This document explains the function of the Camera Payload, its schematic level design, its board level design, and its functional testing

Camera Payload

Camera Payload Design

Revision: 1.1.1

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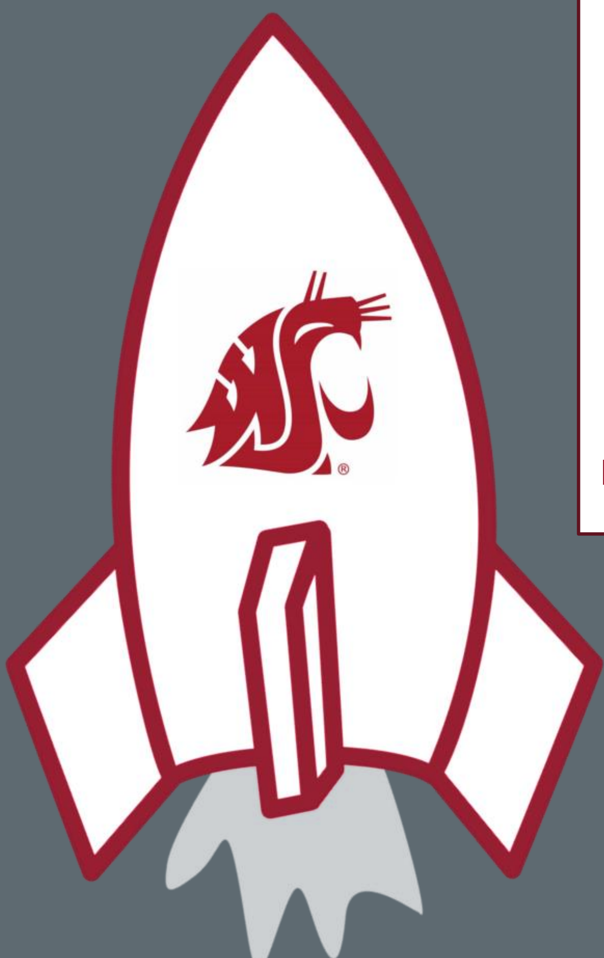

Table of Contents

1 Introduction

This document explains how the Camera Payload will fulfill the following Functions and conform to the following Requirements. This document refers to Camera Payload version 1.1.

1.1 Functions

The Camera Payload is responsible for the following:

- Imaging Earth
- Measure relative ionizing radiation event rate

1.2 Requirements

The system requirements and Camera Payload design requirements can be found on GitHub.

2 Detailed Description

This section refers to the Camera Payload schematic. Page numbers will be listed and may have coordinates listed (number and letter combination found around the frame).

2.1 Functional Block Diagram

The block diagram can be found on page 1 of the schematic.

2.1.1 Ionizing Radiation Sensor

The Ionization Radiation Sensor is responsible for generating digital electronic signals corresponding to high-energy particle hits.

2.1.2 Particle Counter

The Particle Counter is responsible for counting the number of electrical pulses generated by the Ionizing Radiation Sensor.

2.1.3 Cameras

The cameras take pictures of the Earth's surface. There are two cameras on board, one with a wide-angle lens for taking large scale pictures, and another with a telephoto lens, for taking pictures of locations of interest, such as Pullman.

Data from the Cameras will be received and stored by the C&DH subsystem.

2.1.4 Temperature Monitoring

The temperature monitoring is carried out by an ADC connected to the C&DH subsystem. The temperature of various components and at various points on the board are periodically measured and recorded.

2.2 Schematic

2.2.1 Power Rails

Page 2 of the schematic shows the various power rails used by the camera payload.

2.2.2 Isolated Grounds

The 4 isolated grounds can be found on page 4 of the schematic. Power ground ($PGND$) is connected to the backplane and to the power devices (5V Regulation). All other grounds are shorted to $PGND$ through a 0Ω resistor rated up to $2A$. The expected current is less than $50mA$. Digital ground ($DGND$) is connected to the digital components on the board, including the counter, GPIO expander, and cameras. Analog ground ($AGND$) is connected to the analog components on the board, including the amplifiers and ADC. Chassis ground ($CHASSIS$) is connected to the mechanical features of the satellite, including the bolt holes and card rails.

2.2.3 5V Regulation

The $5V$ regulation can be found on page 3 of the schematic and contains two stages. The first is a switching mode boost converter[1], chosen for its high efficiency. The voltage feedback is set through a voltage divider such that the output is $5.5V$. The second stage is a $5V$ LDO regulator[2], chosen for its high PSRR, which regulates the SMPS output down to $5.0V$ and attenuates ripple or noise introduced by the switching.

2.2.4 Temperature Monitoring

The temperature monitoring ADC[3] can be found on page 3 of the schematic. The ADC is an I^2C device which lives on *BUS_I2C1* (address 0x22), and relays it's data to the IHU. There are 8 single-ended inputs, all of which read thermistors from various locations on the board.

