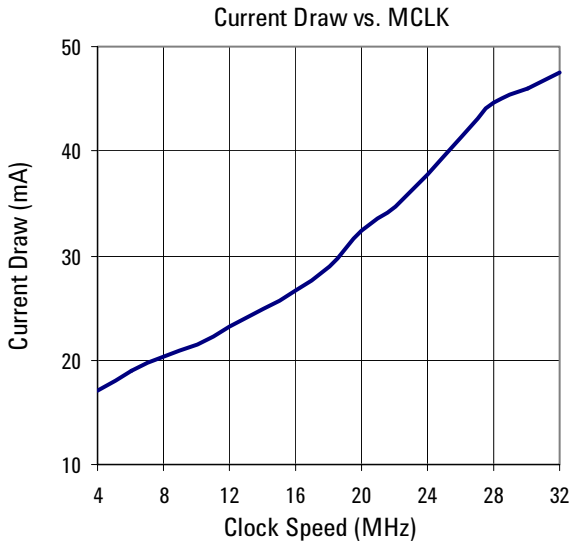


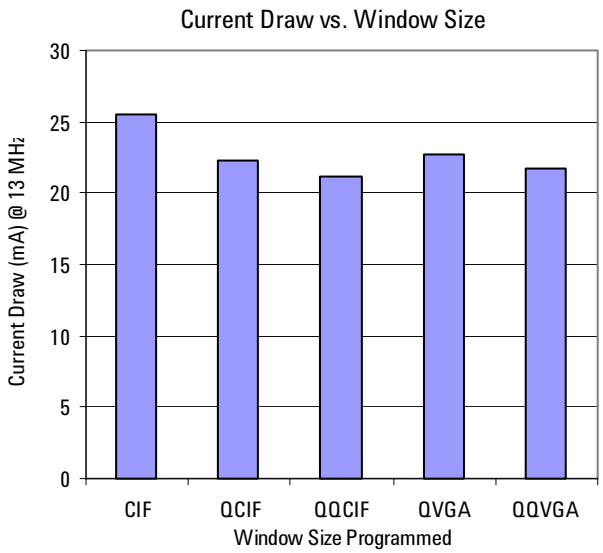
Mating Connector: Molex 52892-1890

Power Up Timing

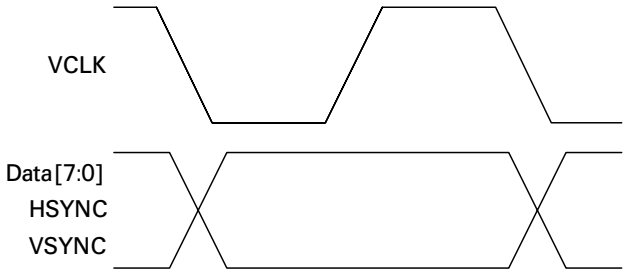


Parameter	Symbol	Minimum	Units	Notes
V_{CC} to ON ↑	t_{ON}	0	ms	
ON ↑ to MCLK ON	t_{M_CLK}	30	ms	
MCLK ON to First Serial Communication	t_{SETUP}	2048	Cycles of MCLK	
Time from V_{CC} OFF to V_{CC} ON	t_{VCCOFF}	600	ms	



