X-Cube Imaging System X-Cube Machine Vision Reference Module Developer Guide

AND9891/D

INTRODUCTION

This document describes both the mechanical and electrical features and functions of the X−Cube Imaging System (X−Cube).

The X−Cube is designed to demonstrate the features of **onsemi**'s XGS family of image sensors in machine vision applications. The X−Cube is designed to conform to the machine vision industry standard 29 mm × 29 mm form factor.

The X−Cube is a modular system consisting of multiple circuit boards. The configuration of the X−Cube can be adjusted depending upon which features are desired to be implemented.

X−Cube compatible circuit boards include:

- Imager Boards (XGS Family of Imagers)
- HiSPi−to−MIPI Converter Board

Other X−Cube compatible boards can be designed to implement additional features and operating modes.

SYSTEM OVERVIEW

The X−Cube Imaging System consists of a small form factor XGS Imager Board installed in a machine vision industry standard form factor (29 mm × 29 mm) C−Mount Lens Housing. For the color X−Cube option an integrated IR−Cut filter is also provided and is installed in the lens housing prior to the installation of the imager board. For detailed information refer to the X−Cube XGS 12000 Imager Board User's Manual (EVBUM2636/D).

A HiSPi−to−MIPI Converter Board with the same form factor as the imager board is included in the X−Cube. The converter board is designed to be connected to the imager board and to convert the HiSPi Packetized−SP Mode image data output format of the XGS image sensor (12 lane implementation) to the MIPI CSI−2 image data format (4 lane implementation) and to output this MIPI image data to an external Host through a FLEX interface cable board that is also provided. For detailed information refer to the X−Cube HiSPi−to−MIPI Converter Board User's Manual (EVBUM2635/D).

The lens mount housing design includes a mounting post that enables the attachment of the lens housing to any tripod with a 1/4 inch sized mounting screw. A mini tabletop tripod that is compatible with the mounting post is included in the X−Cube Kit.

The block diagram of the X−Cube is shown in Figure 1.

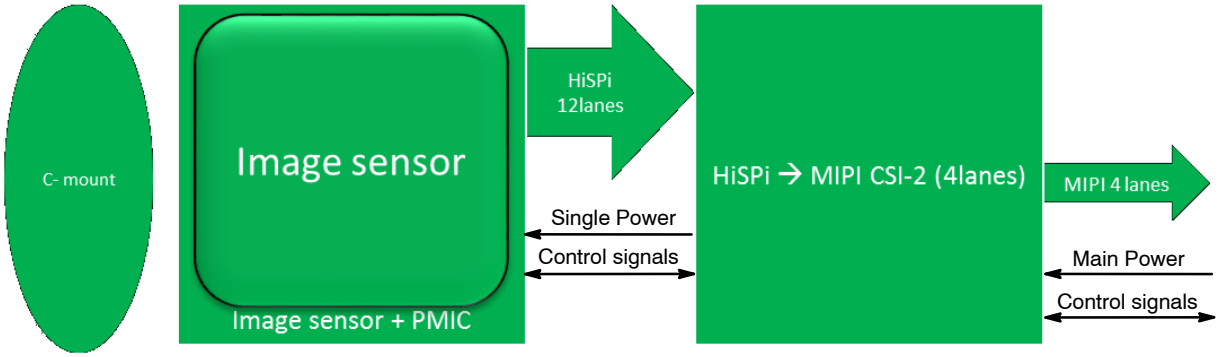

Figure 1. X−Cube Block Diagram

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A representation of the complete X−Cube assembly including the C−Mount Lens Housing, the XGS Imager Board, and the HiSPi−to−MIPI Converter Board is shown in Figure 2.

X−Cube compatible adapter boards have been designed and are available to enable the demonstration and evaluation of the X−Cube using **onsemi** development software tools.

Refer to the Development Tools section of this document for more information.

