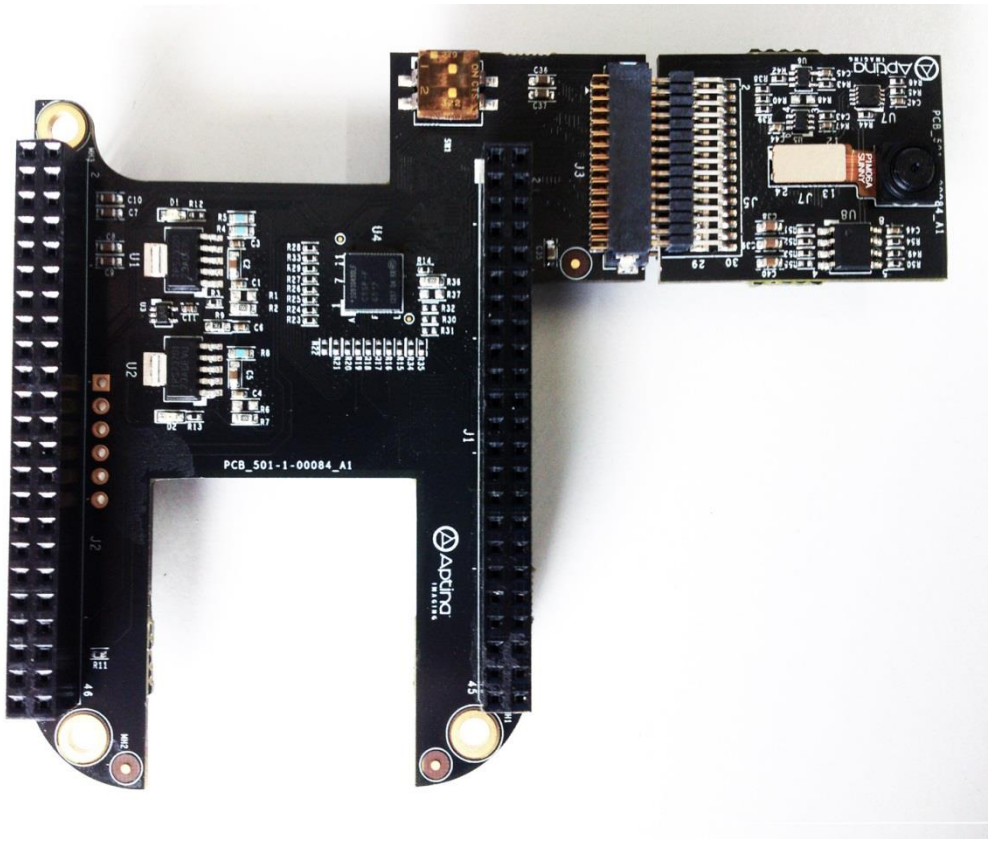
HD Camera Cape

for

BeagleBone Black



System Reference Manual

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ADDRESS FOR CORRESPONDENCE

RadiumBoards is a sister concern of **VVDN Technologies Pvt. Ltd**. (an Embedded Design and Services Company) which offers very flexible and innovative business models.

Corporate Office

B-22, Infocity Sector-34,

Gurgaon-122001, Haryana, India

Tel No: +91 124 4284250

US Office

2025 Gateway Place, Suite 465,

San Jose, California 95110

Tel No: +1 408 807 3951

E-MAIL

info@radiumboards.com

WEBSITE

www.radiumboards.com

Revision History

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INTRODUCTION

This document is the System Reference Manual for the HD Camera Cape for BeagleBone Black.

This document is intended as a guide to assist anyone purchasing or who are considering purchasing the board to understand the overall design and usage of the HD Camera Cape for BeagleBone Black from the system level perspective.

The design is subject to change without notice as we will work to keep improving the design as the product matures.

The key sections in this document are:
Overview: A high level overview of the HD Camera Cape for BeagleBone Black.

Features & specification: Provided here are the features and the electrical specifications of the board.

System Architecture & Design: This section provides information on the overall architecture and design of the HD Camera Cape for BeagleBone Black.
This is a very detailed section that goes into the design of each circuit on the board.

Mechanical: Information is provided here on the dimensions of the HD Camera Cape for BeagleBone Black.

1 HD Camera Cape for BeagleBone Black Overview

1.1 Descriptions

The HD Camera Cape for BeagleBone Black provides a portable camera solution for BeagleBone Black. Each Camera Cape is composed of a Sensor board and an Expansion board. The Sensor board carries a 1.26 megapixel camera sensor and transmits captured image data to the Expansion board over camera interface (CAM I/F). The Expansion board features a CSSP bridge connectivity device, which stores image data received from Sensor board and transfers them to the AM335x through general purpose memory controller (GPMC) interface.

1.2 Package Contents

The final packaged product will contain the following items:

1. HD Camera Cape for BeagleBone Black

2. A Software CD containing:
   - Source Code
   - Drivers
   - Datasheet
   - System Reference Manual

1.3 Getting Started

Note: Video can be viewed through onboard HDMI or via LCD/DVI through separate capability board. If it is used for BeagleBone, it does not have onboard HDMI, so LCD/DVI capability board is must.
System should boot from uSD card instead of onboard eMMC when camera cape board is connected.

The cape is plugged via two 46 pin board to board connectors. To ensure safe plugging, while mounting the HD Camera Cape care should be taken that the switch for EEPROM address and the Ethernet port of BBB are at the same side. The HD Camera Cape board can go in flip way also and that can damage the board if it is powered up. Please refer to the figure given below for the correct placement of the HD Camera Cape board with respect to the BBB Cape Connector.