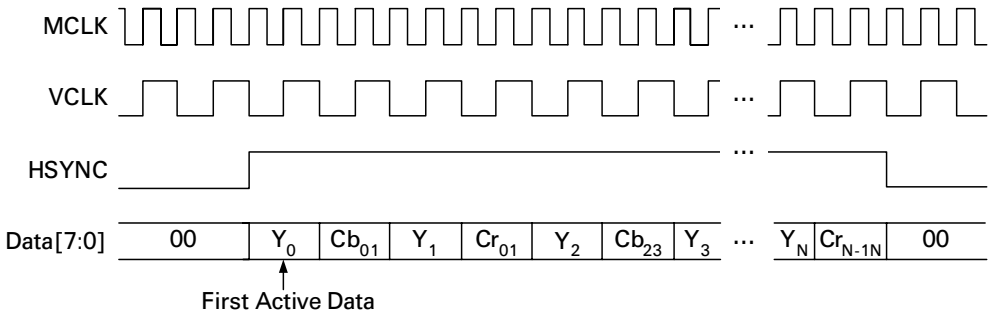


VCLK Timing

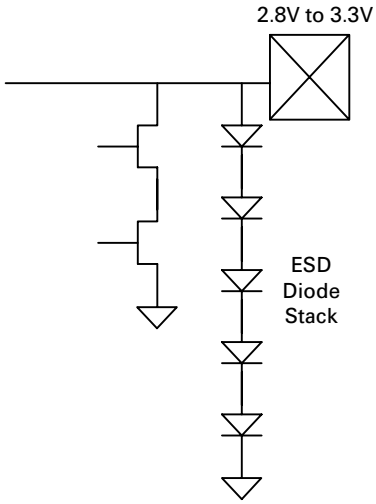


Data is asserted on the rising edge of VCLK (default) but can be programmed using the camera module registers to be asserted on the falling edge.