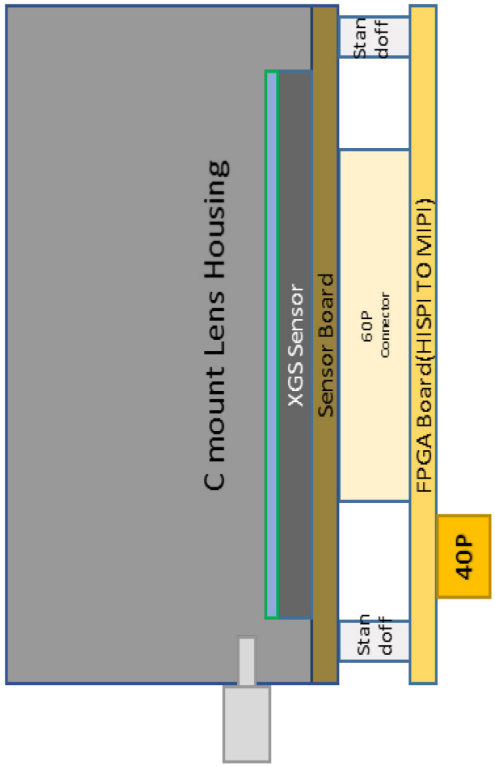

Figure 2. X−Cube Assembly (Note that the Lens is not Included)

System Requirements

This section describes the electrical and mechanical interfaces of each element in the X−Cube assembly.

C−MOUNT LENS HOUSING

The lens housing is designed to conform to the machine vision industry standard 29 mm × 29 mm form factor. The lens mount is compatible with all standard C−Mount type lenses. The lens mount housing includes a mounting post that can be used to attach the housing to any tripod with a 1/4 inch sized mounting screw.

For color X−Cubes, an IR−Cut filter is glued into a cavity in the lens housing between the lens and the image sensor. The lens housing is designed to accommodate filters with a form factor of 20 mm × 20 mm and a thickness less than 3 mm. The spectroscopic characteristics of the IR−Cut filter are shown in Table 1.

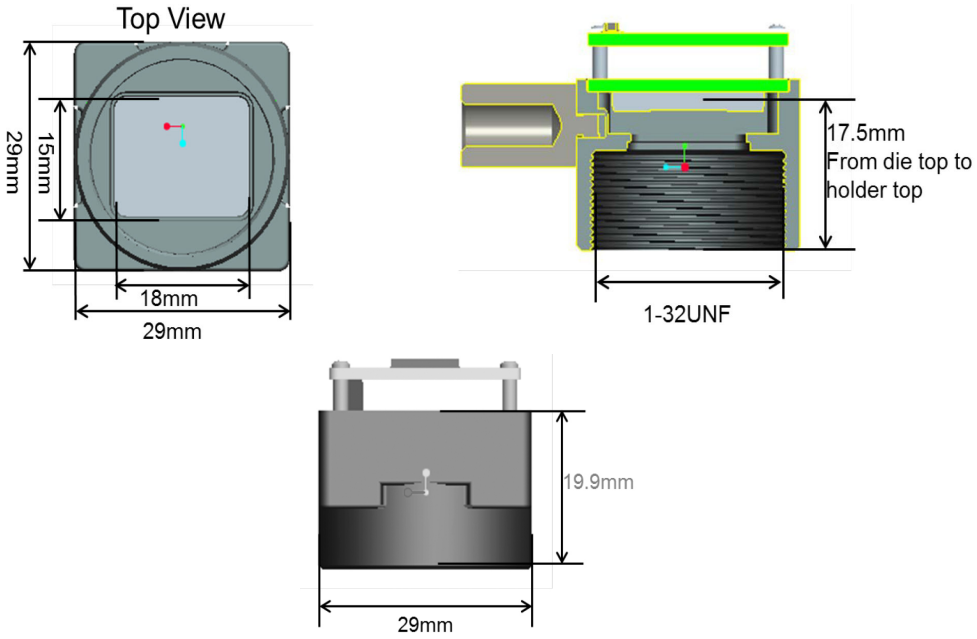

Figure 3. Lens Mount and Dimensions

Table 1. IR−CUT FILTER SPECTROSCOPIC CHARACTERISTICS

Wavelength (nm)	Transmission (T%)
420 − 620 nm	Tavg > 85%
650 ± 10 nm	T = 50%
720 − 1100 nm	Tmax < 2%

