BeagleBone 3.1MP Camera Cape

System Reference Manual

Revision A2
October 12th, 2012

THIS DOCUMENT

For any questions, concerns, or issues submit them to support@beagleboardtoys.com

BEAGLEBONE 3.1MP CAMERA CAPE DESIGN

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1.0 Introduction

This document is the System Reference Manual for the BeagleBone 3.1MP Camera Cape, an add-on board for the BeagleBone.

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 BeagleBone 3.1MP Camera Cape 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:

Section 2.0 – Change History
Provides tracking for the changes made to the System Reference Manual.

Section 3.0 – Overview
This is a high level overview of the BeagleBone 3.1MP Camera Cape.

Section 4.0 – Features and Specification
Provided here are the features and electrical specifications of the board.

Section 5.0 – System Architecture and Design
This section provides information on the overall architecture and design of the BeagleBone 3.1MP Camera Cape. This is a very detailed section that goes into the design of each circuit on the board.

Section 6.0 – Mechanical
Information is provided here on the dimensions of the BeagleBone 3.1MP Camera Cape.

Section 7.0 – Design Materials
This section provides information on where to get the design files.

2.0 Change History

2.1 Change History

Table 1 tracks the changes made for each revision of this document.

Table 1. Change History

Rev	Changes	Date	By
A1	Initial release.	08/06/2012	BBT
A2	A1 vs. A2 (section 2.2)	10/20/2012	BBT

2.2 A1 vs. A2

The only change made in revision A2 is the QuickLogic chip CSSP-FPUN86-6494 has been updated to a newer version to improve the support for the camera sensor. No changes are made in the schematic, board files, or bill of materials.

3.0 BeagleBone 3.1MP Camera Cape Overview

3.1 Descriptions

The BeagleBone 3.1MP Camera Cape provides a portable camera solution for BeagleBone. Each Camera Cape is composed of a Sensor board and an Expansion board. The Sensor board carries a 3.1 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 using general purpose memory controller (GPMC) interface.

Note: BeagleBone 3.1MP Camera Cape should be used with LCD7 Cape or DVI-D Cape for previewing and capturing photos.

Figure 1 below is a picture of the board.

Figure 1. The BeagleBone 3.1MP Camera Cape

3.2 In The Box

The final packaged BeagleBone 3.1MP Camera Cape product will contain the following items:

- 1 BeagleBone 3.1MP Camera Cape

3.3 Getting Started

Note: BeagleBone 3.1MP Camera Cape should be used with LCD7 Cape or DVI-D Cape for previewing and capturing photos.

3.3.1 With LCD7 Cape

Following the instructions below to start using your BeagleBone 3.1MP Camera Cape:

1) Ensure the EEPROM addresses on the LCD7 Cape and 3.1MP Camera Cape are different.
   Note: The EEPROM address is determined by the 2-bit switches SW1 on both LCD7 and 3.1MP Camera capes. Ensure these two switches are configured differently.
2) Mount the BeagleBone 3.1MP Camera to the connectors labeled "Cape Installed Here". Ensure BeagleBone is mounted to the other connectors.
3) Ensure the micro SD card using with BeagleBone has latest Angstrom image.
4) Power up the BeagleBone by connecting a 5V DC power supply to the DC connector of LCD7 Cape.
5) The BeagleBone is now booting up. This process may take from 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 BeagleBone 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 center of Cheese application window.
9) To capture a photo, click the "Take a Photo" button inside Cheese application window.

3.3.2 With DVI-D Cape

Note: you will need an external USB mouse for navigating the system menu on the DVI-D supported monitor.

Following the instructions below to start using your BeagleBone 3.1MP Camera Cape:

1) Ensure the EEPROM addresses on the DVI-D Cape and 3.1MP Camera Cape are different.
   Note: The EEPROM address is determined by the 2-bit switches SW1 on both DVI-D and 3.1MP Camera capes. Ensure these two switches are configured differently.
2) Mount the BeagleBone 3.1MP Camera Cape and DVI-D Cape on a BeagleBone. 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 BeagleBone.
   Note: Certain USB mice are not compatible with BeagleBone Angstrom software.
5) Ensure the micro SD card using with BeagleBone has latest Angstrom image.
6) Power up the BeagleBone by connecting a 5V DC power supply to the DC connector of BeagleBone.
7) The BeagleBone 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 BeagleBone 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 center of Cheese application window.
11) To capture a photo, click the “Take a Photo” button inside Cheese application window.