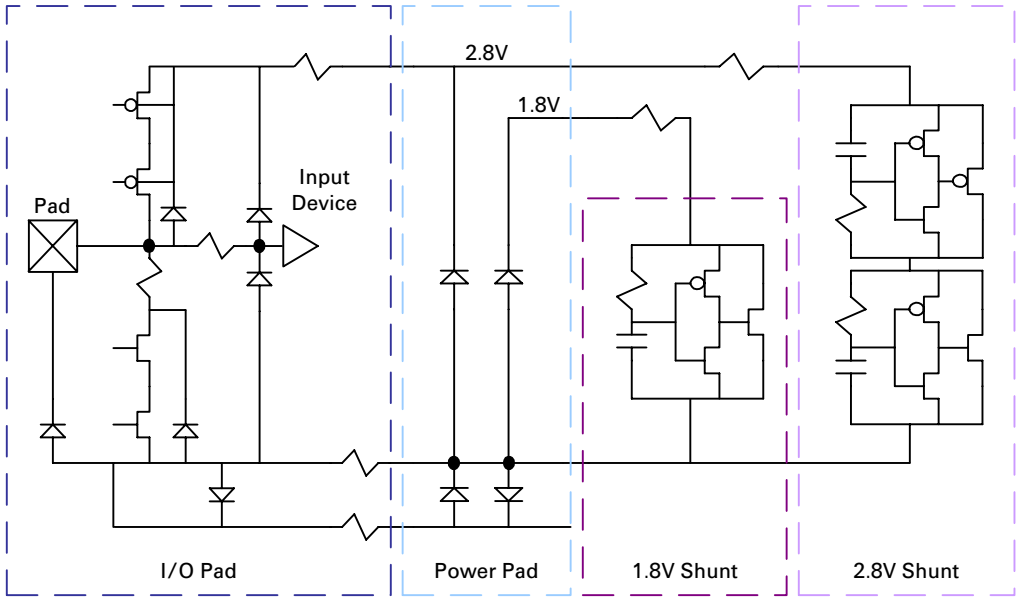
VCLK, HSYNC Timing



Serial Control Pads Equivalent Circuits

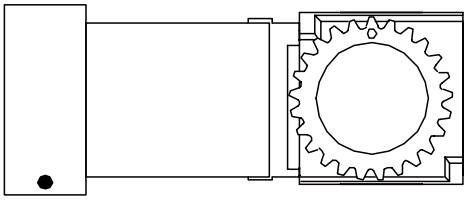


I/O Pad Equivalent Circuits

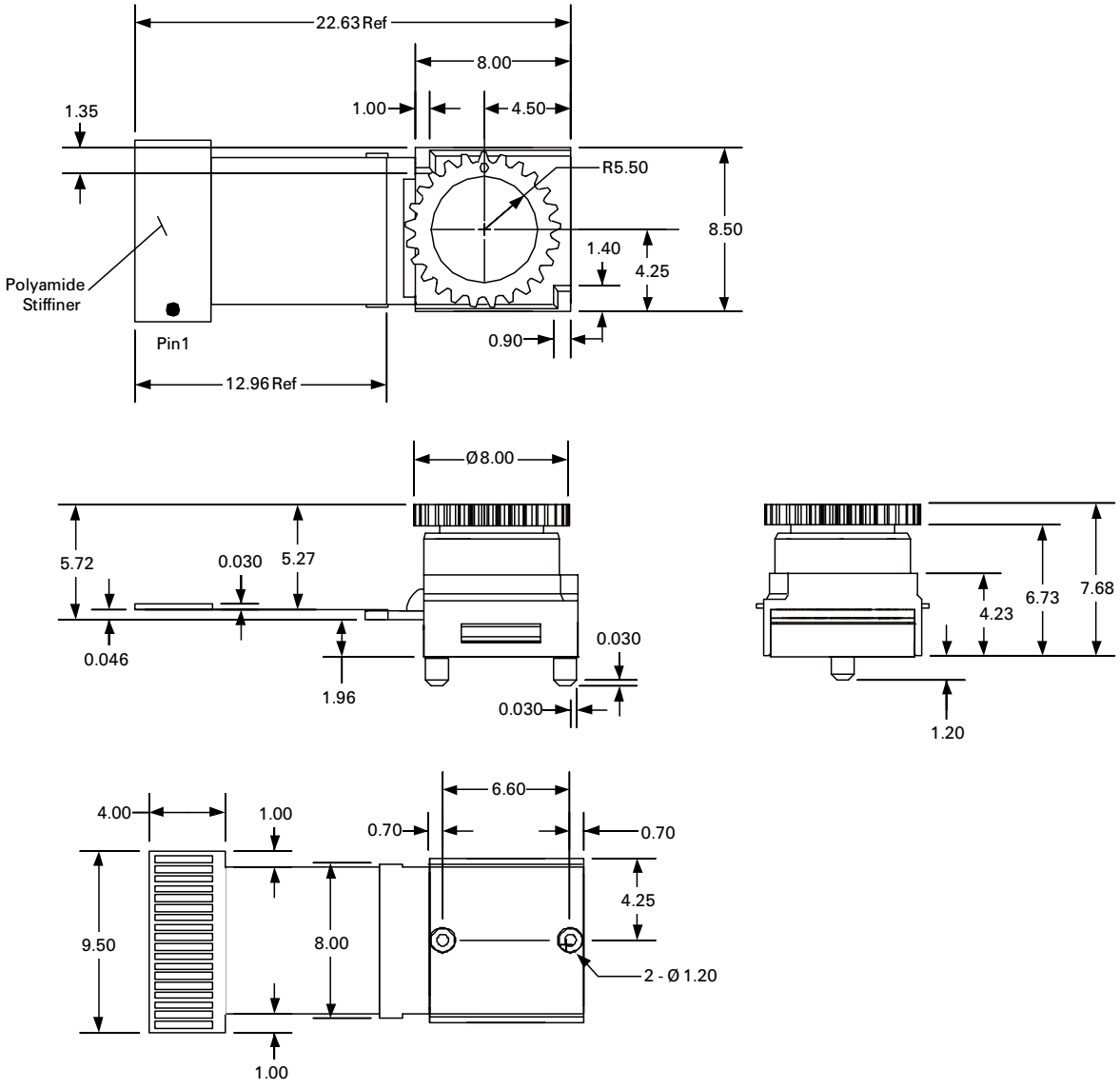


Camera Orientation

To take pictures “right side up”, orient the camera as shown below. The image can be electronically flipped horizontally, vertically or both.



Mechanical Drawings



Programmable Registers

The ADCM-1650 camera module has programmable registers in the image pipeline IC and the image sensor IC. See "*Serial Control Interface*" in the ADCM-1650 Camera Module Technical Reference Manual for details on usage and programming of these registers.