The Lens Mount Housing is fabricated with black anodized aluminum. As shown in Figure 2, the lens housing is designed to contain an X−Cube compatible Imager Board, but not any additional circuit boards being used in the various X−Cube configurations. Other circuit boards in the system, such as the HiSPi−to−MIPI Converter Board will remain visible outside of the lens housing. The Lens Mount Housing for the X−Cube was designed with the understanding that the customer would design a custom case for their camera which would depend upon which features and board configuration options they chose to implement in their design.

IMAGER BOARD

The Imager Board is designed to support the operation of imagers from **onsemi**'s XGS family of image sensors. The board is designed to operate an XGS image sensor in HiSPi Packetized−SP Mode output data format operation with a 12 lane implementation. The imager board is designed to have a form factor that is compatible with the X−Cube's Lens Mount Housing.

Several X−Cube compatible Imager Board options are available to support different image sensors in **onsemi**'s XGS family of imagers. Each of these boards share the same connector type and pinout, as well as the same mechanical dimensions.

The imager board interfaces with other elements of the imaging system through a single board interface connector. The imager board requires only a single +3.3 V power supply input. A power management IC (PMIC) on the board is used to generate all of the power supply voltages required by the image sensor. The power required by the imager board is input via the board interface connector. Both the image sensor and the PMIC on the Imager Board are programmed by the Host via the I^2C communications interface provided through the connector. In addition, the control signals necessary for imager board operation are also input to the imager board via the board interface connector. Finally, the image sensor HiSPi data is output from the board via the board interface connector as well.

Refer to Tables 1 and 2 for detailed information regarding the imager board's board interface connections.

Table 2. IMAGER BOARD CONNECTOR INFORMATION

Connector	Manufacturer	Part Number	Description
J1	HRS	DF40C−60DP−0.4 V(51)	CONN, PLUG, VERTICAL, FPC, DF40 SERIES, NARROW PITCH, 2 × 30, 60 PIN, 0.4 MM PITCH

Table 3. CONNECTOR J1 PIN DESCRIPTION

Pin No.	Dir	Function	Pin No.	Dir	Function
1	OUT	TX0_DATA2_P	2	OUT	TX4_DATA18_P
3	OUT	TX0_DATA2_N	4	OUT	TX4_DATA18_N
5	PWR	GND	6	PWR	GND
7	OUT	TX2_DATA10_P	8	OUT	TX2_CLK2_P
9	OUT	TX2_DATA10_N	10	OUT	TX2_CLK2_N
11	PWR	GND	12	PWR	GND
13	OUT	TX0_DATA0_P	14	OUT	TX4_DATA16_P
15	OUT	TX0_DATA0_N	16	OUT	TX4_DATA16_N
17	PWR	GND	18	PWR	GND
19	OUT	TX2_DATA8_P	20	OUT	TX3_CLK3_P
21	OUT	TX2_DATA8_N	22	OUT	TX3_CLK3_N
23	PWR	GND	24	PWR	GND
25	OUT	TX0_DATA1_P	26	OUT	TX2_DATA11_P
27	OUT	TX0_DATA1_N	28	OUT	TX2_DATA11_N
29	PWR	GND	30	PWR	GND
31	OUT	TX2_DATA9_P	32	OUT	TX4_DATA17_P
33	OUT	TX2_DATA9_N	34	OUT	TX4_DATA17_N
35	PWR	GND	36	PWR	GND
37	OUT	TX0_DATA3_P	38	OUT	TX4_DATA19_P
39	OUT	TX0_DATA3_N	40	OUT	TX4_DATA19_N
41	PWR	GND	42	PWR	GND
43	IN	TRIG_RD	44	IN	RST_L
45	IN	TRIG_INT	46	OUT	MONITOR0
47	IN	CS (Not used)	48	OUT	MONITOR1
49	OUT	SDATAOUT (Not used)	50	OUT	MONITOR3
51	IN/OUT	SDA (I2C DATA)	52	PWR	+3.3 V VDD
53	IN	SCL (I2C DATA)	54	PWR	+3.3 V VDD