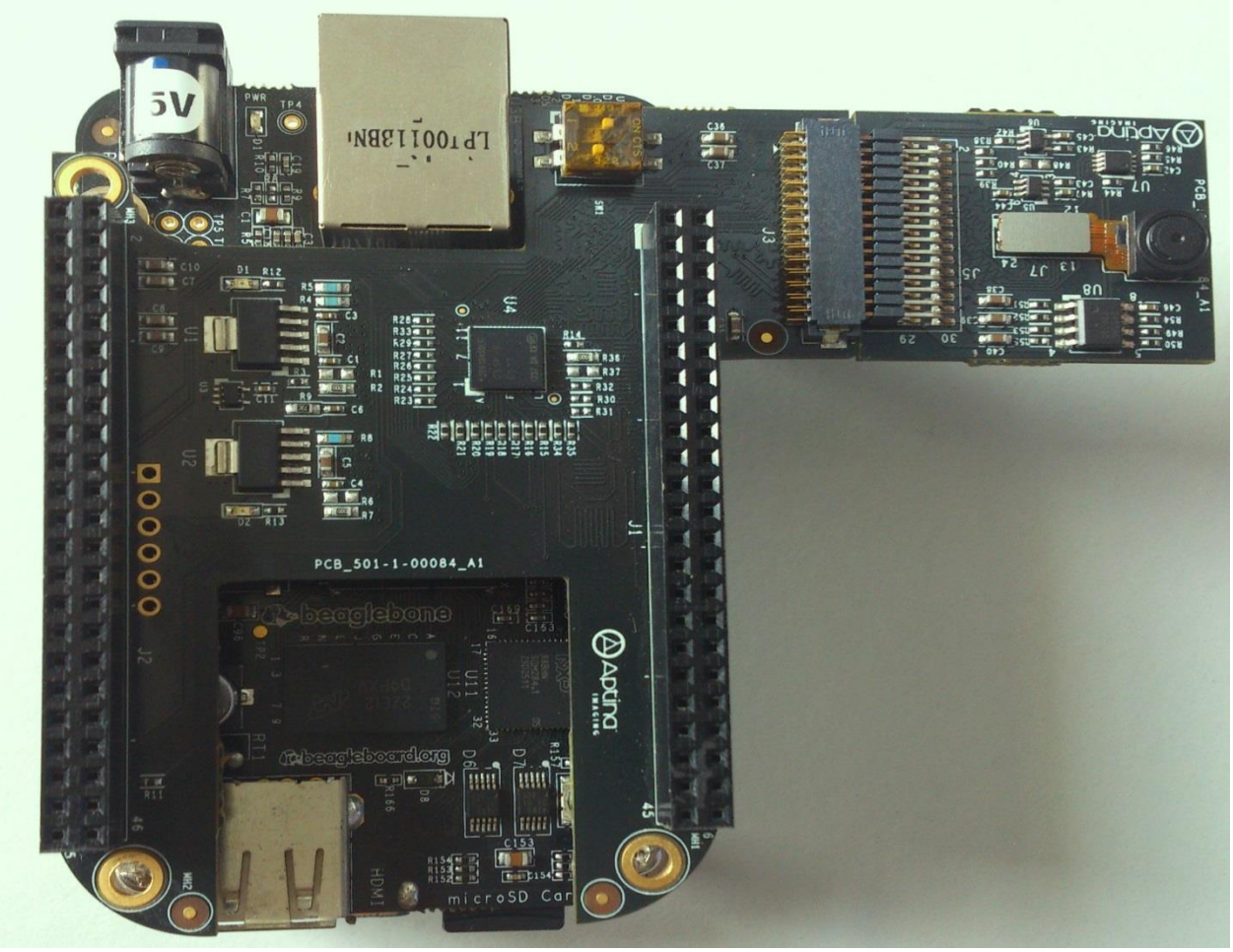

Figure 1: HD Camera Cape mounted to the BBC Cape Connector

1.3.1 With LCD7 Cape

Follow the instructions below to start using the HD Camera Cape for BeagleBone Black (BBB):

1. Ensure the EEPROM addresses on the LCD7 Cape and HD Camera Cape are different.
   Note: The EEPROM address is determined by the 2-bit switches SW1 on both LCD7 and HD Camera capes. Ensure these two switches are configured differently.

2. Mount the HD Camera Cape to the BBB Cape Connector as shown in the Figure given above.

3. Ensure the micro SD card being used with BBB has the latest Image (Latest Armstrong applied with HD camera cape board patch).

4. Power up the BBB by connecting a 5V DC power supply to the DC connector of LCD7 Cape.

5. The BBB is now booting up. This process may take 1 to 2 minutes.
   LEDs D3 and D4 on LCD7 Cape and LEDs D1 and D2 on the Camera Cape should be lit.
   Note: For more information about LCD7 Cape, please visit its wiki page at

http://beagleboardtoys.com/wiki/index.php?title=BeagleBone_LCD7

6. After BBB finishes booting up, you should see a desktop with black background. This is the Angstrom desktop.

7. Go to the system menu bar at the top, select Applications > Sound & Video >Cheese Webcam Booth to open the Cheese application.
   Note: A stylus is recommended to use the Angstrom user interface on LCD7 Cape.

8. A live photo preview should be displayed at the centre of Cheese application window.

9. To capture a photo, click the "Take a Photo" button inside Cheese application window.

1.3.2 With DVI-D Cape

Note: The user will need an external USB mouse for navigating the system menu on the DVI-D supported monitor. Follow the instructions below to start using your HD Camera Cape for BeagleBone Black:

1. Ensure the EEPROM addresses on the DVI-D Cape and HD Camera Cape are different.
   Note: The EEPROM address is determined by the 2-bit switches SW1 on both DVI-D and HD Camera capes. Ensure these two switches are configured differently.

2. Mount the HD Camera Cape for BeagleBone Black and DVI-D Cape on a BBB. The mounting order is not important.

3. Connect a HDMI-to-DVI cable from the HDMI connector of DVI-D Cape to a DVI-D supported monitor.
   Note: For more information about DVI-D Cape, please visit its wiki page at

   http://beagleboardtoys.com/wiki/index.php?title=BeagleBone_DVI-D

4. Connect a USB mouse to the USB host connector P2 of BBB.
   Note: Certain types of USB mouse are not compatible with BeagleBone Angstrom software.

5. Ensure the micro SD card being used with BBB has the latest Image (Latest Armstrong applied with HD camera cape board patch).

6. Power up the BBB by connecting a 5V DC power supply to the DC connector of BBB.

7. The BBB is now booting up. This process may take from 1 to 2 minutes. LEDs D5 and D6 on DVI-D Cape and LEDs D1 and D2 on the Camera Cape should be lit.

8. After BBB finishes booting up, you should see a desktop with black background on the monitor. This is the Angstrom desktop.

9. Go to the system menu bar at the top, select Applications > Sound & Video > Cheese Webcam Booth to open the Cheese application.