2.2.5 Analog Voltage Reference and Supply

The camera payload has an analog voltage supply (Page 3, D3) fed by power rail *PR3.3-10* and filtered by a ferrite bead and capacitors. This powers the ADC and the reference voltage buffer. Precision on this rail is not required, as the ADC produces its own $2.5V$ precision voltage reference. This voltage reference is fed through a unity gain buffer[4] and used to power the thermistors.

2.2.6 Cameras

The Cameras[5] can be found on page 4 of the schematic. There are two cameras. The first has a wide-angle lens ($140°$ FOV, capable of seeing the whole earth) for taking large-scale photos of the earth, and the second has a telephoto lens ($21°$ FOV, $\sim 70x70m$ square per pixel), for taking images of locations of interest, such as Pullman or Area 51. Each camera uses the I^2C bus *BUS_I2C1* (address 0x20) for receiving commands, and *BUS_SPI* for transferring data. The camera CS pins are connected to *GPIO*-0 and *GPIO*-1 for the telephoto and wide-angle lenses respectively. The cameras are operated by the C&DH[6] subsystem.

2.2.7 Ionizing Radiation Sensor

The ionizing radiation sensor[7] can be found on page 4 (C1) of the schematic. The sensor itself is a PIN diode with black epoxy encasement such that its peak sensitivity is particles with energies $2keV - 25keV$, which correspond to gamma radiation. The amplifiers are designed to amplify the signal from the photodiode so that the counter can read them. The exact design is a two stage amplifier consisting of a charge amplifier and a differentiator taken directly from

[1] CIS PN: 60-0007
[2] CIS PN: 60-0012
[3] CIS PN: 27-0003
[4] CIS PN: 08-0002
[5] CIS PN: 66-0005
[6] C&DH
[7] CIS PN: 66-0004

the white poper[8] for the device, with a comparator added to the output to square up the output signal.

2.2.8 Particle Counter

The particle counter is a 12-bit binary counter[9] which counts the pulses from the Ionizing Radiation Sensor. The data is read by an I²C GPIO expander[10] operated by the IHU on *BUS_I2C1*. The same GPIO expander can be used to reset the counter.

2.3 Board

The board shall be double layered with 1 oz copper and ENIG finish. The board shall also conform to the dimensions specified by the [CougSat Module Standard].

2.3.1 Layout Constraints

Unless specified in the following subsections, all signals shall us the default parameters below. Signals in the following subsections do not include their sense signals unless otherwise specified. Trace width can be broken if the trace needs to bottleneck down to a pin; the bottleneck shall be minimized.

Trace width:	$0.16mm$
Vias:	$\emptyset 0.3mm$, unlimited count
Separation:	$0.16mm$
Length:	unlimited

Devices with specific placement and routing considerations are called out on the schematic, see "CAD Note:"

2.3.1.1 Camera Power Rails - 3.3V-[11,12], PGND

PGND Applies between the cameras and the backplane connector

Trace width: $0.3mm$

[8] Photodiode white paper
[9] CIS PN: 28-0004
[10] CIS PN: 27-0001

3 Testing

All tests shall be performed at room temperature and not under vacuum unless otherwise specified. If any modifications are performed, take note. Include enough information to understand circuit behavior and for others to replicate the results. Include any software written to execute the test and link it in the test notes section. Save all software, waveforms, etc. in a subfolder of the board's test folder for each test[11].

- Waveforms shall be captured whenever appropriate
- Have the event take fill the screen (for fast events, zoom in; for slow events, zoom out)
- Label each channel accurately
- Only have bandwidth limiting if necessary for the test (this applies to the oscilloscope and probe settings)
- If ringing or overshoot occurs, use a ground spring or differential probe

Results Location: https://github.com/CougsInSpace/CougSat1-Hardware/tree/master/CougSat1-Payload/Testing/CameraBoard1.1

Common test instructions can be found on the wiki.

3.1 Before First Power-On Check

Configuration:

This test shall be executed before any power is applied to the board.

3.1.1 Test Instructions

Measure the resistance of various points in reference to *PGND* located at the backplane. When measuring in-circuit resistances, flip the probes and take the lower value.

3.1.2 Test Data

Node	Resistance		Node	Resistance
3.3V-10			*5.0V*	
3.3V-11			*AVDD*	
3.3V-12			*AVREF-0*	
BOOST_OUT				

3.1.3 Test Notes

Delete me if no notes are required.

3.2 5V Regulator

Configuration:

[11] For test 3.1, place files in subfolder "3.1" and so on

Result:

This test evaluates the circuit described in 5V Regulation.

3.2.1 Output Voltage

3.2.1.1 Test Instructions

Apply $3.3V$ to *3.3V-10* at the backplane before executing this test. Measure the voltage of the 5.0V regulator at no load and at a $30mA$ resistive load.