Table 3. CONNECTOR J1 PIN DESCRIPTION (continued)

Pin No.	Dir	Function	Pin No.	Dir	Function
55	IN	FWSI_EN (Internal use only set to VDD)	56	PWR	+3.3 V VDD
57	IN	HWEN – PMIC enable	58	PWR	+3.3 V VDD
59	IN	CLK_GEN (Optional image sensor EXTCLK input)	60	PWR	V_HOST_IO

Table 4. IMAGER BOARD POWER REQUIREMENTS

Power	Current (mA) Typ
+ 3.3 V	500

The mechanical information for the Imager Board is shown in Figure 4. The physical size of the circuit board is 26 mm × 26 mm. The imager board is designed to fit into the 29 mm × 29 mm X−Cube C−Mount Lens Housing.

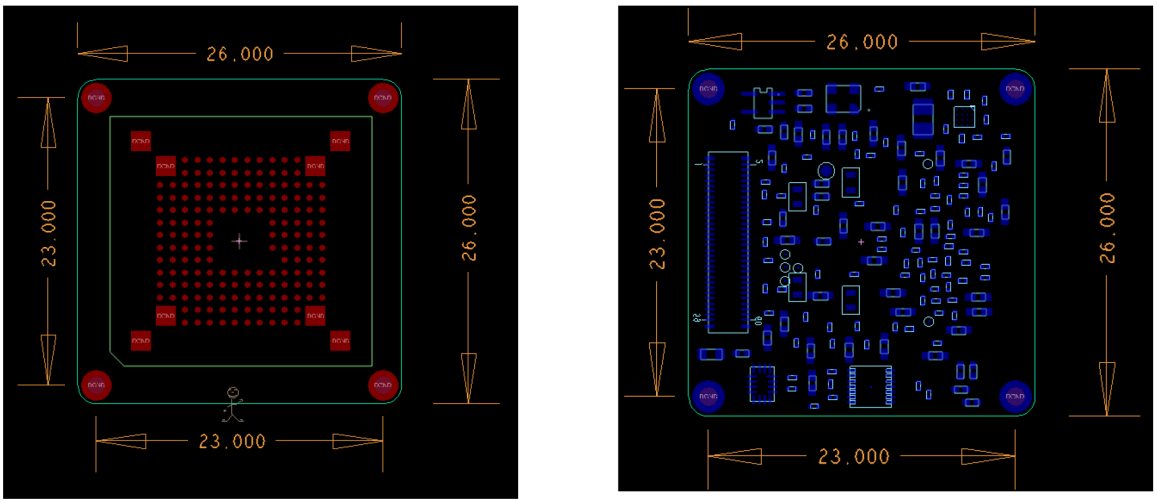

Figure 4. Imager Board (26 mm × 26 mm Form Factor)

HISPI−TO−MIPI CONVERTER BOARD

The HiSPi−to−MIPI Converter Board utilizes a third party FPGA (Lattice LIF−MD6000) to implement a HiSPi−to−MIPI data format conversion process. Image data in HiSPi Packetized−SP video format is input to the FPGA from the Imager Board. The FPGA converts the image data from the HiSPi format to the MIPI CSI−2 format. The image data is then output from the converter board to the Host using a four lane MIPI output configuration. It is the Host's responsibility to then buffer the incoming MIPI data stream and to process this image data as desired (color interpolation etc..).

The converter board is designed to be operated with XGS image sensors utilizing HiSPi Packetized−SP mode and that are configured for 12 lane output operation. The converter board can be connected to a number of X−Cube compatible Imager Boards. Note however, that the FPGA on the HiSPi−to−MIPI Converter Board requires unique firmware programming for each image sensor resolution.