10. A live photo preview should be displayed at the centre of Cheese application window.

11. To capture a photo, click the "Take a Photo" button inside Cheese application window.

1.4 Camera Cape Settings

The Camera Cape settings are configured for 720P Resolution video. Cheese player is used in Angstrom to view video. As video framework implementation is done in V4L2, any V4L2 supported player with YUV 4:2:2 input format can capture and display video. The Camera provides the functionalities of resolution control, auto-white balance etc.

2 Features & Specifications

This section covers the specifications of the HD Camera Cape for BeagleBone Black and provides a high level description of the major components and interfaces that make up the board.

Table 1: Specifications of HD Camera Cape for BeagleBone Black

Camera Sensor	1/6-Inch 720p High-Definition Aptina MT9M114
Data Interface	CAM I/F GPMC
Power	3.3V via expansion header
	5V via expansion header
Indicator	Two Power LEDs
Connectors	Two 46-position BeagleBone Black connectors One 6-position BeagleBone connector (optional) Two pairs of 30-position Sensor board connectors One 24-position camera sensor socket

2.1 Key Component Locations

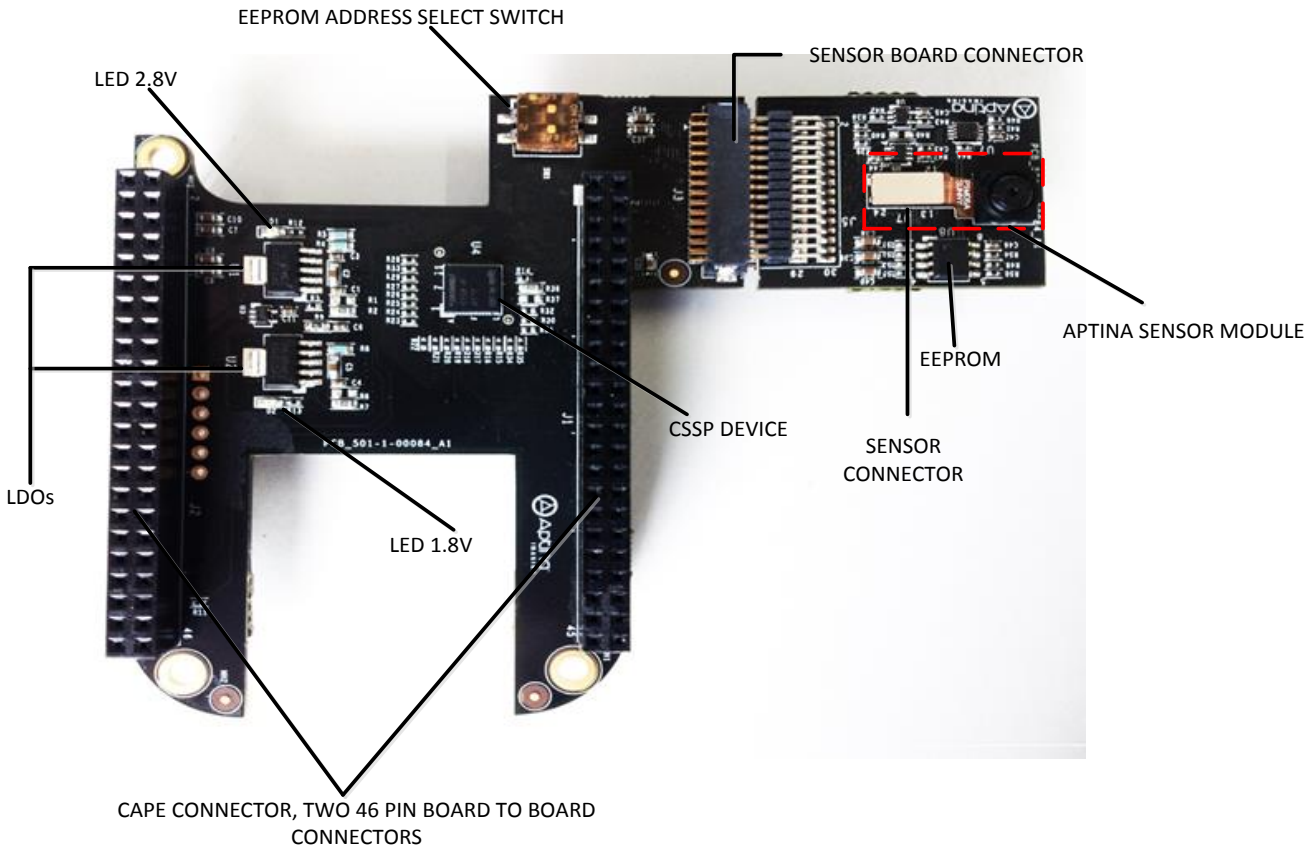

Figure 2: Key Component Locations on the HD Camera Cape for BeagleBone Black

2.2 Expansion Board & Sensor Board

The BeagleBone Black HD Camera Cape is composed of an Expansion board and a Sensor board. The Expansion board provides BBB the capability to connect to a camera sensor via camera interface (CAM I/F). The Expansion board carries QuickLogic CSSP device (part no. CSSP-FPUN86-6494) which receives processed video data from camera sensor and transmits it to BeagleBone Black via GPMC bus. The Expansion board, powered by the BeagleBone Black, also provides different power supplies to the Sensor board. The Expansion board mounts directly to BeagleBone Black via its stackable connectors.

The Sensor board, on the other hand, is mated to Expansion board via two 30-position connectors. The Sensor board also features a 24-position socket to connect to camera sensor. The BeagleBone Black HD Camera Cape uses MT9M114 camera sensor; however, other sensors with the same interface can also be used. The Sensor board also includes an EEPROM to store board information, which is required by BeagleBone Black for cape identification and pin muxing configuration.

2.3 Camera Sensor

The HD Camera Cape for BeagleBone Black uses Aptina camera sensor MT9M114, which is a 1/6-Inch 720p High-Definition (HD) System-On-A-Chip (SOC) Digital Image Sensor. MT9M114 features an integrated image processor to process the acquired image then transmits the processed data to QuickLogic CSSP chip. The data is transmitted in YUV 4:2:2 format (565RGB, 444RGB and Bayer formats also supported).