Image Pipeline Registers

Mnemonic	Description	Mnemonic	Description
AE_TARGET	Auto Exposure Target	CC_OFFSET_0	Color Correction Offset 0
AE_TOL	Auto Exposure Tolerance	CC_OFFSET_1	Color Correction Offset 1
AEWB_AUTO	Auto-Exposure/White Balance Function	CC_OFFSET_2	Color Correction Offset 2
AEWB_CTRL	Auto Functions Control	CCIR_CONFIG	CCIR Configuration
AEWB_STATUS	Auto-Exposure/White Balance Status	CCIR_TIMING	CCIR Timing Control
APS_COEF_BLUE	Blue Color Gain Coefficient	CFG_MAIN1	Main Configuration 1
APS_COEF_GRN1	Green 1 Color Gain Coefficient	CFG_MAIN2	Main Configuration 2
APS_COEF_GRN2	Green 2 Color Gain Coefficient	CSC_COEF_00	Color Space Conversion Coefficient 00
APS_COEF_RED	Red Color Gain Coefficient	CSC_COEF_01	Color Space Conversion Coefficient 01
APS_DM_CONFIG	Sensor Data Mode	CSC_COEF_02	Color Space Conversion Coefficient 02
AWB_BLUE_DFLT	Default Blue/Green Ratio	CSC_COEF_10	Color Space Conversion Coefficient 10
AWB_BLUE_MAX	Maximum Blue/Green Ratio	CSC_COEF_11	Color Space Conversion Coefficient 11
AWB_BLUE_MIN	Minimum Blue/Green Ratio	CSC_COEF_12	Color Space Conversion Coefficient 12
AWB_RED_DFLT	Default Red/Green Ratio	CSC_COEF_20	Color Space Conversion Coefficient 20
AWB_RED_MAX	Maximum Red/Green Ratio	CSC_COEF_21	Color Space Conversion Coefficient 21
AWB_RED_MIN	Minimum Red/Green Ratio	CSC_COEF_22	Color Space Conversion Coefficient 22
AWB_TOL	Auto White Balance Tolerance	CSC_OFFSET_0	Color Space Conversion Offset 0
BLUE_SUM	Blue Sum Data	CSC_OFFSET_1	Color Space Conversion Offset 1
CbCr_MAX	Clip CbCr Values to this Maximum	CSC_OFFSET_2	Color Space Conversion Offset 2
CbCr_MIN	Clip CbCr Values to this Maximum	ETIME_DEFAULT	Default Exposure Time
CC_COEF_00	Color Correction Coefficient 00	ETIME_MAX	Maximum Exposure Time
CC_COEF_01	Color Correction Coefficient 01	ETIME_MIN	Minimum Exposure Time
CC_COEF_02	Color Correction Coefficient 02	EXT_CLK_DIV	External Clock Divisor
CC_COEF_10	Color Correction Coefficient 10	G1_G2_THRESH	Green Filter Threshold
CC_COEF_11	Color Correction Coefficient 11	GAIN_MAX	Maximum Gain
CC_COEF_12	Color Correction Coefficient 12	GAIN_MIN	Minimum Gain
CC_COEF_20	Color Correction Coefficient 20	GREEN1_SUM	Green 1 Sum Data
CC_COEF_21	Color Correction Coefficient 21	GREEN2_SUM	Green 2 Sum Data
CC_COEF_22	Color Correction Coefficient 22	HALF_AC_CYCLE	One Half AC Cycle Time Exposure

Image Pipeline Registers (continued)