The converter board requires only a single +5 V power supply input that is provided by the Host. The converter board utilizes on−board power regulators designed by **onsemi** to generate all of the power supply voltages required by the FPGA from the +5 V power supply input. In addition, the converter board includes a LDO regulator to generate a +3.3 V power supply that can be used to power an X−Cube Imager Board when the boards are connected together.

Communication to the converter board is accomplished via an I^2C connection with the Host.

The converter board is designed to have a form factor that is compatible with the X−Cube's Lens Mount Housing and to be able to be connected directly to imager boards from **onsemi**'s X−Cube family of imager boards.

Refer to Tables 4, 5, and 6 for detailed information regarding the converter board's connector interfaces.

Table 5. HISPI−TO−MIPI CONVERTER BOARD CONNECTORS PART NUMBERS

Connector	Manufacturer	Part Number	Description
J1	HRS	DF40HC(4.0)−60DS−0.4V(51)	CONN, Receptacle, VERTICAL, FPC, DF40 SERIES, NARROW PITCH, 2 × 30, 60 PIN, 0.4 MM PITCH
J2	HRS	DF40C−40DP−0.4V(51)	CONN, PLUG, VERTICAL, FPC, DF40 SERIES, NARROW PITCH, 2 × 20, 40 PIN, 0.4 MM PITCH

Table 6. HISPI−TO−MIPI CONVERTER BOARD TO IMAGER BOARD CONNECTOR J1 PIN OUT

Pin No.	Dir	Function	Pin No.	Dir	Function
1	IN	TX0_DATA2_P	2	IN	TX4_DATA18_P
3	IN	TX0_DATA2_N	4	IN	TX4_DATA18_N
5	PWR	GND	6	PWR	GND
7	IN	TX2_DATA10_P	8	IN	TX2_CLK2_P
9	IN	TX2_DATA10_N	10	IN	TX2_CLK2_N
11	PWR	GND	12	PWR	GND
13	IN	TX0_DATA0_P	14	IN	TX4_DATA16_P
15	IN	TX0_DATA0_N	16	IN	TX4_DATA16_N
17	PWR	GND	18	PWR	GND
19	IN	TX2_DATA8_P	20	IN	TX3_CLK3_P
21	IN	TX2_DATA8_N	22	IN	TX3_CLK3_N
23	PWR	GND	24	PWR	GND
25	IN	TX0_DATA1_P	26	IN	TX2_DATA11_P
27	IN	TX0_DATA1_N	28	IN	TX2_DATA11_N
29	PWR	GND	30	PWR	GND
31	IN	TX2_DATA9_P	32	IN	TX4_DATA17_P
33	IN	TX2_DATA9_N	34	IN	TX4_DATA17_N
35	PWR	GND	36	PWR	GND
37	IN	TX0_DATA3_P	38	IN	TX4_DATA19_P
39	IN	TX0_DATA3_N	40	IN	TX4_DATA19_N
41	PWR	GND	42	PWR	GND
43	OUT	TRIG_RD	44	OUT	RST_L
45	OUT	TRIG_INT	46	IN	MONITOR0

Table 6. HISPI−TO−MIPI CONVERTER BOARD TO IMAGER BOARD CONNECTOR J1 PIN OUT

Pin No.	Dir	Function	Pin No.	Dir	Function
47	OUT	CS (Not used)	48	IN	MONITOR1
49	IN	SDATAOUT (Not used)	50	OUT	MONITOR3
51	OUT/IN	SDA (I2C DATA)	52	PWR	+3.3 V VDD
53	OUT	SCL (I2C DATA)	54	PWR	+3.3 V VDD
55	OUT	FWSI_EN (Internal use only set to VDD)	56	PWR	+3.3 V VDD
57	OUT	HWEN − PMIC enable	58	PWR	+3.3 V VDD
59	OUT	CLK_GEN (Optional image sensor EXTCLK input)	60	PWR	V_HOST_IO