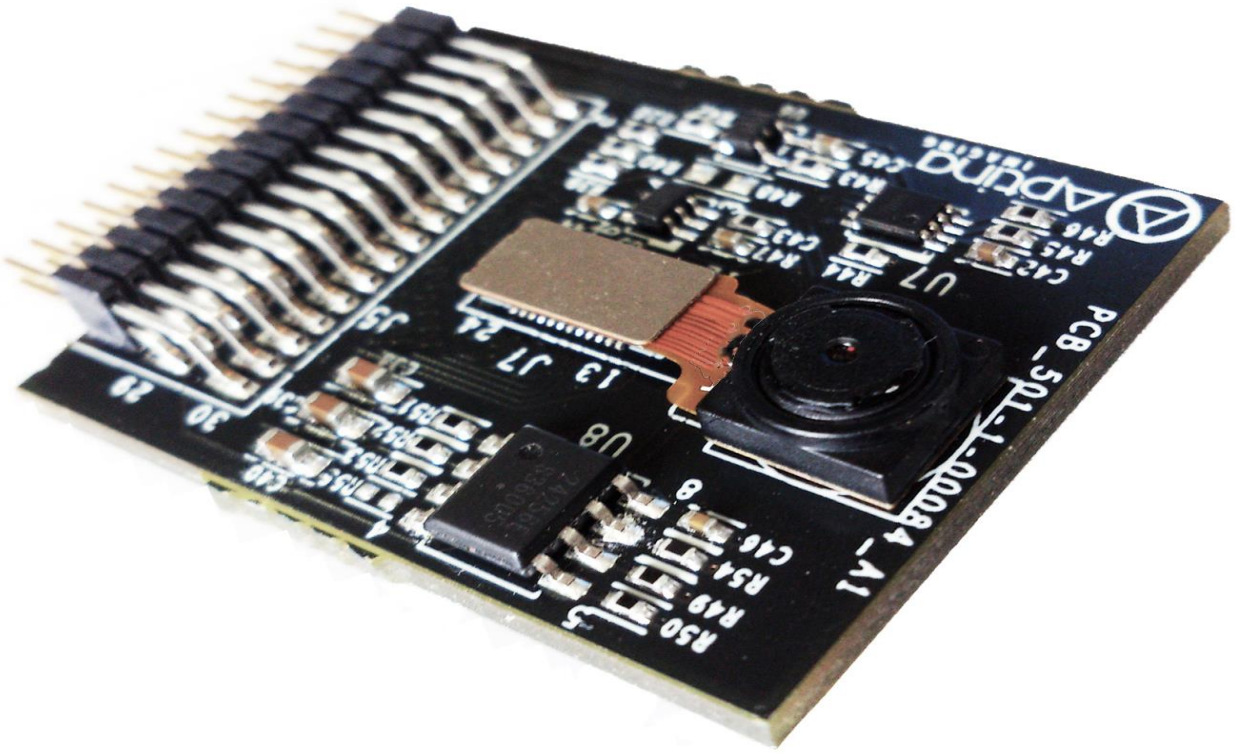

Figure 3: Sensor Board

2.4 CCSP Device

The CSSP bridge connectivity device, an 86-pin thin profile fine pitch ball grid array (TFBGA), is a Customer Specific Standard Product by QuickLogic. This device provides camera interface (CAM I/F) to connect to the 1.26MP camera sensor. The camera image data is received and stored by the CSSP device before being transmitted to the BeagleBone Black over GPMC interface.

2.5 Connectors

There are three stackable connectors on the HD Camera Cape for BeagleBone Black. The 46-position and 6-position connectors will stack on top of the expansion connectors of BeagleBone Black. The 6-position optional connector will stack on top of the JTAG expansion connector (J1) of BeagleBone Black. The HD Camera Cape also uses two pairs of 30-position connector to connect the Expansion board and Sensor board. A 24-position socket is located on the Sensor board for camera sensor connection.

2.6 Power Indicators

The HD Camera Cape for BeagleBone Black features two LEDs to indicate that power rail 1.8V and 2.8V are applied to the cape. These LEDs are green when lit.

2.7 Mechanical specifications

Table 2: Mechanical Specifications of HD Camera Cape for BeagleBone Black

Size:	3.40” x 3.90”
Layers:	4
PCB thickness:	.062”
RoHS Compliant:	Yes

2.8 Electrical Specifications

Table 3: Electrical Specifications of HD Camera Cape for BeagleBone Black

Specification	Min	Type	Max	Unit
Power				
Input Voltage DC		3.3		V
		5.0		V
Environmental				
Temperature range	0		+85	C

2.9 Software/Hardware Interface/Ports

Software Interface: SW interface is via Linux-V4L2 layer. Cape board driver is compactable to V4l2.

Hardware Ports: BeagleBone expansion connector extender for other capes.

2.10 Compatible media

Cape board can be connected with any GPCM/Local Bus supported CPUs. Video comes in YUV 4:2:2 format from Cape board.

3 System Architecture & Design

This section provides a high level description of the design of the HD Camera Cape for BeagleBone Black and its overall architecture.