Note: Measure the DC Component of the voltage with PLC[12] > 100.

3.2.1.2 Test Data

Measure the DC voltage at the output of the 5.0V regulator			
Load	Voltage	Passing Criteria	Pass / Fail
$No\ Load$		$4.900V < V < 5.100V$	
$30mA$		$4.900V < V < 5.100V$	

3.2.1.3 Test Notes

Delete me if no notes are required.

3.2.2 Output Ripple and Noise

3.2.2.1 Test Instructions

Apply $3.3V$ to *3.3V-10* at the backplane before executing this test. Measure the ripple of the 5.0V regulator at no load and at a $30mA$ resistive load.

Note: Measure the RMS value of the AC component with $f > 3Hz$.

3.2.2.2 Test Data

Measure the RMS ripple at the output of the 5.0V regulator			
Load	Ripple	Passing Criteria	Pass / Fail
$No\ Load$		$\lvert V_{ripple} \rvert < 25mV$	
$30mA$		$\lvert V_{ripple} \rvert < 25mV$	

3.2.2.3 Test Notes

Delete me if no notes are required.

3.3 Analog Voltage Reference and Supply

Configuration:
Result:

This test evaluates the circuits described in Analog Voltage Reference and Supply.

[12] Power Line Cycles: DMM setting to average during 100 cycles of the 60Hz wall outlet

3.3.1 Analog Voltage Supply

3.3.1.1 Test Instructions

Apply $3.3V$ to *3.3V-10* at the backplane before executing this test.

Measure the noise and ripple of *AVDD* under a $10mA$ load.

Note: Measure DC voltage with $PLC > 100$, measure the RMS AC component with $f > 3Hz$.

3.3.1.2 Test Data

Measure the noise and ripple of *AVDD* under a $10mA$ load			
Measured	Voltage	Passing Criteria	Pass / Fail
DC Voltage		$3.2V < V < 3.4V$	
Ripple		$\lvert V_{ripple}\rvert < 17mV$	

3.3.1.3 Test Notes

Delete me if no notes are required.

3.3.2 Analog Voltage Reference

3.3.2.1 Test Instructions

Apply $3.3V$ to *3.3V-10* at the backplane before executing this test.

Measure the DC voltage, noise, and ripple of *AVREF-0*.

Note: Measure DC voltage with $PLC > 100$, measure the RMS AC component with $f > 3Hz$.

3.3.2.2 Test Data

Measure the noise and ripple of *AVREF-0*			
Measured	Voltage	Passing Criteria	Pass / Fail
DC Voltage		$2.4975V < V < 2.5025V$	
Ripple		$\lvert V_{ripple}\rvert < 3.3mV$	

3.3.2.3 Test Notes

Delete me if no notes are required.

3.4 Temperature Monitoring

Configuration:
Result:

This test evaluates the circuit described in Temperature Monitoring.

3.4.1 Test Instructions

Apply $3.3V$ to *3.3V-10* before executing this test. Connect the ADC to a microcontroller on *BUS_I2C1*. Compare the voltage measured by the microcontroller and the voltage measured by a thermometer at the following temperature sensors:

- Camera 0
- Top Left

Note: $Error = |T_{\mu C} - T_{thermometer}|$

3.4.2 Test Data

Compare the temperatures read by a μController and a Thermometer					
Location	μController Temperature	Thermometer Temperature	Error	Passing Criteria	Pass / Fail
Camera 0				$Error < 2°C$	
Top Left				$Error < 2°C$	

3.4.3 Test Notes

Delete me if no notes are required.

3.5 Cameras

Configuration:
Result:

This test evaluates the circuit described in Cameras.

3.5.1 Test Instructions

Apply $3.3V$ to both *3.3V-11* and *3.3V-12* before executing this test.

Connect the cameras to a microcontroller on *BUS_I2C1* and *BUS_SPI*. Take a photo with each. Include the photograph.

3.5.2 Test Data

Camera	Photo	Passing Criteria	Pass / Fail
Camera 0		Signal Integrity	
Camera 1		Signal Integrity	

3.5.3 Test Notes

Delete me if no notes are required.

3.6 Particle Counter

Configuration:
Result:

This test evaluates the circuits described in Ionizing Radiation Sensor and Particle Counter.

3.6.1 Test Instructions

Apply 3.3*V* to *3.3V-10* before executing this test. Read the value on the binary counter continuously while bringing a non-irradiated sample, a banana, and a known gamma source close to the sensor.

3.6.2 Test Data

Bring various samples close to the sensor, observe the value on the counter.		
Sample	Passing Criteria	Pass / Fail
Non-Irradiated Sample	Counter value increases very little	
Banana	Counter value increases some	
Known Gamma Source	Counter value increases a lot	

3.6.3 Test Notes

Delete me if no notes are required.