3.4 Repairs

If you feel the board is in need of repair, follow the RMA Request process found at http://www.beagleboardtoys.com/support/rma

Do not send the board in for repair until an RMA authorization has been provided.

Do not return the board to the distributor unless you want to get a refund. You must get authorization from the distributor before returning the board.

4.0 Features and Specifications

This section covers the specifications of the BeagleBone 3.1MP Camera Cape and provides a high level description of the major components and interfaces that make up the board.

Table 2 provides a list of the BeagleBone 3.1MP Camera Cape's features.

Table 2. BeagleBone 3.1MP Camera Cape Features

Camera Sensor	1/4 inch 3.1 megapixel Aptina MT9T111
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 connectors
	One 10-position BeagleBone connector
	Two pairs of 30-position Sensor board connectors
	One 28-position camera sensor socket

4.1 Key Component Locations

Figure 2 shows the location of the key components on the board.

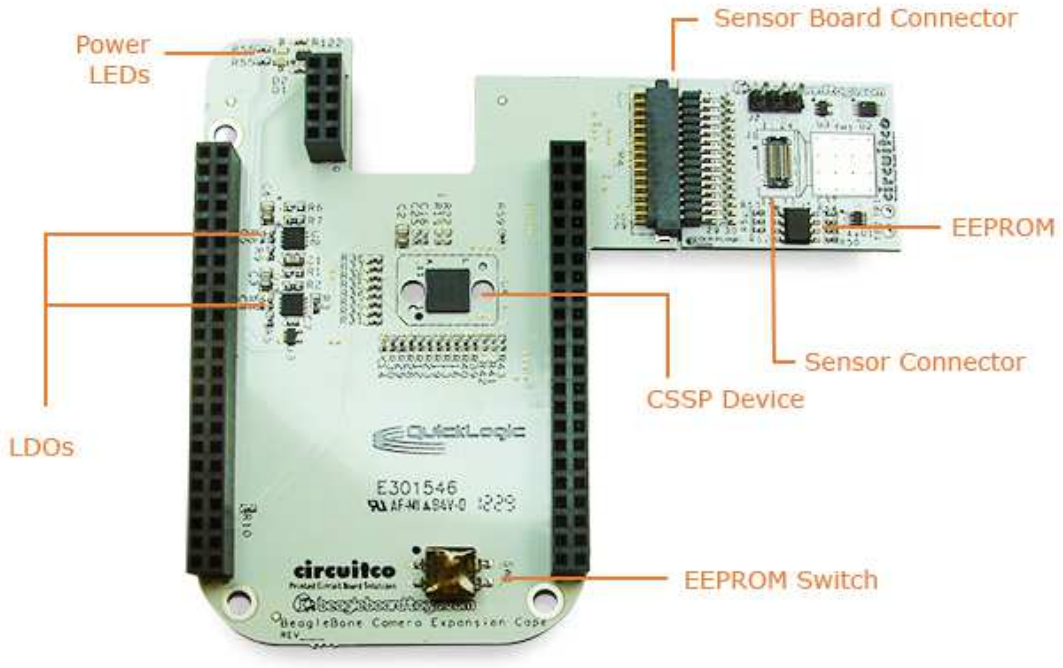

Figure 2. Key Components

4.2 Expansion Board and Sensor Board

The BeagleBone 3.1MP Camera Cape is composed of an Expansion board and a Sensor board. The Expansion board provides BeagleBone the capability to connect to a camera sensor via camera interface (CAM I/F). The Expansion board carries QuickLogic CSSP device which receives processed camera data from camera sensor and transmits these data to BeagleBone via GPMC bus. The Expansion board, powered by the BeagleBone, also provides different power supplies to the CSSP device as well as the Sensor board. The Expansion board mounts directly to BeagleBone 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 28-position socket to connect to camera sensor. The BeagleBone 3.1MP Camera Cape uses MT9T111 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 for cape identification and pin muxing configuration.