Mnemonic	Description	Mnemonic	Description
I_HEIGHT	Current Image Height (Read Only)	RESTART	JPEG Restart Marker Interval
I_WIDTH	Current Image Width (Read Only)	REV	Revision
NEG_CLIP_CNT	Negative Clip Count	SENSOR_ADDRESS	Sensor Interface Address
OFL_THRESHOLD	Auto Q Adjust Overflow Threshold	SENSOR_CTRL	Sensor Interface Control
ONE_AC_CYCLE	One AC Cycle Time Exposure	SENSOR_DATA1	Sensor Interface Data Word 1
P_OUTPUT_SPEED	Parallel Output Data Speed	SENSOR_DATA2	Sensor Interface Data Word 2
PC_BAD_PIX	Number of Bad Pixels, Current Frame	SER_CTRL_TMG	Serial Control Timing
PC_OUTL	Pixel Control Outliers	SSC_PERIOD	Sensor Serial Clock Period
PC_SF_PED	Pixel Control Scale Factor, Pedestal	STAT_CAP_CTRL	Image Statistics Capture Control
PEAK_DATA	Peak Sensor Data	STAT_MODE_CTRL	Image Statistics Mode Control
PLL_CTRL	PLL Control	STATUS	General Image Pipeline Status
PLL_DIVBY	PLL Divby Coefficient	SZR_IN_H	Sizer Input Height
PLL_M	PLL M Coefficient	SZR_IN_W	Sizer Input Width
PLL_PCNT0	PLL P0 Coefficient	SZR_OUT_H	Sizer Output Height
PLL_PCNT1	PLL P1 Coefficient	SZR_OUT_W	Sizer Output Width
PLL_QCNT	PLL QCNT Coefficient	T_DGEN_H	Test Data Generator Height (pixels)
PLL_SUM	PLL SUM Coefficient	T_DGEN_M	Test Data Generator Mode Control
POS_CLIP_CNT	Positive Clip Count	T_DGEN_W	Test Data Generator Width (pixels)
Q_TABLE_SELECT	Index to JPEG Q-Tables	TWO_AC_CYCLES	Two AC Cycle Time Exposure
QTABLE_SEL_MAX	Maximum Value of QTABLE_SELECT	UFL_THRESHOLD	Auto Q Adjust Underflow Threshold
QTABLE_SEL_MIN	Minimum Value of QTABLE_SELECT	Y_MAX	Clip Y Values to this Maximum
RED_SUM	Red Sum Data	Y_MIN	Clip Y Values to this Minimum

Image Sensor Registers

Mnemonic	Description	Mnemonic	Description
CONFIG	Configuration	OROCPGA	Odd Row, Odd Column PGA Gain
CONFIG_2	Configuration 2	PRST	Preset Pulse Width Control
CONTROL	Control	ROWEXPH	Row Exposure High
ERECPGA	Even Row, Even Column PGA Gain	ROWEXPL	Row Exposure Low
EROCPGA	Even Row, Odd Column PGA Gain	SROWEXP	Sub Row Exposure
ERROR	Errors	STATUS	Status
FWCOL	First Window Column	TCTRL	Timing Control
FWROW	First Window Row	TEST0	Test Control 0
HBLANK	Horizontal Blank	TEST1	Test Control 1
ICTRL	Interface Control	TEST2	Test Control 2
IDENT	Identification	TEST3	Test Control 3
ITMG	Interface Timing	TEST4	Test Control 4
LWCOL	Last Window Column	TEST5	Test Control 5
LWROW	Last Window Row	VBLANK	Vertical Blank
ORECPGA	Odd Row, Even Column PGA Gain		

www.agilent.com/semiconductors

For product information and a complete list of distributors, please go to our web site.

For technical assistance call:

Americas/Canada: +1 (800) 235-0312 or
+1 (408) 654-8675
Europe: +49 (0) 6441 92460
China: 10800 650 0017
Hong Kong: (+65) 271 2451
India, Australia, New Zealand: (+65) 271 2394
Japan: (+81 3) 3335-8152 (Domestic/International)
or 0120-61-1280 (Domestic Only)
Korea:(+85) 271 2194
Malaysia, Singapore:(+65) 271 2054
Taiwan:(+65) 271 2654

May 13, 2003
5988-8934EN

Agilent Technologies