Table 7. HISPI−TO−MIPI CONVERTER BOARD TO HOST CONNECTOR J2 PIN OUT

Pin No.	Dir	Function	Pin No.	Dir	Function
1	PWR	GND	2	IN	HOST_RST_L
3	OUT	MIPI_DATA_N_2	4	OUT	MONITOR0
5	OUT	MIPI_DATA_P_2	6	IN	HWEN − Sensor Board Power enable
7	PWR	GND	8	PWR	GND
9	OUT	MIPI_DATA_N_0	10	IN	HOST_TRIGGER_IN
11	OUT	MIPI_DATA_P_0	12	PWR	GND
13	PWR	GND	14	IN	HOST_CLK_GEN − optional external Sensor clock
15	OUT	MIPI_CLK_N	16	PWR	GND
17	OUT	MIPI_CLK_P	18	IN	FWSI_EN (Internal use only set to VDD)
19	PWR	GND	20	IN	HOST_SCL I^2C Clock line
21		NC	22	IN/OUT	HOST_SDA I^2C Data line
23		NC	24	PWR	GND
25	PWR	GND	26	IN	HOST_TRIG_INT
27	OUT	MIPI_DATA_N_1	28	IN	HOST_TRIG_RD
29	OUT	MIPI_DATA_P_1	30	PWR	GND
31	PWR	GND	32	PWR	GND
33	OUT	MIPI_DATA_N_3	34	PWR	GND
35	OUT	MIPI_DATA_P_3	36	PWR	+5 V External Power supply
37	PWR	GND	38	PWR	+5 V External Power supply
39	PWR	V_Host_IO	40	PWR	+5 V External Power supply
41	PWR	GND	42	PWR	GND
43	PWR	GND	44	PWR	GND

Table 8. HISPI−TO−MIPI CONVERTER BOARD POWER REQUIREMENTS

Power	Current (mA) Typ
+ 5 V External power supply	400

The mechanical information for the HiSPi−to−MIPI Converter Board is shown in Figure 5. The physical size of the circuit board is 26 mm × 26 mm.

The board is designed to be connected to an X−Cube compatible imager board. The board is sized to conform to the X−Cube Lens Mount Housing's form factor.

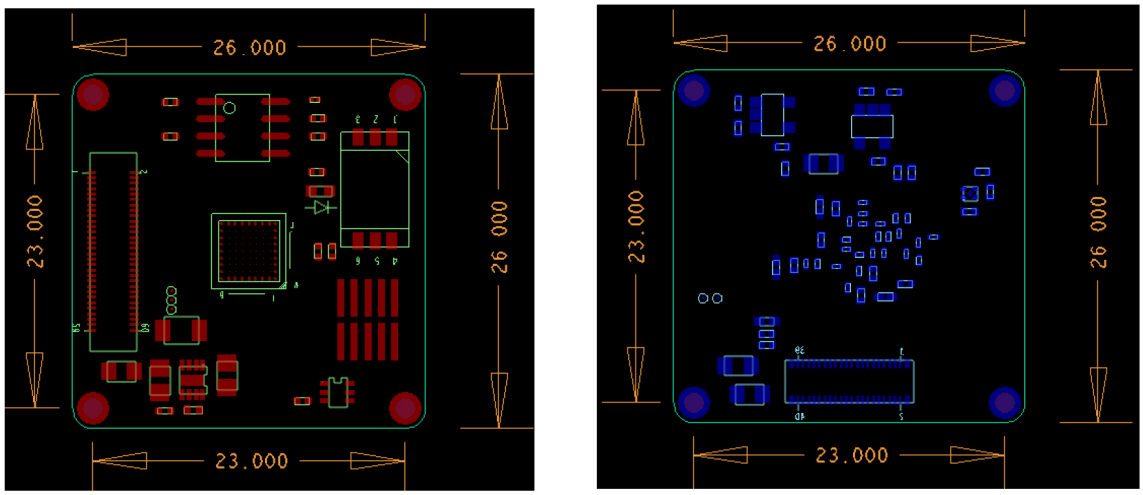

Figure 5. HiSPi−to−MIPI Converter Board (26 mm × 26 mm form factor)

FLEX INTERFACE CABLE BOARD

The FLEX Interface Cable Board is a flexible circuit board designed to provide connectivity between the X−Cube HiSPi−to−MIPI Converter Board and an external Host.