4.3 Camera Sensor

The BeagleBone 3.1MP Camera Cape uses Aptina camera sensor MT9T111, which is a 1/4 inch 3.1 megapixel system-on-a-chip (SOC) image sensor. MT9T111 features an integrated image processor to process the acquired image then transmits the processed data to QuickLogic CSSP chip. The data is transmitted in RAW 10-bit Bayer format.

4.4 CSSP 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 3.1MP camera sensor. The camera image data is received and stored by the CSSP device before being transmitted to the BeagleBone over GPMC interface.

4.5 Connectors

There are three stackable connectors on the BeagleBone 3.1MP Camera Cape. The 46-position and 20-position connectors will stack on top of the expansion connectors of BeagleBone. The 10-position connector will stack on top of the backlight expansion connector of BeagleBone.

The 3.1MP Camera Cape also uses two pairs of 30-position connector to connect the Expansion board and Sensor board. A 28-position socket is located on the Sensor board for camera sensor connection.

4.6 Power Indicator

The BeagleBone 3.1MP Camera Cape features two LEDs to indicate that power rail 1.8V and 2.8V are applied to the cape. These LEDs are green when lit.

4.7 Mechanical Specifications

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

4.8 Electrical Specifications

Table 3 is the electrical specification of the external interfaces to the BeagleBone 3.1MP Camera panel.

Table 3. BeagleBone 3.1MP Camera Electrical Specifications

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

5.0 System Architecture and Design

This section provides a high level description of the design of the BeagleBone 3.1MP Camera Cape and its overall architecture.

5.1 System Block Diagram

Figure 3 is the high level block diagram of the BeagleBone 3.1MP Camera Cape.