3.1 System Block Diagram

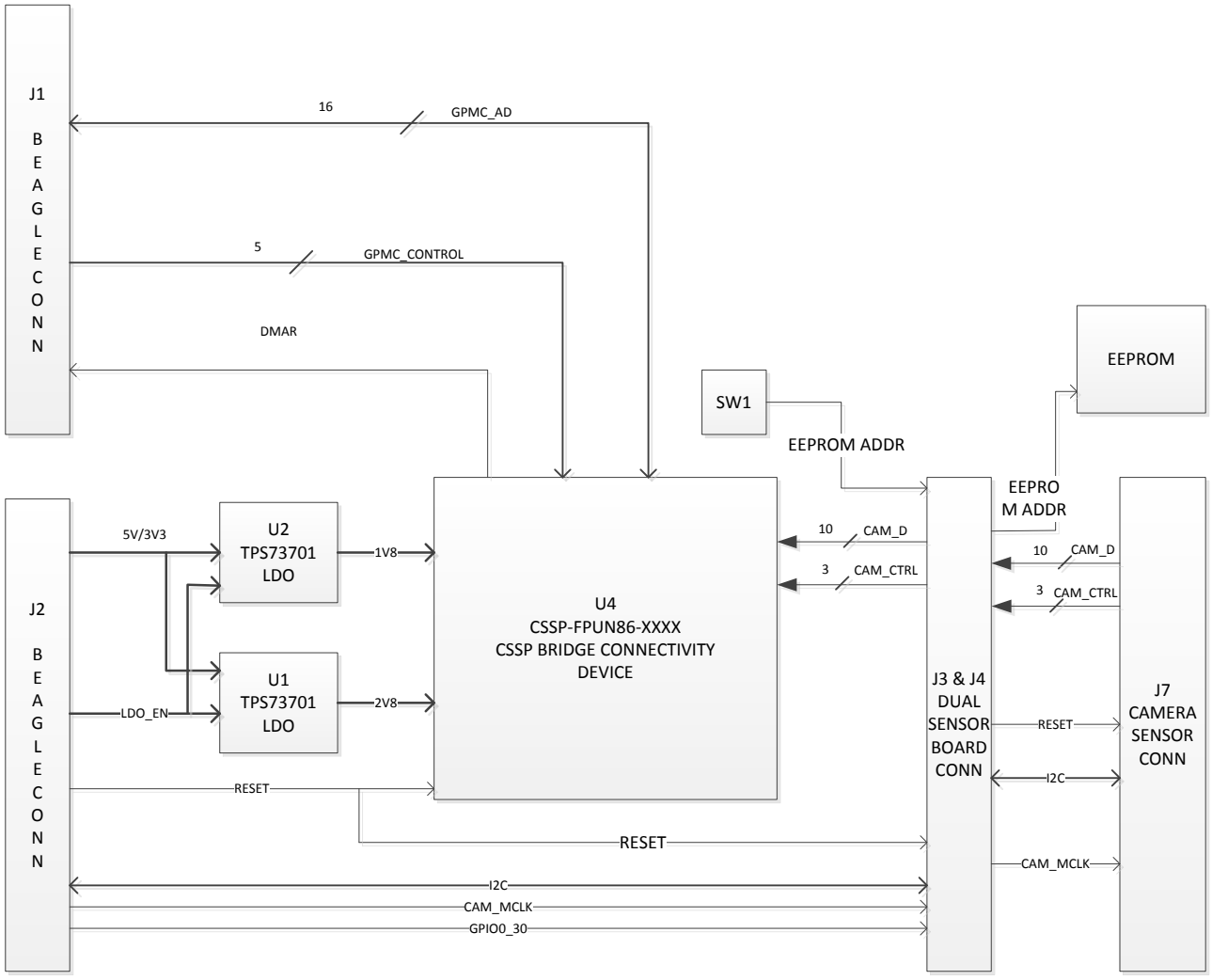

Figure 4: High Level Block Diagram of HD Camera Cape for BeagleBone Black

3.2 Camera Sensor

The 1.26megapixel on the HD Camera Cape for BeagleBone Black is an Aptina CMOS digital image sensor, MT9M114, which integrates on-chip camera function and is programmable through serial interface. MT9M114 is capable of being a stand-alone camera solution that includes both image acquisition and processing. Following are some feature highlights of MT9M114 camera sensor:

- 720p HD video at 30 fps
- Active-pixel array of 1296H x 976V
- Superior low-light performance

- Ultra-low-power
- Electronic rolling shutter (ERS), progressive scan
- Automatic image correction and enhancement
- Adaptive Polynomial lens shading correction

The MT9M114 receives its master clock (CAM_MCLK) and an active-low hard reset signal (CAM_RESET) directly from the BeagleBone Black. This clock signal is used as a reference to generate the pixel clock (CAM_PCLK) for parallel output data bus to CSSP device. Internal registers and variables can be programmed via MT9M114 two-wire interface (I2C2_SCL and I2C2_SDA).