Power and control signals are provided by the Host to the X−Cube via the FLEX board, and MIPI image data is output from the X−Cube to the Host via the FLEX board.

The FLEX board is approximately 5 inches long and consists of two connectors. One connector is compatible with the X−Cube's MIPI output interface, and the other is compatible with **onsemi**s Image Access System (IAS).

An IAS adapter board that is compatible with the X−Cube is available and can be ordered separately. This adapter board enables the interfacing of the X−Cube to **onsemi**'s standard demonstration and development platform. This development platform utilizes the **onsemi** Demo3 Board to interface with a PC, and DevWare, the **onsemi** imager evaluation software. See the Development Tools section for additional details.

Other FLEX interface boards can be created to interface the X−Cube with other imaging system platforms that accept image data in MIPI CSI−2 format.

DEVELOPMENT TOOLS (OPTIONAL)

onsemi offers a number of tools to assist in operating, demonstrating, and evaluating the X−Cube. These tools are optional.

The **onsemi** X−Cube demonstration system is shown in Figure 6. This system consists of the X−Cube connected to the standard **onsemi** Demo3 development platform.

To connect the X−Cube to the Demo3 board, an X−Cube compatible IAS adapter board is used. The X−Cube FLEX interface cable is used to connect the X−Cube to the IAS adapter board, and the IAS adapter board plugs directly into the Demo3 board.

The IAS adapter board serves two functions, to provide power to the X−Cube, and to provide a data and communications interface between the X−Cube and the Demo3 board. MIPI image data and communication and control signals are routed through the IAS adapter board from the Demo3 compatible connector to the X−Cube compatible connector.

In addition, the +5 V power adapter that provides power to the X−Cube plugs into the IAS adapter board. Power is sent from the IAS adapter board to the X−Cube over the FLEX interface cable.

Communication and data transfer between the Demo3 board and the PC is accomplished via a USB3 cable. Utilizing the Demo3 platform enables the use of DevWare, **onsemi**s image display and evaluation software.

The X−Cube compatible IAS Adapter Board and the Demo3 Board are optional and can be ordered separately if desired.