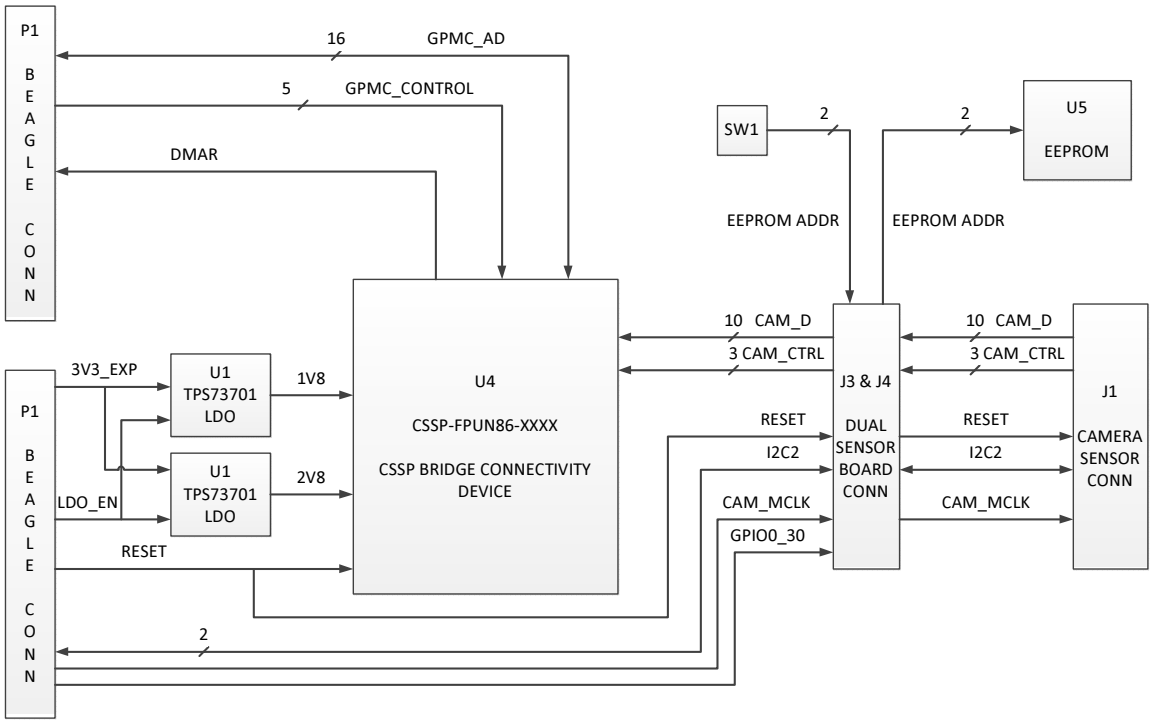

Figure 3. BeagleBone 3.1MP Camera Cape High Level Block Diagram

5.2 3.1MP Camera Sensor

The 3.1 megapixel on the BeagleBone 3.1MP Camera Cape is an Aptina CMOS digital image sensor, MT9T111, which integrates on-chip camera function and is programmable through serial interface. MT9T111 is capable to be a stand-alone camera solution that includes both image acquisition and processing. Followings are some feature highlights of MT9T111 camera sensor:

- 1024 x 768 YUV output with maximum frame rate of 30 frames per second (fps)
- 2048 x 1536 JPEG output with maximum frame rate of 15 fps
- Anti-shake and auto focus
- Hard standby with or without memory retention
- Soft standby with memory retention

The MT9T111 receives its master clock (CAM_MCLK) and an active-low hard reset signal (CAM_RESET) directly from the BeagleBone. This clock signal is used as a reference to generate the pixel clock (CAM_PCLK) for parallel output data bus to CSSP device. In RAW 10-bit Bayer format, the Dout[7:0] signals represents the highest significant output data bits CAM_D[9:2] while the lowest two are output on GPIO[1:0] signals. Internal registers and variables can be programmed via MT9T111 two-wire interface (I2C2_SCL and I2C2_SDA).

Figure 4 shows camera sensor connector J1 on the Camera Sensor board.

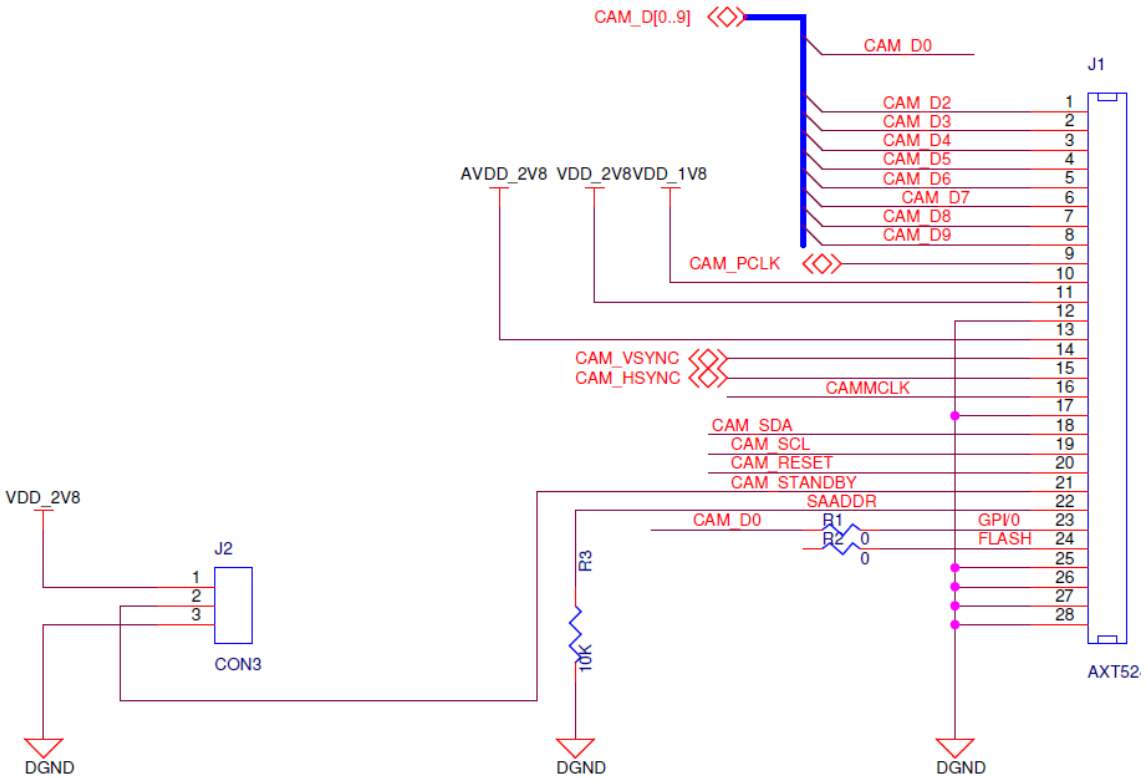

Figure 4. Camera sensor connector

5.3 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 RAW 10-bit Bayer pattern format up to 12 fps. After CAM_HSYNC and CAM_VSYNC signals have been asserted, 10-bit camera output data is transmitted from the camera sensor and 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 5 below shows the camera interface on the CSSP device.