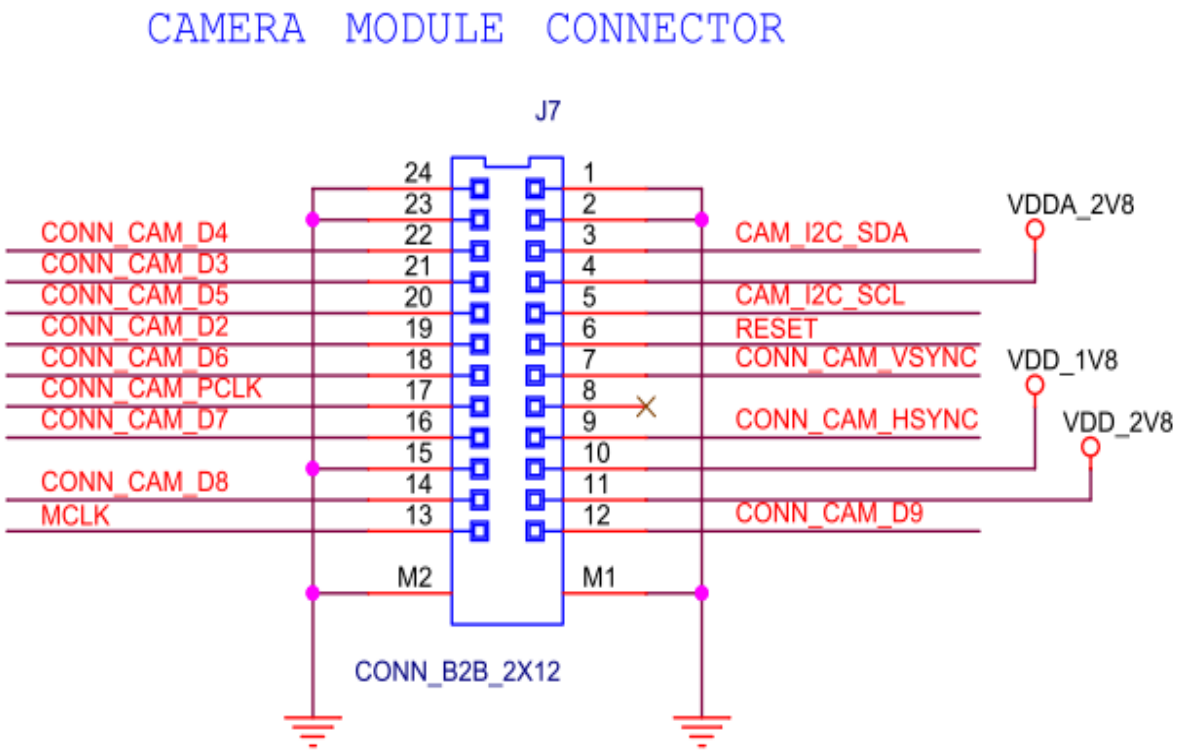

Figure 5: Camera Module Connector of HD Camera Cape for BeagleBone Black

3.3 Camera Interface (CAM I/F)

The CSSP device uses CAM I/F to connect to Aptina camera sensor chip.This interface supports transmitting camera data in YUV format up to 30 fps. After CAM_HSYNC and CAM_VSYNC signals have been asserted, 8-bit camera output data is transmitted from the camera sensor to a 512-word FIFO of CSSP device. This transmission is clocked by the camera sensor output pixel clock signal (CAM_PCLK). All signals are at 2.8V voltage level.

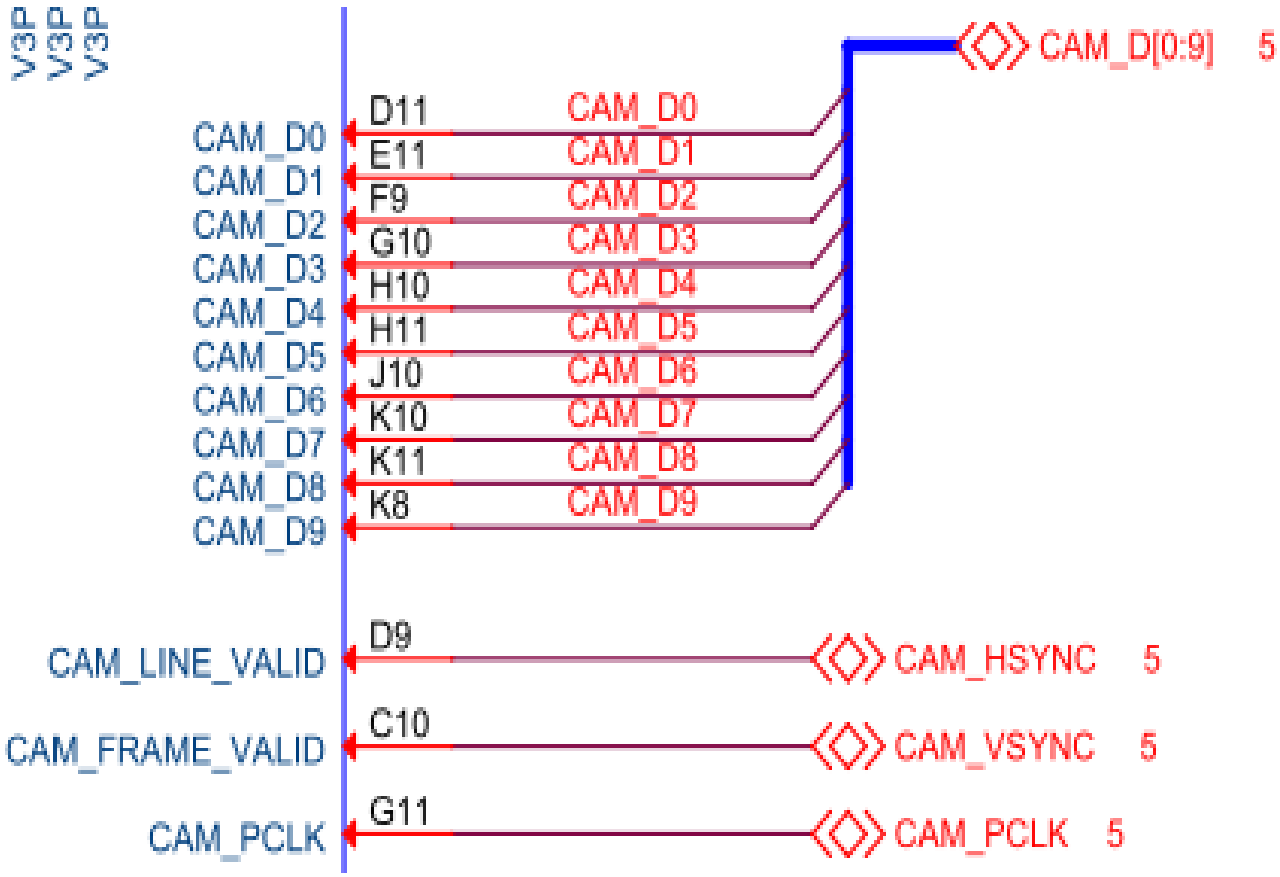

Figure 6: Camera Interface on the CSSP Device

3.4 General Purpose Memory Controller Interface

The GPMC is a 16-bit external memory controller, which is used for communication between standard memories and a wide range of external devices. The connection between the GPMC and CSSP devices is a 16-bit synchronous address/data-multiplexed. After the CSSP FIFO is filled with 128 words of camera data, the CSSP device will assert the DMA request signal (DMAR) to start transferring data to the BeagleBone Black AM335x. The data is transferred from the FIFO as 16-bit, which consists of YUV 4:2:2 data. The transfer is clocked by a 48MHz GPMC clock signal (GPMC_CLK) provided by the AM335x.