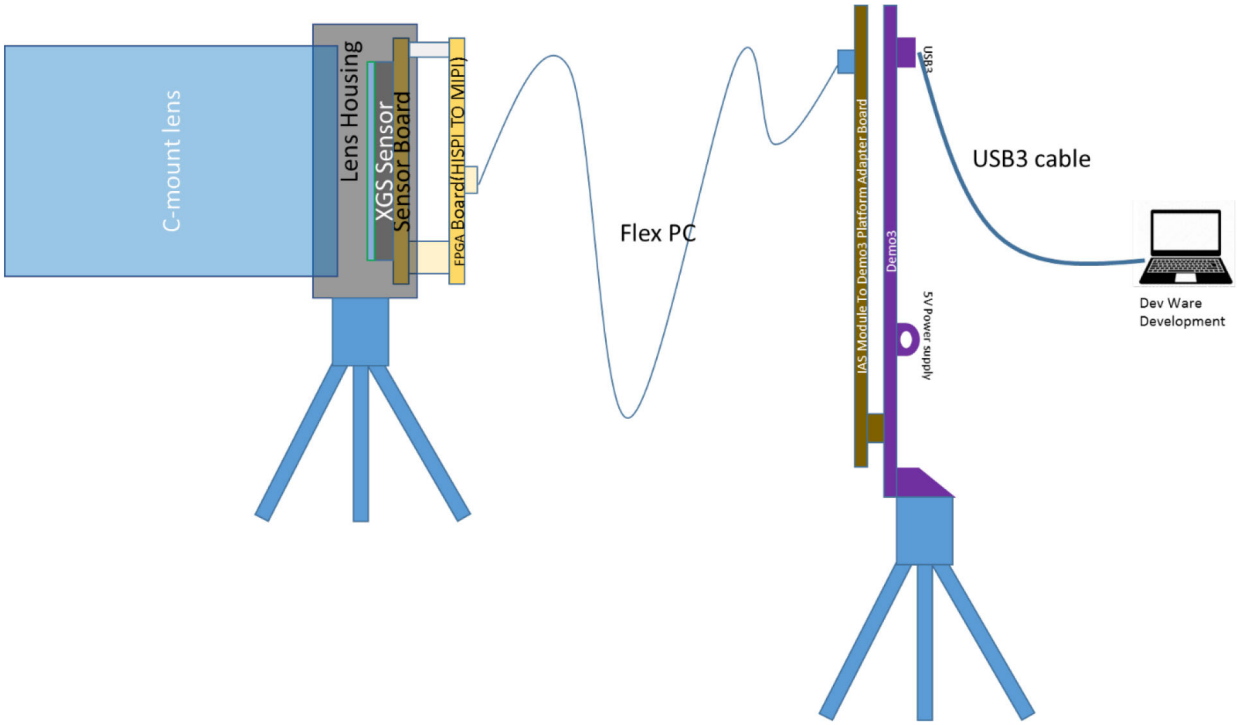

Figure 6. X−Cube Demonstration System

Table 9. ORDERABLE PART NUMBERS

Part Numbers	Product Description
XCUBE−NOIX1SN012KBL−GEVK	X−Cube XGS 12000 Monochrome Module Kit (Kit includes XGS 12000 Monochrome Imager Board, HiSPi−to−MIPI Converter Board, FLEX Interface Board, C−Mount Lens Housing with tripod mount, and a mini tabletop tripod)
XCUBE−NOIX1SE012KBL−GEVK	X−Cube XGS 12000 Color Module Kit (Kit includes XGS 12000 Color Imager Board, HiSPi−to−MIPI Converter Board, FLEX Interface Board, C−Mount Lens Housing with integrated IR−Cut filter and a tripod mount, and a mini tabletop tripod)
XCUBE−NOIX1SN016KBL−GEVK	X−Cube XGS 16000 Mono Module Kit (Kit includes XGS 16000 Monochrome Imager Board, HiSPi−to−MIPI Converter Board, FLEX Interface Board, C−Mount Lens Housing tripod mount, and a mini tabletop tripod)
XCUBE−NOIX1SE016KBL−GEVK	X−Cube XGS 16000 Color Module Kit (Kit includes XGS 16000 Color Imager Board, HiSPi−to−MIPI Converter Board, FLEX Interface Board, C−Mount Lens Housing with integrated IR−Cut filter and a tripod mount, and a mini tabletop tripod)
XCUBE−NOIX4SN5000BL−GEVK	X−Cube XGS 5000 Mono Module Kit (Kit includes XGS 5000 Monochrome Imager Board, HiSPi−to−MIPI Converter Board, FLEX Interface Board, C−Mount Lens Housing with tripod mount, and a mini tabletop tripod)
XCUBE−NOIX4SE5000BL−GEVK	X−Cube XGS 5000 Color Module Kit (Kit includes XGS 5000 Color Imager Board, HiSPi−to−MIPI Converter Board, FLEX Interface Board, C−Mount Lens Housing with integrated IR−Cut filter and a tripod mount, and a mini tabletop tripod)
AGBCBNCS−GEVK	AP21121 X−Cube IAS−Demo3 Adapter Board Kit (Kit includes the Adapter Board and a AC/DC Power Adapter with +5 V DC output)
AGB1N0CS−GEVK	Demo3 Kit (Kit includes Demo3 Board, USB Cable, and a mini tabletop tripod)

REFERENCES

[1] EVBUM2636/D (n.d.) X−Cube XGS 12000 Imager Board User's Manual

[2] EVBUM2635/D (n.d.) X−Cube HiSPi−to−MIPI Converter Board User's Manual

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