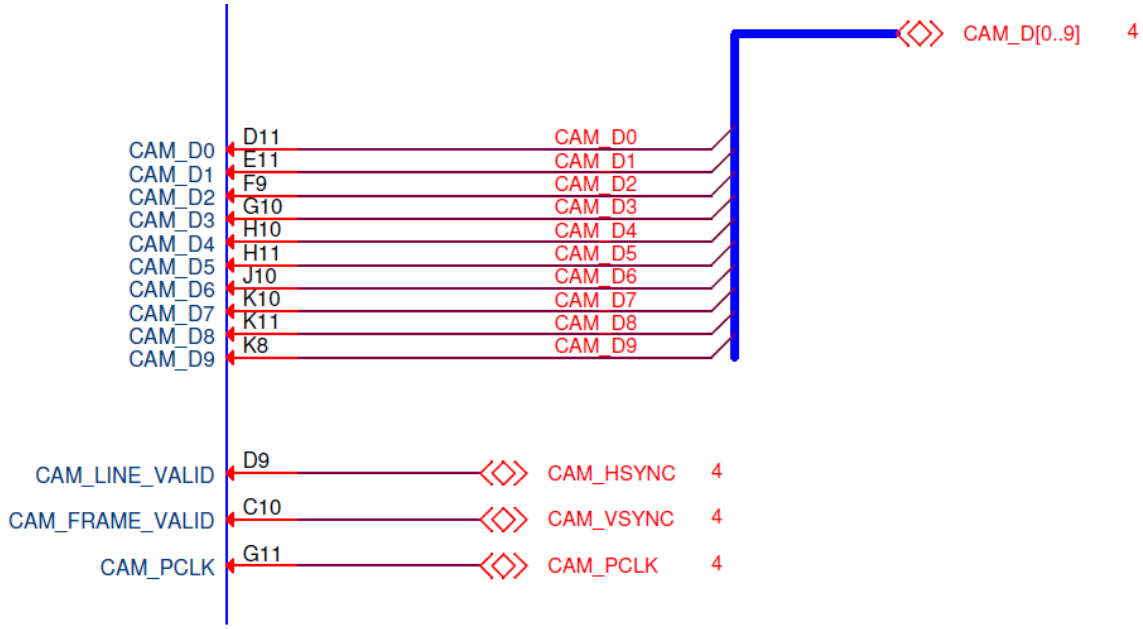

Figure 5. Camera interface

5.4 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 AM335x. The data is transferred from the FIFO as 16-bit, which consists of RAW 10-bit Bayer data as lower 10-bit and zeros as the upper 6 bits. The transfer is clocked by a 48MHz GPMC clock signal (GPMC_CLK) provided by the AM335x.
Figure 6 shows the GPMC interface on CSSP device.