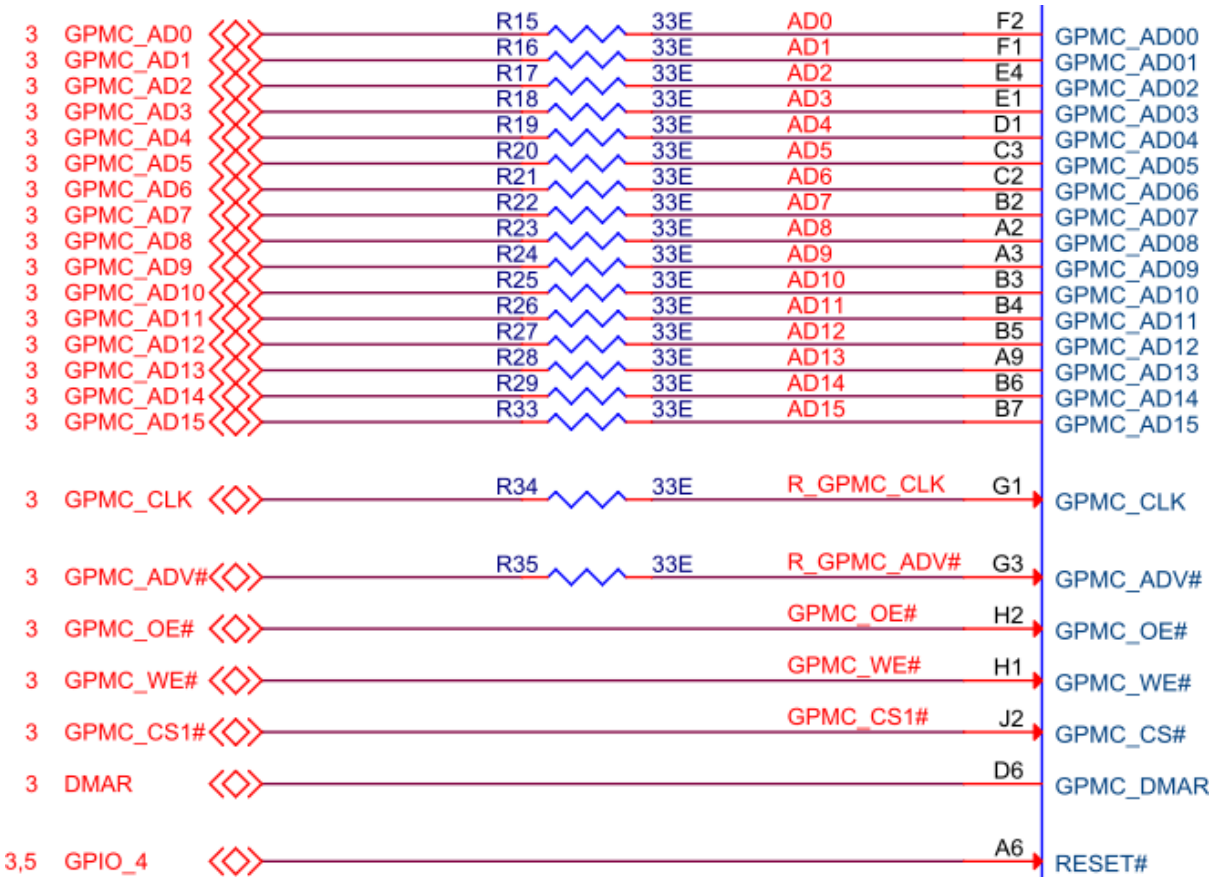

Figure 7: General Purpose Memory Controller Interface

3.5 Power Supply

The HD Camera Cape for BeagleBone Black generates 1.8V and 2.8V power supplies for I/O signals of CSSP device as well as the camera sensor. Two low-dropout (LDO) voltage regulators TPS73701 are used to regulate VCC_1V8 and VCC_2V8 power rails. The LDO's are on when their enable pins are pulled high and go to shutdown mode when the enable inputs are low. These enable pins are controlled by a GPIO signal, GPIO0_5, which can be accessed at pin 17 of J2 connector.

3.6 Voltage Translator

Voltage translations are required on the Sensor board to bring the signals from BeagleBone Black down to the voltage level of camera sensor. These signals include the I2C2 bus, CAM_RST, and CAM_MCLK.

3.7 EEPROM

The HD Camera Cape for BeagleBone Black has an EEPROM containing information that will allow the SW to identify the board and to configure the expansion headers pins as needed. EEPROMs are required for all Capes sold in order for them to operate correctly when plugged in the BeagleBone Black.

The EEPROM used on this cape is the same one as is used on the BeagleBone Black, a CAT24C256. The CAT24C256 is a 256 kb Serial CMOS EEPROM, internally organized as 32,768 words of 8 bits each. It features a 64-byte page write buffer and supports the Standard (100 kHz), Fast (400 kHz) and Fast-Plus (1 MHz) I2C protocol.