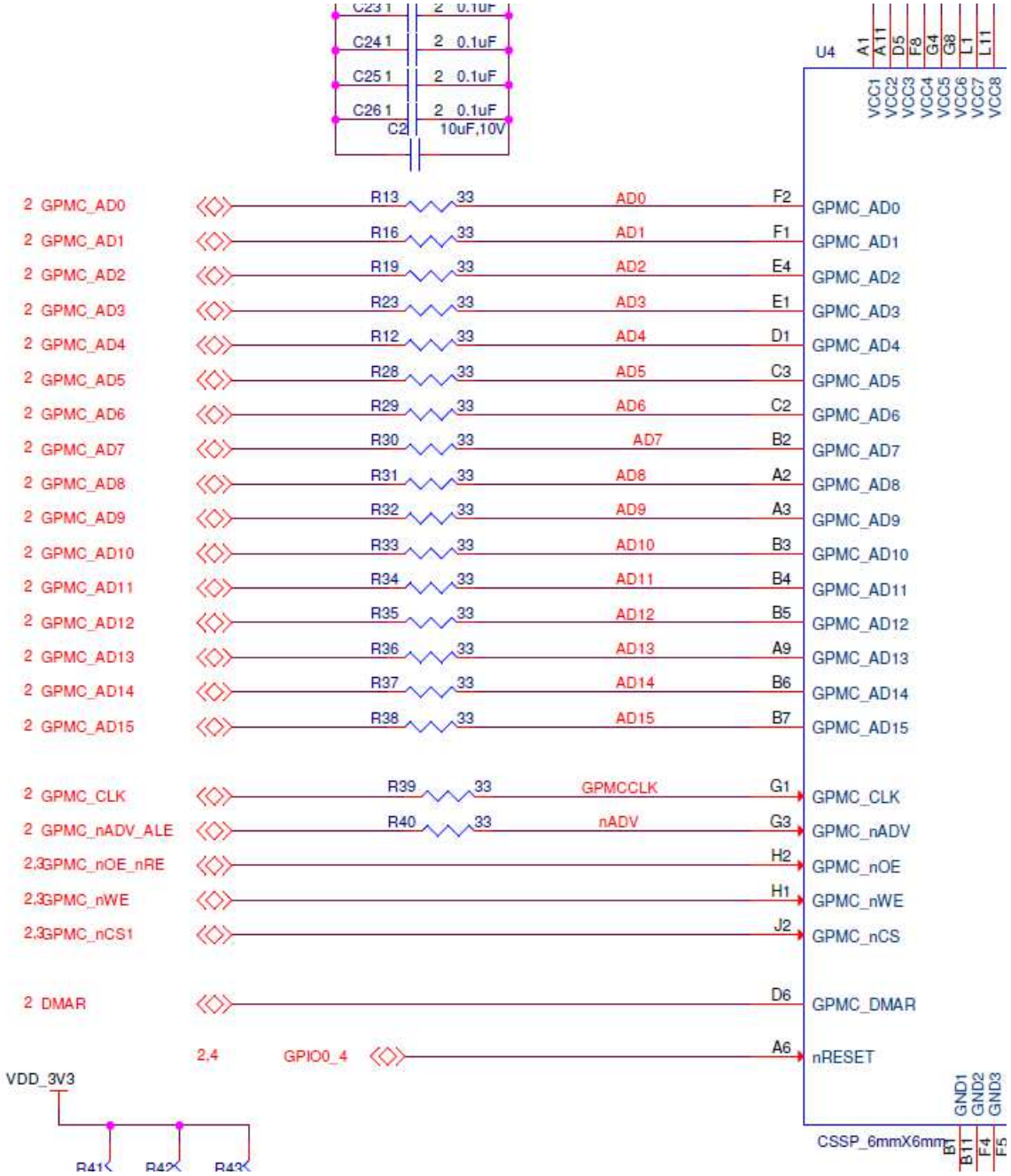

Figure 6. GPMC interface on CSSP device

5.5 Power Supply

The BeagleBone Camera Cape 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 VDD_1V8 and VDD_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 P2 connector.

5.6 Voltage Translator

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

5.7 EEPROM

The BeagleBone 3.1MP Camera Cape 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.

The EEPROM used on this cape is the same one as is used on the BeagleBone, 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 7** is the design of the EEPROM circuit.

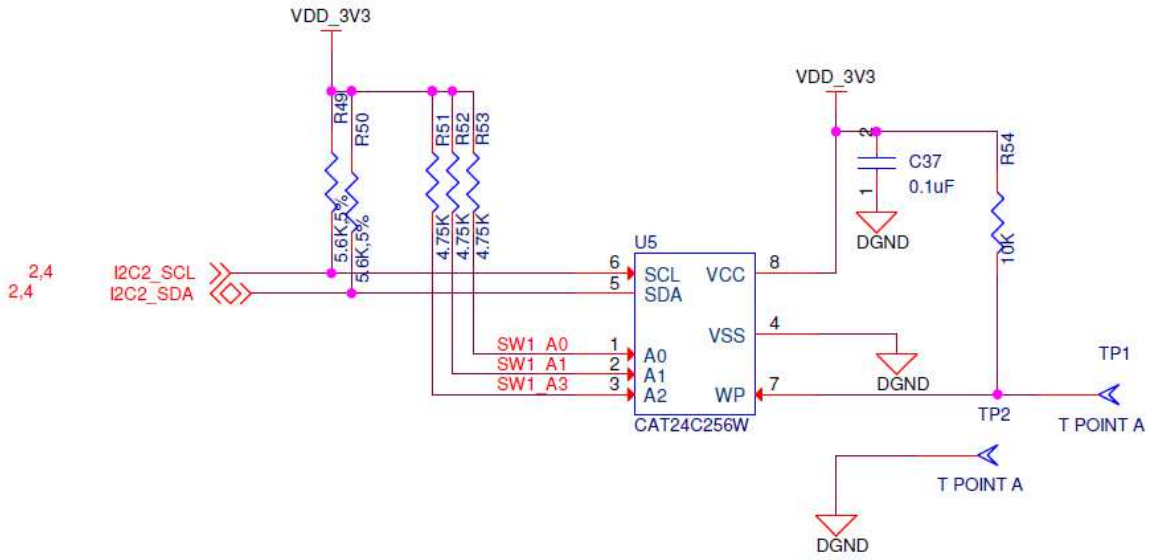

Figure 7. BeagleBone 3.1MP Camera Cape EEPROM

5.7.1 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 BeagleBone 3.1MP Camera Cape, the EEPROM address switch is located on the Expansion board, whereas the EEPROM IC is on the Sensor board.

5.7.2 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. Each board must have a 5.6K resistor on these signals. With four resistors this will be an affective resistance of 1.4K if all Capes were installed.

6.0 Mechanical Information

This section provides information on the mechanical aspect of the BeagleBone 3.1MP Camera Cape.

Figure 8 is the dimensions of the BeagleBone 3.1MP Camera Cape.

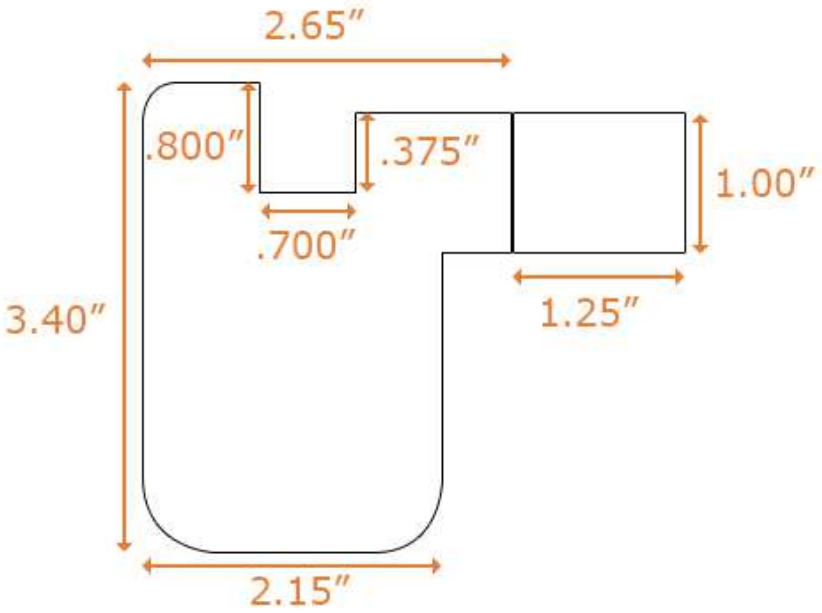

Figure 8. BeagleBone 3.1MP Camera Cape Dimensions Drawing

7.0 Design Materials

Design information can be found at BeagleBoardToys wiki:
http://beagleboardtoys.com/wiki/index.php?title=BeagleBone_3.1MP_Camera

Provided there is:

- Schematic in PDF
- Schematic in OrCAD
- Manufacturing files
  - PCB Gerber
  - PCB Layout (Allegro)
- Bill of Materials
- System Reference Manual (This document)

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