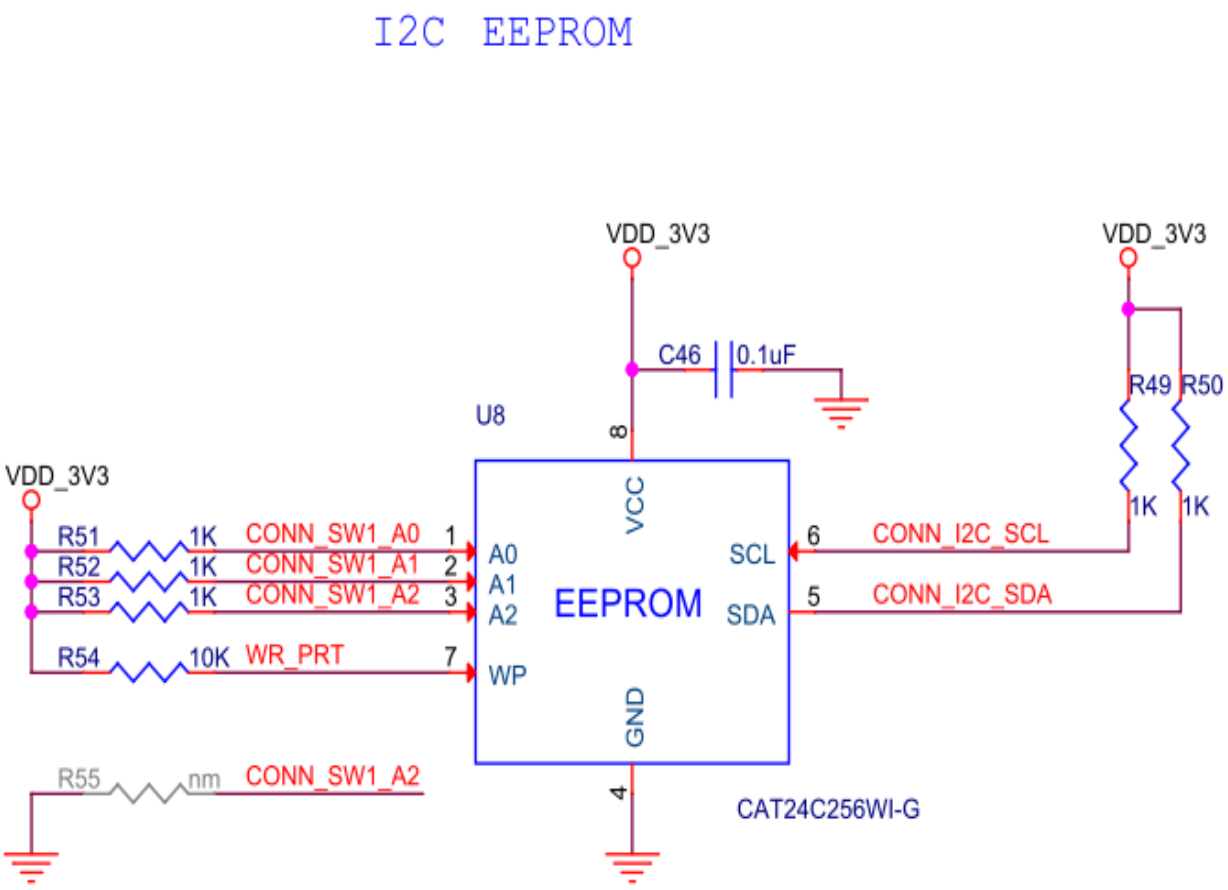

Figure 8: Design of EEPROM Circuit

3.7.1 EEPROM Address

In order for each Cape to have a unique address, a board ID scheme is used that sets the address to be different depending on the order in which it is stacked onto the main board. A two position dipswitch or jumpers is used to set the address pins of the EEPROM. It is the responsibility of user to set the proper address for each board. Address line A2 is always tied high. This sets the allowable address range for the expansion cards to 0x54 to 0x57.All other I2C addresses can be used by the user in the design of their Capes. But, these addresses must not be used other than for the board EEPROM information. On the HD Camera Cape for BeagleBone Black, the EEPROM address switch is located on the Expansion board, whereas the EEPROM IC is on the Sensor board.

3.7.2 I2C Bus

The EEPROMs on each expansion board is connected to I2C2. For this reason I2C2 must always be left connected and should not be changed by SW to remove it from the expansion header pin mux. The I2C signals require pull-up resistors.

4 Mechanical Information

This section provides information on the mechanical aspect of the HD Camera Cape for BeagleBone Black .

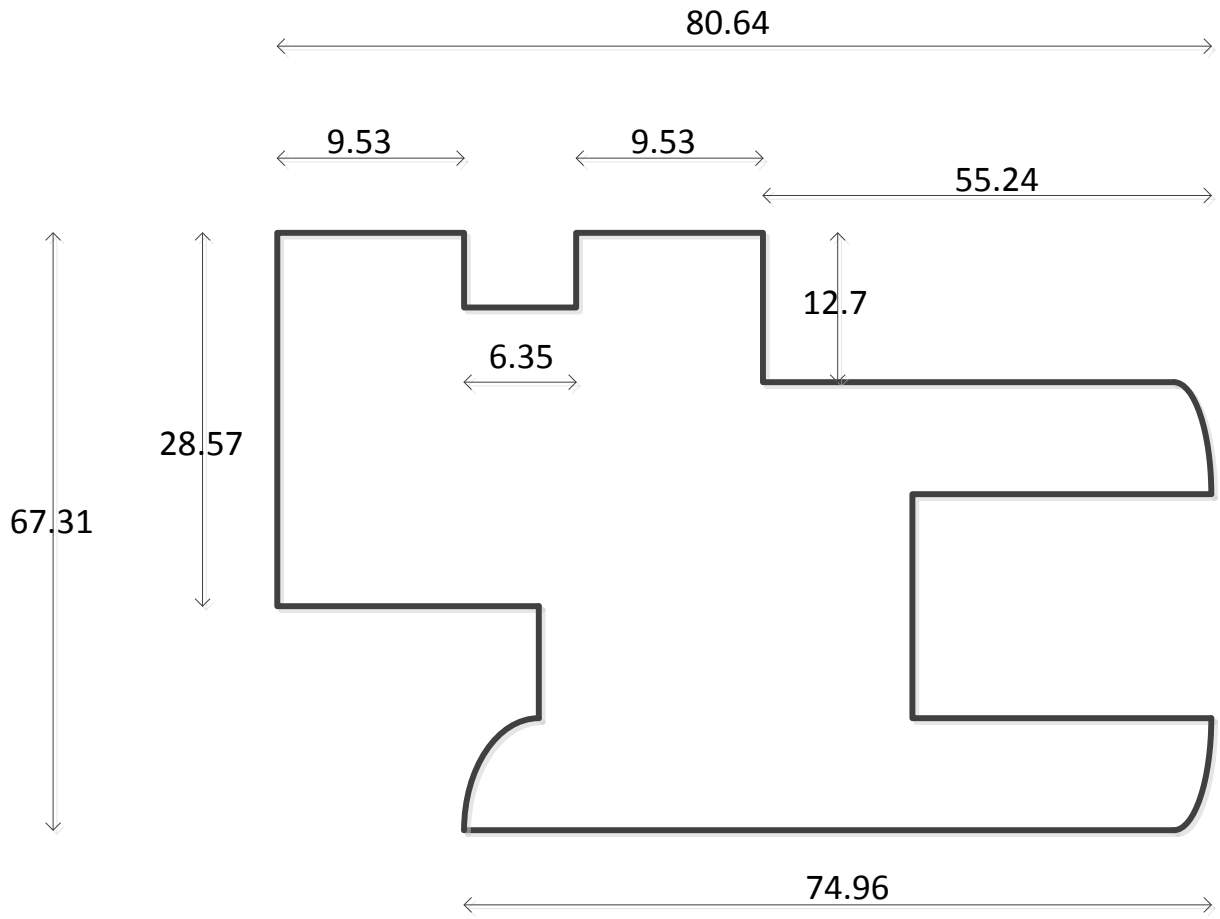

Figure 9: Detailed Dimensions of HD Camera Cape for BeagleBone Black

5 Design Materials

The Design materials provided are:

1. Source Code
2. Schematic and PCB Layout source files (in Orcad/Allegro 16.6 format)
3. BOM File
4. Fabrication file
5. Assembly file
6. System Reference Manual (This document)
7. Brochure